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on

COMPILATION OF FATIGUE, FATIGUE-CRACK PROPAGATION, AND FRACTURE DATA FOR 2024 AND 7075 ALUMINUM, Ti-6Al-4V TITANIUM, AND 300M STEEL

VOLUME I: DESCRIPTION OF DATA AND DATA STORAGE ON MAGNETIC TAPE

by

Richard C. Rice and J. L. Reynolds

June 1976

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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16. Abstract

This report documents fatigue, fatigue-crack-propagation, and fracture data that were compiled and stored on magnetic tape as a part of the studies reported in references 1 and 2. Data for 202 and 7075 aluminum alloys, Ti-6Al-4V titanium alloy, and 300M steel are included in the compilation. Approximately 4500 fatigue, 6500 fatigue-crack-propagation, and 1500 fracture data points are stored on magnetic tape.

Volume I of this report includes descriptions of the data, an index to the data on the magnetic tape, information on data storage format on the tape, a listing of all data source references, and abstracts of other pertinent test information from each data source reference.

Volume II of this report is a 7-track magnetic tape recording of all the data compiled in this study.

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CONTENTS

TABLES

FIGURES

FIGURES (Continued)

COMPILATION OF FATIGUE, FATIGUE-CRACK-PROPAGATION, AND FRACTURE DATA FOR 2024 AND 7075 ALUMINUM, Ti-6Al-4V TITANIUM, AND 300M STEEL

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SUMMARY

This report documents fatigue, fatigue-crack-propagation, and fracture data that were compiled and stored on magnetic tape as a part of the studies reported in references 1 and 2. Data for 2024 and 7075 aluminum alloys, Ti-6Al-4V titanium alloy, and 300M steel are included in the compilation. Approximately 4500 fatigue, 6500 fatigue-crack-propagation, and 1500 fracture data points are stored on magnetic tape.

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COMPILATION OF FATIGUE, FATIGUE-CRACK-PROPAGATION, AND FRACTURE DATA FOR 2024 AND 7075 ALUMINUM, Ti-6Al-4V TITANIUM, AND 300M STEEL

VOLUME I: DESCRIPTION OF DATA AND DATA STORAGE ON MAGNETIC TAPE

INTRODUCTION

In 1972, Battelle's Columbus Laboratories (BCL) began work on a study sponsored by the National Aeronautics and Space Administration (NASA), Langley Research Center. It involved collection of a large quantity of fatigue, fatigue-crack-propagation, and fracture data and development of techniques for consolidation of those data so that they might be more useful in design of aerospace structures.

Results of the initial phase of this study are reported in detail in reference 1. It contains a description of the evolution of analytical ideas leading to the final consolidation procedures used on the collected data sets. Fatigue and fatigue-crack-propagation data are given primary emphasis. It also includes a description of how and where the data were obtained, how they were encoded for computer calculations, and plots of all the data in consolidated form.

Subsequently, the fatigue and fatigue-crack-propagation data collections were reviewed and improved consolidation and analytical procedures were developed for these data (ref. 2). This reference includes detailed examples that illustrate how the approach can be used in a preliminary design analysis. No fracture data or analyses are included in reference 2, because little emphasis was placed on this aspect of the initial phase of the study.

Because such a large collection of fatigue, fatigue-crack-propagation, and fracture data was developed during the course of the above programs, the present program was conducted to index and abstract the collected data sources from reference 1 and to place the complete collection of raw data on magnetic tape. The purpose of this report is to document the data collection described in reference 1. In the sections which follow, the selection criteria for each type of data are discussed, the index of data on the magnetic tapes is provided, and the data source references are tabulated.

DATA DESCRIPTIONS

Three types of data--fatigue, fatigue-crack propagation, and fracture--were reviewed in reference 1. An effort was made to procure data both from the open literature and company reports, so that as large a collection as possible could be obtained. Fairly restrictive selection criteria were placed on those data. First, only four materials were considered--2024 and 7075 aluminum, Ti-6Al-4V, and 300M steel. Second, the specimen geometries and laboratory procedures were critically reviewed for consistency and comparability. Third, data were limited to a room temperature (about 15 to 30°C) air environment. The selection criteria for each type of data are discussed further in the following paragraphs.

Fatigue Data

Only tests on simple, axially loaded specimens were considered in the collection of fatigue data. Data for fatigue lives ranging between 10^2 and 10^7 cycles to failure were of primary interest. Data from both strain- and load-controlled experiments were considered, but load-controlled experiments that could have involved substantial plastic deformation and possible ratcheting* were excluded in most cases.

Basic test data were desired; i.e., tables of stress or strain versus cycles to failure. In cases where crack initiation had been measured, this information was also noted, along with the initiation criterion employed. Cyclic stress-strain information was recorded in cases where it was available.

Along with the test data, correlative information concerning specimen geometry and fabrication, material product form, dimensions and processing,

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* Ratcheting refers to the cycle-by-cycle elongation and subsequent tensile failure of an unnotched axial fatigue specimen subjected to load-controlled conditions that induce cyclic plasticity.

test techniques and controls, laboratory environment, and mechanical properties were recorded. This information was useful in making decisions about pooling of various samples of data.

Fatigue-Crack-Propagation-Data

A variety of specimen geometries were considered acceptable for the fatigue-crack-propagation data collection, including center-cracked panels, part-through-cracked or surface-flawed plates, compact-tension specimens, and double-cantilever-beam specimens.

Basic constant-amplitude test data again were desired; i.e., tabular displays of crack size versus cycles. The type of stress cycle employed for each test, as well as the test frequency, was also important information. If multiple tests were conducted on a single specimen (different constant-amplitude load levels over different segments of crack growth), each condition was considered as a single test in the analysis.

As done with the fatigue data, information was also recorded concerning test conditions and basic material properties.

Fracture Data

Specific test specimen geometries for which fracture data were desired included center-cracked panels, part-through-cracked or surface-flawed specimens, compact-tension specimens, double-cantilever-beam specimens, and notched-bend specimens.

The basic test data which were recorded for all tests included original crack length, critical crack length, ultimate load or stress, and load or stress at which slow stable crack growth initiated. Load-compliance records were also obtained when possible. Other information on test methods and procedures were recorded as precisely as possible.

It was necessary to obtain very complete documentation for all fracture toughness data because it is generally accepted that the fracture behavior of a material is dependent not only on the mechanical properties of the material, but also on such factors as specimen thickness and geometry, crack length and orientation, and loading rate.

DATA RECORDING AND STORAGE

Information used in this program was stored in a format for computerized analysis. Detailed data were recorded on punched cards for use at Battelle's Columbus Laboratories (BCL) and later were transferred to a magnetic tape. That tape represents Volume II of this document. Each source from which data were taken is listed in Appendix A and abstracts prepared for each of those documents are listed in Appendix B.

The basic medium for recording the fatigue, fatigue-crack-propagation, and fracture data collected and compiled on this program is the standard 80-column computer punch card. Data card file sequences and formats which have been selected to provide a consistent procedure for encoding these data are described in the following subsections.

Each data file may contain up to four basic types of cards depending on the type of information being recorded. These card forms are

Card 1: Title or lead care, identifying test and material

Card 2: Subtitle card, containing supplementary testing, compositional, or processing information where desirable

Card 3: Data card describing specific test parameters and results

Card 4: Crack-growth card listing cycle count and crack size.

Each data file always contains at least Cards 1 and 3. Card 2 is an optional card which may be necessary to supplement, clarify, or expand Card 1 information in particular situations. Card 4 is a particular addenda of crack-growth information (i.e., cycle count and crack size) necessary only for fatigue-crack-propagation analysis.

Title or lead card (Card 1) format. — The format of Card 1 is illustrated in figure 1. Eleven fields of general descriptive information are presented. Their contents are as follows:

(1) The type of data contained in the associated data file is indicated in columns 1 through 3 by using an alphanumeric format with

Field	1	2	3	4	5	6	7	8	9	10	11
	Type of Data A3	Units I1	Reference Number A7	Material A8	Alloy Designation A10	Product Form A10	Heat Treatment A10, A9	TYS, MN/m^2 (or ksi) F5.0	TUS, MN/m^2 (or ksi) F5.0	Thickness or Diameter, mm(or in.) F6.0	Width, mm(or in.) F6.0
	2	4	6 8 10	12 14 16 18	20 22 24 26 28	30 32 34 36 38	40 42 44 46 48 50 52 54 56 58	60 62	64 66 68	70 72 74	76 78 80

Figure 1. – Format for encoding of title or lead card (card 1).

three coding abbreviations:

FAT – data from constant-amplitude-fatigue tests were the controlled variable is stress or strain and the dependent variable is the total number of cycles to complete failure of the specimen (i.e., the fatigue life).

FCP – fatigue-crack-propagation data from a constant-amplitude stress or strain-cycling test where the size of a fatigue crack is monitored as a function of the number of loading cycles.

FT – data from a monotonic loading (load or displacement controlled) test to fracture of a specimen with an initial fatigue precrack.

(2) The dimensional units of the recorded data in the file are identified in column 4. A blank denotes International System (SI) of Units; a value of 1 indicates English units; and a value of 2 indicates CGS units.

(3) The source reference number is listed in columns 5 through 11 in an alphanumeric code of the following format:

"NNNNNNL",

where N is a numeric character (0 to 9) and L is an alphabet character (A to Z). The numeric code corresponds to the reference numbers in Appendix A. The suffix letter refers to a specific batch of data from the referenced document. This refer-

reference number is the same as that listed on the succeeding data cards.

(4) The type of material (e.g., aluminum, steel, and titanium) is described in columns 11 through 19 using an alphanumeric format.

(5) The alloy designation (e.g., SAE 4340, 7075-T651, Ti-6Al-4V) is given in columns 20 through 29 in an alphanumeric format.

(6) The product form (e.g., plate, sheet, bar, forging, and casting) is listed in columns 30 through 39 in an alphanumeric format.

(7) The heat treatment (e.g., Q and T, STA, annealed, normalized) is described in columns 40 through 58 in an alphanumeric format.

(8) The TYS, MN/m^2 (or ksi), is given in columns 59 through 63 in a fixed point numeric format.

(9) The TUS MN/m^2 (or ksi), is given in columns 64 through 68 in a fixed point numeric format.

(10) Thickness or diameter, mm (or in.), of the specimen is listed in columns 69 through 74 in a fixed point numeric format. For a round specimen where this value represents the diameter, columns 75 through 80 (item 11 below) will be blank.

(11) Width, mm (or in.), of the specimen is given in columns 75 through 80 in a fixed point numeric format. For a round specimen these columns are blank and the diameter is given in item 10 above.

Subtitle card (card 2) format. - The subtitle card is an optional card provided for particular instances where supplementary information is necessary or desirable. This is an open-field card whose format is coded alphanumerically and read directly as a subtitle to Card 1 in data listings or tabulations.

Data card (card 3) format. - This card contains the principal test parameters and results of each test on which data are collected and compiled. Since the types of data may represent either fatigue, fatigue-crack propagation, or fracture tests, three formats are necessary for this card as detailed in the following subsections. Where similar test parameters are encountered among the types of data, common fields have been assigned to the formats.

Fatigue (FAT) data card format. - The fatigue data card contains 13 fields of information listed in the following formats (see fig. 2):

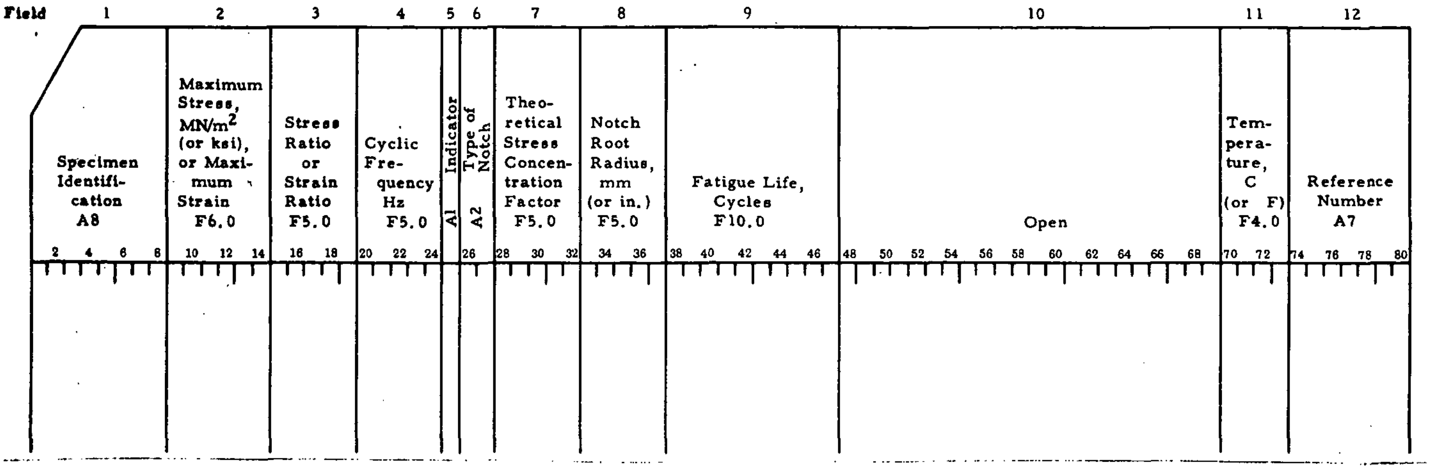

Figure 2. — Format for encoding fatigue data card (card 3).

(1) Specimen identification is listed in columns 1 through 8 using an alphanumeric format.

(2) Maximum stress, MN/m^2 (or ksi), or maximum strain is listed in columns 9 through 14 in a fixed point numeric format. The stress or strain option is designated by the Field 5 indicator.

(3) Stress ratio or strain ratio (ratio of minimum to maximum value) is listed in columns 15 through 19 in a fixed point numeric format. The stress or strain option is designated by the Field 5 indicator.

(4) Cyclic frequency, Hz, is listed in columns 20 through 24 in a fixed point numeric format.

(5) An indicator is given in column 25 to show whether items 2 or 3 above are in terms of stress or strain. If this column is blank, stress is indicated; and if this column contains an "E", strain is indicated.

(6) The type of notch configuration is listed in columns 26 and 27 by the following abbreviations:

CN — center-notched sheet or plate

EN — edge-notched sheet or plate

FN — fillet-notched sheet or plate

CR — circumferentially notched round bar.

These columns are blank for an unnotched specimen.

(7) The theoretical stress-concentration factor of the notch geometry is given in columns 28 through 32 in a fixed point numeric format. These columns are blank for an unnotched specimen.

(8) The notch root radius, mm (or in.), is given in columns 33 through 37 in a fixed point numeric format. These columns are blank for an unnotched specimen.

(9) The fatigue life, cycles, is given in columns 38 through 47 in a fixed point numeric format.

(10) An indicator is given in column 48 to show whether or not the specimen was a runout. A "1" in column 48 indicates that the specimen did not fail (DNF).

(11) This is an open field and columns 48 through 69 are left blank.

(12) Test temperature, $^{\circ}$C (or $^{\circ}$F), is listed in columns 70 through 73 in a fixed point numeric format.

(13) The source reference number is given in columns 74 through 80 in an alphanumeric format of the following type:

"NNNNNNL",

where N is a numeric character (0 to 9) and L is an alphabet character (A to Z). The numeric code corresponds to the source reference numbers in Appendix A. The suffix letter refers to a specific batch of data from the referenced document. This source reference number is the same as that listed on the corresponding Number 1 Lead Data Card.

Fatigue crack propagation (FCP) data card format. — The complete recording of fatigue-crack-propagation data requires two different card formats. Card 3, described herein, contains the basic test information; Card 4, described later, contains the cycle counts and crack size measurements as determined from the test. Thus, the data file from a single fatigue-crack-propagation test is made up of one Card 3 and one or more Card 4's.

The layout of Card 3 for the fatigue-crack-propagation test parameters is shown in figure 3. A total of 16 fields are indicated. The field contents are as follows:

(1) Specimen identification is listed in columns 1 through 8 using an alphanumeric format.

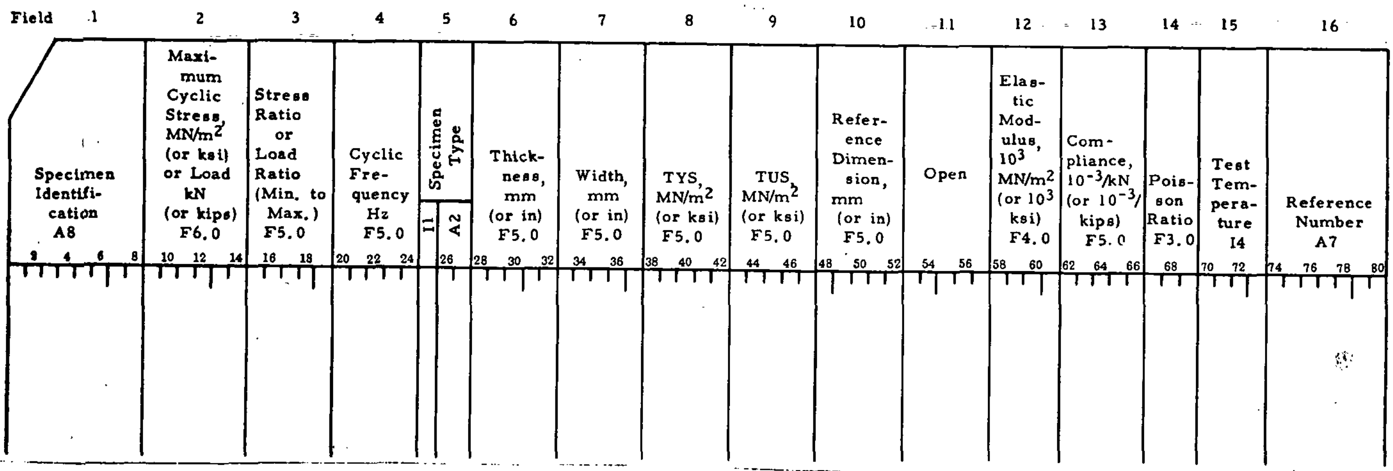

Figure 3. — Format for encoding fatigue-crack-propagation data card (card 3).

(2) Maximum cyclic stress, MN/m^2 (or ksi), or maximum cyclic load, kN (or kips) is listed in columns 9 through 14 in a fixed point numeric format. The stress or load option is designated by the Field 3 indicator.

(3) Stress ratio or load ratio (ratio of minimum to maximum values) is listed in columns 15 through 19 in a fixed point numeric format. The stress or load option is designated by the Field 5 indicator.

(4) Cyclic frequency, Hz, is listed in columns 20 through 24 in a fixed point numeric format.

(5) The specimen type is indicated in column 25 as a numeric code and supplemented in columns 26 and 27 by an acronymonic code for easier identification. Since the specimen type also determines the usual convention for selecting either stress or load in the analysis, it is this field that designates the stress or load option for Fields 2 and 3. The following convention is used in fatigue-crack propagation:

Code	Specimen Type	Option
1CT	Compact Tension	Load
2CC	Center Crack	Stress
3SF	Surface Flaw or Part-Through Crack	Stress
4DC	Double Cantilever Beam	Load
5NB	Notch Bend	Load.

(6) Specimen thickness, mm (or in.), is listed in columns 28 through 32 in a fixed point numeric format.

(7) Specimen width, mm (or in.), is listed in columns 33 through 37 in a fixed point numeric format.

(8) Tensile yield strength, MN/m^2 (or ksi), representative of that specimen material is listed in columns 38 through 42 in a fixed point numeric format.

(9) Tensile ultimate strength, MN/m^2 (or ksi), representative of that specimen material is listed in columns 43 through 47 in a fixed point numeric format.

(10) A reference dimension, mm (or in.), is listed in columns 48 through 52 in a fixed point numeric format. This dimension is utilized when experimental measurements are recorded relative to a point other than the crack origin prescribed by the analysis.

(11) This is an open field and columns 53 through 57 are left blank.

(12) Elastic modulus, 10^3 MN/m^2 (or 10^3 ksi), is listed in columns 58 through 61 in a fixed point numeric format.

(13) Specimen compliance, $10^{-6}N^{-1}$ (or $10^{-6}lb^{-1}$), used specifically for the double cantilever specimen is listed in columns 62 through 66 in a fixed point numeric format.

(14) Poisson's ratio for elastic deformation is listed in columns 67 through 69 in a fixed point numeric format.

(15) Test temperature, $^{\circ}C$ (or $^{\circ}F$), is listed in columns 70 through 73 in a fixed point numeric format.

(16) The source reference number is given in columns 74 through 80 in an alphanumeric format of the following type:

"NNNNNNL",

where N is a numeric character (0 to 9) and L is an alphabet character (A to Z). The numeric code corresponds to the source reference numbers in Appendix A. The suffix letter refers to a specific batch of data from the referenced document. This source reference number is the same as that listed on the corresponding Number 1 lead data card.

Fracture (FT) data card format. - Fracture data for a variety of test specimen configurations is accommodated on the card format shown in figure 4. The detail presented in dictated to a large degree by the number of important crack lengths and stresses which are associated with and reported for thin sheet (plane stress) fracture studies.

Field	1	2	3	4	5	6	7	8	9	10	11	12	13		14	15	16
	Specimen Identification A8	Thickness, mm (or in.) F5.0	Width, mm (or in.) F5.0	Initial Crack Length, mm (or in.) F5.0	Pop-in Stress MN/m^2 (or ksi) or Load kN (or kips) F5.0	Offset Stress MN/m^2 (or ksi) or Load kN (or kips) F5.0	Visually Determined Critical Crack Length, mm (or in.) F5.0	Photo-Recorded Critical Crack Length, mm (or in.) F5.0	Maximum Stress MN/m^2 (or ksi) or Load kN (or kips) F5.0	TYS, MN/m^2 (or ksi) F5.0	TUS, MN/m^2 (or ksi) F5.0	Special Dimension (1), mm (or in.) F5.0	Specimen	Type	Open	Test Temperature, C (or F) I4	Reference Number A7
													I1	A2			
	2 4 6 8	10 12	14 16 18	20 22	24 26 28	30 32	34 36 38	40 42	44 46 48	50 52	54 56 58	60 62	64	66	68	70 72	74 76 78 80

Figure 4. — Format for encoding fracture data card (card 3).

A total of 16 fields of data are contained on the card. Their contents are as follows:

(1) Specimen identification is listed in columns 1 through 8 using an alphanumeric format.

(2) Specimen thickness, mm (or in.), is listed in columns 11 through 13 using a fixed point numeric format.

(3) Specimen width, mm (or in.), is listed in columns 14 through 18 using a fixed point numeric format.

(4) Initial crack length, mm (or in.), as measured for the fatigue precrack is listed in columns 19 through 23 using a fixed point numeric format.

(5) "Pop-in" stress, MN/m^2 (or ksi), or "pop-in" load, kN (or kips), is listed in columns 24 through 28 using a fixed point numeric format. The stress or load option is designated by the Field 13 indicator.

(6) Offset stress, MN/m^2 (or ksi), or offset load, kN (or kips), is listed in columns 29 through 33 using a fixed point numeric format. The stress or load option is designated by the Field 13 indicator.

(7) Visually determined critical crack length, mm (or in.), is listed in columns 34 through 38 using a fixed point numeric format.

(8) Photo-recorded critical crack length, mm (or in.), is listed in columns 39 through 43 in a fixed point numeric format.

(9) Maximum stress, MN/m^2 (or ksi), or maximum load, kN (or kips), is listed in columns 44 through 48 in fixed point numeric format. The stress or load option is designated by the Field 13 indicator.

(10) Tensile yield strength, MN/m^2 (or ksi), representative of that specimen material is listed in columns 49 through 53 in a fixed point numeric format.

(11) Tensile ultimate strength, MN/m^2 (or ksi), representative of that specimen material is listed in columns 54 through 58 in a fixed point numeric format.

(12) A special dimension, mm (or in.), characteristic of that specimen type is listed in columns 59 through 63 in a fixed point numeric format.

(13) The specimen type is indicated in column 64 as a numeric code and supplemented in columns 65 and 66 by an acronymonic code for easier identification. Since the specimen type also determines the usual convention for selecting either stress or load in the analysis, it is this field that designates the option for Fields 5, 6, and 9. The following conventions that were used in fatigue-crack propagation are also used for fracture:

Code	Specimen Type	Option
1CT	Compact Tension	Load
2CC	Center Crack	Stress
3SF	Surface Flaw or Part-Through Crack	Stress
5DC	Double Cantilever Beam	Load
6NB	Notch Bend	Load.

(14) An open field is in columns 67 through 69.

(15) Test temperature, $^{\circ}$C (or $^{\circ}$F), is listed in columns 70 through 73 in an integer format.

(16) The source reference number is given in columns 74 through 80 in an alphanumeric format of the following type:

"NNNNNNL",

where N is a numeric character (0 to 9) and L is an alphabet character (A to Z). The numeric code corresponds to the source reference numbers in Appendix A. The suffix letter will refer to a specific batch of data from the referenced document. This source reference number is the same as that listed on the corresponding Number 1 Lead Data Card.

Crack-growth card (Card 4) format. - The crack-growth card is used for recording the crack-size measurements and cycle counts associated with a given fatigue-crack-propagation test or test specimen. Each card contains one set of data points. The format of Card 4 for crack-growth measurements is illustrated in figure 5.

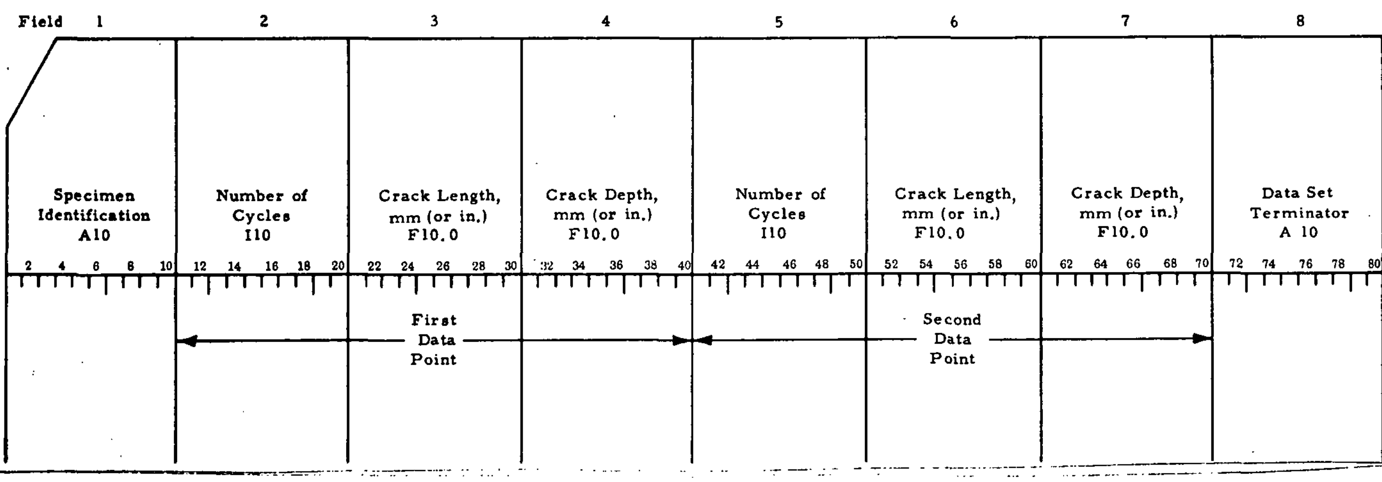

Figure 5.— Format for encoding crack-growth data card (card 4).

A total of 4 fields are indicated. Their contents are as follows:

(1) Specimen identification is listed in columns 1 through 8 using an alphanumeric format.

(2) Number of cycles associated with the first data point on the card is listed in columns 11 through 20 in an integer format.

(3) Crack length, mm (or in.), associated with the first data point on the card as measured in the width dimension of the specimen is listed in columns 21 through 30 in a fixed point numeric format.

(4) Crack depth, mm (or in.), as measured into the thickness of the specimen is listed in columns 31 through 40 in a fixed point numeric format.

DATA HANDLING AND RETRIEVAL

A complete data handling system (such as that developed initially at BCL) must consist of two programs. The first program must implement storage of data on magnetic tape, while the second must implement retrieval of data on the basis of certain specified parameters.

The BCL storage program placed the data in card-image format on seven-track magnetic tape at a density of 800 bits per inch. Materials were separated from each other by end-of-file cards. The various files of data which were developed are individually described in the next section.

Data retrieval can be implemented through programs (or program) that sort(s) the data, first by file, then according to desired parameters which may include stress ratio, stress, frequency, environment, or test temperature.

The following sequence of job control cards may be used (with a CDC 6400 computer) to access a single data file:

```
KBD, T10, MT1                    (ID)
PROJECT, G-3127-6300             (Job Card)
VSN (TAPE 1 = XXX)               (VSN)
REQUEST, TAPE 1, HI, OUT         (Tape Request)

SKIPF (TAPE 1, 4, 17, B)         (Skip forward four files)

COPY CF (TAPE 1, A)              (Copy fifth coded file on A)
REWIND, A                        (Rewind A)
COPY SBF (A, OUTPUT)             (Print A)
EOR
FTN Program Calling Tape 1 (from file 6 on).
```

Once individual files are accessed, they may be scanned further to pick out the desired data for a given analysis.

INDEX OF DATA ON THE SEVEN-TRACK MAGNETIC TAPES

The data described in this section represent the complete collection of fatigue, fatigue-crack-propagation, and fracture data. The data are separated according to files for different types of data and materials. Files 1 through 9 contain fatigue-crack-propagation data (see table 1). Files 10 through 54 (see table 2) contain fatigue data for the various materials, product forms, and notch geometries. Fracture data are contained in Files 55 through 63 (see table 3). Reference numbers from which particular sets of data were taken are indicated in tables 1 through 3. Appendix A provides a listing of those data references and Appendix B includes a complete collection of abstracts for those references.

DATA SOURCE REFERENCES

During earlier work (ref. 1), 130 abstracts of data reference sources were prepared. Data from 75 of them were encoded for analysis and consolidation. Data from the remaining number of reports were excluded from encoding and analysis for a variety of reasons that are discussed later in this section.

Forty-five source references from those references initially abstracted were defined by NASA-Langley to be limited in distribution. BCL sent out a letter to the originators of all limited distribution documents requesting that approval be given for release of their data to the public. Approval for release was given on all but 5 of the limited distribution documents. Those not approved were excluded from the eata tapes, and their abstracts are not included in Appendix B.

Background information for all source references is given in Table 4. The principal author, experimental laboratory, and year of publication are listed first for each abstracted data source reference. Additional information is also provided which includes the material(s) and product form(s); whether data release was required, and (if it was) whether it was obtained; and finally, whether data from a given reference was included in the final collection of data, and (if it was not) reasons for data exclusion.

REFERENCES

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2. Rice, R. C.; Davies, K. B.; Jaske, C. E.; and Feddersen, C. E.: Consolidation of Fatigue and Fatigue-Crack-Propagation Data for Design Use. NASA CR-2586, 1975.

TABLE 1. — INDEX OF FATIGUE-CRACK-PROPAGATION DATA

File Number	Material	Product Form	Specimen Type[a]	Reference Numbers[b]
1	7075-T7351	Sheet	CC	41
2	7075-T6	Clad Sheet	CC	118
3	7075-T6	Sheet	CC	32, 48, 92, 93
4	2024-T3	Clad Sheet	CC	118, 119, 120, 121
5	2024-T3	Sheet	CC	68, 92, 93
6	300M	Plate	CC	15
7	Ti-6Al-4V	Sheet	CC	125
8	Ti-6Al-4V	STA Forging	CT	115
9	Ti-6Al-4V	STA + Annealed Forging	CT	115

[a] Specimen type abbreviations are as follows: CC = center-crack specimen; CT = compact-tension specimen.

[b] See Appendix A.

TABLE 2. — INDEX OF FATIGUE DATA

File Number	Material	Product Form	Specimen Type[a]	Reference Numbers[b]
10	7075-T6	Sheet	S	1, 7, 10, 130
11	7075-T6	Sheet	EN	2, 3, 4, 5, 7, 8, 9
12	7075-T6	Sheet	CN	6, 10
13	7075-T6	Sheet	FN	2
14	7075-T6	Sheet, Clad	S	91
15	7075-T6	Extrusion	S	83
16	7075-T6	Bar and Rod	S	82, 129
17	7075-T6	Bar	CR	82
18	7075-T651	Bar	CR	87
19	7075-T651	Bar	EN	87
20	2024-T3	Sheet	S	1, 7, 130
21	2024-T3	Sheet	EN	2, 3, 5, 7, 8, 9
22	2024-T3	Sheet	CN	26
23	2024-T3	Sheet	FN	2
24	2024-T3	Sheet, Clad	S	91
25	2024-T4	Bar and Rod	S	82
26	2024-T4	Bar	CR	13, 82, 129
27	2024-T4	Extrusion	S	83
28	2024-T4	Extrusion	CR	83
29	2024-T351	Plate	EN	66
30	300M	Billet	S	14, 89
31	300M	Billet	CR	14
32	300M	Forging	S	11, 12, 88, 89

[a] Specimen type abbreviations are as follows: S = smooth (unnotched) specimen; EN = edge-notched specimen; CN = center-notched specimen; FN = fillet-notch specimen; and CR = circumferentially-notched specimen.

[b] See Appendix A.

TABLE 2. – (Continued)

File Number	Material	Product Form	Specimen Type[a]	Reference Numbers[b]
33	300M	Forging	CR	11, 12
34	Ti-6Al-4V	Sheet, Annealed	S	75, 81
35	Ti-6Al-4V	Sheet, Annealed	EN	75
36	Ti-6Al-4V	Sheet, STA	S	84
37	Ti-6Al-4V	Sheet, STA	CN	84
38	Ti-6Al-4V	Sheet, STOA	S	12
39	Ti-6Al-4V	Sheet, STOA	EN	12
40	Ti-6Al-4V	Plate, STA	S	78
41	Ti-6Al-4V	Plate, STA	EN	78
42	Ti-6Al-4V	Forging, Annealed	S	73, 76, 79
43	Ti-6Al-4V	Forging, Annealed	CR	73, 76, 79
44	Ti-6Al-4V	Forging, STA	S	79
45	Ti-6Al-4V	Casting, Annealed	S	71, 80
46	Ti-6Al-4V	Casting, Annealed	EN	71, 72
47	Ti-6Al-4V	Casting, Annealed	CR	72, 80
48	Ti-6Al-4V	Casting, STA	S	80
49	Ti-6Al-4V	Casting, STA	CR	80
50	Ti-6Al-4V	Extrusion, Annealed	S	12, 69
51	Ti-6Al-4V	Extrusion, Annealed	CN	69
52	Ti-6Al-4V	Extrusion, Annealed	CR	12
53	Ti-6Al-4V	Bar, Annealed	S	70
54	Ti-6Al-4V	Bar, Annealed	CR	70

[a] Specimen type abbreviations are as follows: S = smooth (unnotched) specimen; EN = edge-notched specimen; CN = center-notched specimen; FN = fillet-notch specimen; and CR = circumferentially-notched specimen.

[b] See Appendix A.

TABLE 3. —INDEX OF FRACTURE DATA

File Number	Material	Product Form	Specimen Type[a]	Reference Numbers[b]
55	7075-T6	Clad Sheet, Extrusion, and Forging	CT	96, 100
56	7075-T6	Clad Sheet, Plate, Forging, and Extrusion	CC	21, 35, 36, 37, 38, 42, 48, 49, 124
57	7075-T7351	Sheet and Plate	CC	19, 23, 41, 100
58	2024-T3	Clad Sheet and Plate	CC	20, 29, 34, 35, 36, 38, 39, 40, 124
59	300M	Sheet	CC	15
60	300M	Plate and Forging	SF	15
61	Ti-6A-4V	Sheet - STA and Annealed	CT	97
62	Ti-6A-4V	Annealed Sheet and Plate and STA Forging	CC	17, 27, 33, 44, 125
63	Ti-6Al-4V	STA Sheet and Annealed Plate and Bar	SF	60, 63, 64, 126

[a] Specimen type abbreviations are as follows: CT = compact-tension specimen; CC = center-cracked specimen; and SF = surface-flawed specimen.

[b] See Appendix A.

TABLE 4. — BACKGROUND INFORMATION ON DATA SOURCE REFERENCES

Reference Number	Principal Author	Laboratory	Year of Publication	Type of[a] Data	Material and Product Form	Data Release Required	Data Release Approved	Data Included in Final Compilation	Reason for Data Deletion
1-4	Grover, H. J.	Battelle-Columbus	1951, 52	FAT	2024-T3 Sheet 7075-T6 Sheet			X X	
5	Hardrath, H. F.	NASA-Langley	1954	FAT FAT	2024-T3 Sheet 7075-T6 Sheet			X X	
6	Landers, C. B.	NASA-Langley	1956	FAT FAT	2024-T3 Sheet 7075-T6 Sheet			X X	
7	Illg, W.	NASA-Langley	1959	FAT FAT	2024-T3 Sheet 7075-T6 Sheet			X X	
8	Grover, H. J.	Battelle-Columbus	1959	FAT FAT	2024-T3 Sheet 7075-T6 Sheet			X X	
9	Naumann, E. C.	NASA-Langley	1959	FAT FAT	2024-T3 Sheet 7075-T6			X X	
10	Smith, C. R.	General Dynamics - Convair Div.	1966	FAT	7075-T6 Sheet			X	
11	Harmsworth, C. L.	Air Force Materials Lab.	1969	FAT	Ti-6Al-4V-2Sn Forging 300M Forging			 X	A[b]
12	Deel, O. L.	Battelle-Columbus	1970	FAT	300M			X	
13	Topper, T. H.	University of Illinois	1970	FAT FAT	2024-T4 Bar 4340	X X	X X	X X	
14	Bateh, E. J.	Lockheed-Georgia Company	1969	FAT	300M	X	X	X	
15	Pendleberry, S. L.	Lockheed-California Company	1968	FCP, FT	300M			X	
16	Newcomer, R. E.	McDonnell Douglas Corp.	1972	FCP, FT	X7475-T61, 2024-T81	X	X		A
17	Anon.	Air Force Materials Lab., Research and Tech. Division	1964	FT	Ti-6Al-4V	X	X	X	
18	Lindh, D. V.	The Boeing Company	1963	FT	7075-T6, Ti-6Al-4V, 18Ni	X	X		B[c]
19	Nordmark, G. E.	ALCOA Research Laboratories	1964	FT, FCP	7075-T651, -T7351	X	X	X	
20	Anderson, W. E.	The Boeing Company	1962	FT	2024-T3	X	X	X	
21	Echenberger, T. W.	The Boeing Company	1962	FT	7075-T6	X	X	X	

[a] FAT = fatigue, FCP = fatigue-crack propagation, and FT = fracture toughness.
[b] A = The material (or its processing) was not of primary interest in this study.
[c] B = Biaxial stress conditions.

TABLE 4. – (Continued)

Reference Number	Principal Author	Laboratory	Year of Publication	Type of Data[a]	Material and Product Form	Data Release		Data Included in Final Compilation	Reason for Data Deletion
						Required	Approved		
22	Masters, J. N.	The Boeing Company	1970	FCP, FT	2219-T87, Ti-5Al-2.5Sn				A[b], C[c]
23	Allen, F. C.	McDonnell Douglas Corp.	1971	FT	7075-T6, -T73			X	
24	Eitman, D. A.	Douglas Aircraft Co., Inc.	1966	FCP	2219-T87, Ti-5Al-2.5Sn ELI				A, C
25	Ferguson, C. W.	Douglas Aircraft Co., Inc.	1966	FT	2219, T87, Ti-5Al-2.5Sn ELI				A, C
26	Orange, T. W.	NASA-Lewis	1967	FT	2014-T6				A, C
27	Figge, I. E.	NASA-Langley	1963	FT	Ti-6Al-4V plus various other alloys			X	A, C
28	Orange, T. W.	NASA-Lewis	1971	FT	Ti-5Al-2.5Sn, 2014-T6, 2219-T87				A, C
29	Feddersen, C. E.	Battelle-Columbus	1970	FT	2024-T351			X	
30	Christian, J. L.	General Dynamics	1963	FT	Various materials				A, C
31	Bonesteel, R. M.	Lockheed Missiles and Space Co.	1971	FT	7075-T651 Plate				D[d]
32	Dubensky, R. G.	University of Akron	1971	FCP	2024-T3, 7075-T6 Sheet			X	
33	Christian, J. L.	General Dynamics	1964	FCP	Ti-6Al-4V ELI and other materials	X	X	X	A, C
34	Walker, E. K.	Northrup Norair	1966	FT	2024-T3 Sheet, Ti-8Al-1Mo-1V			X	A
35	Gurion, P. J.	Lockheed Aircraft Corp.	1955	FCP	2024-T3, 7075-T6 Sheet and other materials	X	X	X	A
36	McEvily, A. J.	Langley Aeronautical Laboratory	1956	FT	2024-T3, 7075-T6 Sheet, 2024-T4			X	A
37-40	Broek, D.	National Aerospace Laboratory, Amsterdam	1965, 1966	FT	2024-T3-7075-T6 Sheet			X	
41	Feddersen, C. E.	Battelle-Columbus	1970	FCP, FT	7075-T7351 Sheet and Plate			X	

[a] FAT = fatigue, FCP = fatigue-crack propagation, and FT = fracture toughness.
[b] A = The material (or its processing) was not of primary interest in this study.
[c] C = Most experiments completed at nonambient temperatures.
[d] D = Most experiments completed in corrosive medium.

TABLE 4. – (Continued)

Reference Number	Principal Author	Laboratory	Year of Publication	Type of[a] Data	Material and Product Form	Data Release: Required	Data Release: Approved	Data Included in Final Compilation	Reason for Data Deletion
42	Anon.	The Boeing Company	1966	FT	7075-T6 Sheet				E[b]
43	Babilon, C. F.	ALCOA Research Laboratories	1972	FAT, FCP, FT	Various aluminum alloys				A[c]
44	Anon.	Boeing-North American Rockwell	1964	FT	Ti-6Al-4V Plate and other alloys	X	X	X	A
45	Sullivan, T. L.	NASA-Lewis	1967	FT	Ti-5Al-2.5Sn Sheet				A, C[d]
46	Figge, I. E.	NASA-Langley	1968	FT	Ti-8Al-1Mo-1V Sheet				A
47	Tiffany, C. F.	The Boeing Company	1966	FT	2219-T87 Plate, Ti-5Al-2.5Sn Plate				A, C
48	Hudson, C. M.	NASA-Langley	1969	FCP	2024-T3, 7075-T6 Sheet			X	
49	Bateh, E. J.	Lockheed Aircraft Corporation	1962	FT	7075-T6, 7079-T6 Sheet, Extrusion, and Forging	X	X	X	
50	DeSaw, F. A.	Battelle-Columbus	1971	FAT	Ti-6Al-4V Sheet				F[e]
51	Rjeletick, J. G.	Lockheed Missiles and Space Co.	1972	FAT	Ti-6Al-4V Plate, Ti Beta III				A
52	Orange, T. W.	NASA-Lewis	1969	FT	2014-T651 Plate, 4340 Plate				A, C A, C
53	Pierce, W. S.	NASA-Lewis	1970	FT	2-14-T6 Extrusion				A, C. F
54	Hall, L. A.	The Boeing Company	1968	FT	2014-T62 Plate, Ti-6Al-4V ELI Plate				A, C C
55	Packman, P. F.	Lockheed Aircraft Corporation	1968	FT	7075-T6511 Extrusion, 4330V Tubing				B[f], E A, B, F
56	Maynor, H. W.	Auburn University	1971	FT	4130 Tubing				A, B, F
57	Kerlins, V.	Douglas Aircraft Company	1963	FT	3 Steel alloys	X	X		A
58	Bockrath, G. E.	McDonnell Douglas Astronautics Co.	1971	FT	300M Tubing	X	X		B, F

[a] FAT = fatigue, FCP = fatigue-crack propagation, and FT = fracture toughness.
[b] E = Reference 42 was actually part of reference 124, 7075-T6 data included under that number.
[c] A = The material (or its processing) was not of primary interest in this study.
[d] C = Most experiments completed at nonambient temperatures.
[e] F = Most data were generated on components rather than simple specimens.
[f] B = Biaxial stress conditions.

TABLE 4. – (Continued)

Reference Number	Principal Author	Laboratory	Year of Publication	Type of[a] data	Material and Product Form	Data Release: Required	Data Release: Approved	Data Included in Final Compilation	Reason for Data Deletion
59	Tiffany, C. F.	The Boeing Company	1964	FCP	D6AC Bar, 18Ni Plate Ti-6Al-4V Bar				A[b] C[c]
60	Randall, P. N.	TRW Systems	1966	FT	Ti-6Al-4V Plate D6AC Plate			X	 A
61	Corn, D. L.	Douglas Aircraft Company	1964	FT	18Ni-9Co-5Mo Plate				A
62	Collipriest, J. E.	North American Rockwell	1971	FT	Ti-6Al-4V Plate D6AC Plate	X	X		A A
63	Schwartzberg, F. R.	Martin-Marietta Corporation	1970	FT	Ti-6Al-4V Sheet			X	
64	Hoeppner, D. W.	Battelle-Columbus	1968	FT	Ti-6Al-4V			X	
65	Hall, L. R.	The Boeing Company	1971	FT	2219-T87 Plate Ti-8Al-2.5Sn Plate				A, C A, C
66	Dunsby, J. A.	National Research Council of Canada	1968	FAT	2024-T351 Clad Plate			X	
67	Feddersen, C. E.	Battelle-Columbus	1972	FCP, FT	D6AC Plate				A
68	Schijve, J.	National Aerospace Laboratory	1968	FCP	2024-T3 Sheet	X	X	X	
69	Brockett, R. M.	Lockheed-California Company	1967	FAT, FT	Ti-6Al-4V Extrusion and 2 other titanium alloys			X	A
70	Anon.	Titanium Metals Corp. of America	1957	FAT	Ti-6Al-4V Bar	X	X	X	
71	McClaren, S. W.	LTV Aerospace Corporation	1969	FAT	Ti-6Al-4V Casting Ti-5A-2.5Sn Casting			X	 A
72	Jones, P. L.	General Dynamics	1972	FAT, FT	Ti-6Al-4V Casting and 5 other materials	X	X	X	A
73	VanOrden, J. M.	Lockheed-California Company	1969	FAT	Ti-6Al-4V Forged Billet	X	X	X	
74	Marrocco, A.	Grumman Aircraft Engineering Co.	1970	FAT	Ti-6Al-4V Extrusion Ti-6Al-6V-2Sn Extrusion	X	X		C A
75	Illg, W.	NASA-Langley	1965	FAT	Ti-6Al-4V Sheet and 6 other materials			X	A
76	Simeny, R. I.	Lockheed-California Company	1966	FAT, FT	Ti-6Al-4V Forging IMI 679 Forging			X	 A
77	(Reference	deleted)				X			

[a] FAT = fatigue, FCP = fatigue-crack propagation, and FT = fracture toughness.
[b] A = The material (or its processing) was not of primary interest in this study.
[c] C = Most experiments completed at nonambient temperatures.

TABLE 4. – (Continued)

Reference Number	Principal Author	Laboratory	Year of Publi-cation	Type of[a] Data	Material and Product Form	Data Release: Required	Data Release: Approved	Data Included in Final Compilation	Reason for Data Deletion
78	Sommer, A. W.	North American Rockwell Corp.	1969	FAT, FT	Ti-6Al-4V Plate and 3 other titanium alloys			X	A[b]
79	Beck, E.	Martin-Marietta Corporation	1969	FAT	Ti-6Al-4V Forging			X	
80	Bass, C. D.	Wright-Patterson Air Force Base	1969	FAT	Ti-6Al-4V Casting			X	
81	McClaren, S. W.	LTV Vought Aeronautics	1963	FAT	Ti-6Al-4V Sheet and 3 other materials			X	A
82, 83	Lazan, B. J.	University of Minnesota	1952	FAT	2024-T4 Rod, 7075-T6 Rod, 2014-T6 Rod			X	A
84	Anon.	Lockheed-Georgia Company	1962	FAT	Ti-6Al-4V Sheet and 3 other titanium alloys			X	A
85	Jones, P. L.	General Dynamics	1964	FAT	D6AC Forging	X	X		A
86	(Reference deleted)					X			
87	Anon.	Beckman Instruments, Inc.	1972	FAT	7075-T651 Bar	X	X	X	
88, 89	Jaske, C. E.	Battelle-Columbus	1968, 1969	FAT	300M Forging and Billet	X	X	X	
90	Gamble, R. M.	University of Florida	1972	FAT	Ti-6Al-4V Bar	X	X	X	
91	Smith, I.	National Bureau of Standards	1955	FAT	2024-T3, 7075-T6 Sheet			X	
92	Hudson, C. M.	NASA-Langley	1961	FCP	2024-T3, 7075-T6 Sheet			X	
93	McEvily, A. J.	NASA-Langley	1958	FCP	2024-T3, 7075-T6 Sheet			X	
94	Unpublished	Martin-Marietta Corporation	--	FT	4 aluminum extru-sions and 1 titanium extru-sion	X	X		A
95	Miller, J.		1972	FAT	Ti-6Al-4V Forging and 3 Steel alloys				B[c] A, B
96	Pearson, H. S.	Lockheed Aircraft Corporation	1957	FT	7075-T6 Sheet and 3 other materials	X	X	X	A
97	Schwartz, R. D.	Lockheed Aircraft Corporation	1961	FT	Ti-6Al-4V and 8 other materials	X	X	X	A
98, 99	Pierce, W. S.		1968, 1969	FCP	2014-76				A
100	Unpublished	Kaiser Aluminum	--	FT FCP, FT	7075-T6 Sheet plus other aluminum alloys	X	X	X	A

[a] FAT = fatigue, FCP = fatigue-crack propagation, and FT = fracture toughness.
[b] A = The material (or its processing) was not of primary interest in this study.
[c] B = Biaxial stress conditions.

TABLE 4. — (Concluded)

Reference Number	Principal Author	Laboratory	Year of Publication	Type of Data[a]	Material and Product Form	Data Release: Required	Data Release: Approved	Data Included in Final Compilation	Reason for Data Deletion
101	Illg, W.	NASA-Langley	1971	FAT	8 aluminum, titanium, and steel materials				A[b]
102	Schijve, J.	National Aerospace Laboratory	1968	FAT	2024-T3 Clad Sheet				F[c]
103	Van Orden, J. M.	Lockheed-California Company	1971	FAT	Ti-6Al-4V Ingot and Forged Bar	X	X		A
104	Wilks, I. E.	National Bureau of Standards	1953	FAT	2024-T3, 7075-T6 Clad Sheet				G[d]
105	Hartzman, R. J.	Grumman Aircraft Engineering Corp.	1967	FAT	D6AC Forged Bar 4340 Forged Bar	X	X		A A
106-108	Morrocco, A. G.	Grumman Aircraft Engineering Corp.	1968, 1969	FAT	Ti-6Al-4V Forging Ti-6Al-6V-2Sn Forging	X	X		H[e] A
109	Schijve, J.	National Aerospace Laboratory	1968	FAT	2024-T3 Clad Sheet and 2 other aluminum alloys				F A, F
110	(Reference deleted)					X			
111	Ostermann, F.	Air Force Materials Lab.	1971	FAT	3 Aluminum alloys				A
112	Nordmark, G. E.	ALCOA Research Laboratories	1970	FAT	6 Aluminum alloys				A, F
113	Van Orden, J. M.	Lockheed-California Company	1971	FAT, FT	Ti-6Al-4V Forged Billet Ti-6Al-6V-2Sn Forged Billet	X	X		G A
114	Wells, C. H.		1969	FAT	Ti-6Al-4V Forging				C
115	Bucci, R. J.	General Electric Company	1973	FCP	Ti-6Al-4V Forging			X	
116	(Reference deleted)					X			
117	Rinning, M. S.	Royal Aircraft Establishment	1970	FAT	3 Aluminum alloys	X	X		I[f]
118, 119	Broek, D.	National Aero- and Astronautical Research Institute	1965	FCP	2024-T3, 7075-T6 Clad Sheet	X	X	X	
120, 121	Schijve, J.	National Aero- and Astronautical Research Institute	1965	FCP	2024-T3 Clad Sheet	X	X	X	
122	Hudson, C. M.	NASA-Langley	1964	FCP	3 Titanium and steel materials				C
123	(Reference deleted)					X			
124	Smith, S. H.	The Boeing Company	1966	FT	2024-T3, 7075-T6 Sheet and many other materials	X	X	X	A
125, 126	Feddersen, C. E.	Battelle-Columbus	1971, 1972	FCP, FT	Ti-6Al-4V Plate			X	
127	Hudson, C. M.	NASA-Langley	1973	FCP, FT	7075-T6 Plate 7178-T6 Plate				A F
128	Carter, T. J.	Aeronautical Research Council	1967	FCP	2024-T3 Sheet				F
129	Endo, T.	University of Illinois	1966	FAT	2024-T4 Rod, 7675-T6 Bar			X	
130	Unpublished	Battelle-Columbus	--	FAT	2024-T3, 7075-T6 Sheet			X	

[a] FAT = fatigue, FCP = fatigue-crack propagation, and FT = fracture toughness.
[b] A = The material (or its processing) was not of primary interest in this study.
[c] F = Most data were generated on components rather than simple specimens.
[d] G = Unknown.
[e] H = Surface condition studies--not directly relatable to other data.
[f] I = Test procedure or operating condition different from that considered desirable.

APPENDIX A

LIST OF DATA SOURCE REFERENCES

1. Grover, H. J.; Bishop, S. M.; and Jackson, L. R.: Fatigue Strengths of Aircraft Materials Axial-Load Fatigue Tests on Unnotched Sheet Specimens of 24S-T3 and 75S-T6 Aluminum Alloys and of SAE 4130 Steel. NACA TN 2324, 1951.

2. Grover, H. J.; Bishop, S. M.; and Jackson, L. R.: Fatigue Strengths of Aircraft Materials Axial-Load Fatigue Tests on Notched Sheet Specimens of 24S-T3 and 75S-T6 Aluminum Alloys and of SAE 4130 Steel with Stress-Concentration Factors of 2.0 and 4.0. NACA TN 2389, 1951.

3. Grover, H. J.; Bishop, S. M.; and Jackson, L. R.: Fatigue Strengths of Aircraft Materials Axial-Load Fatigue Tests on Notched Sheet Specimens of 24S-T3 and 75S-T6 Aluminum Alloys and of SAE 4130 Steel with Stress-Concentration Factor of 5.0. NACA TN 2390, 1951.

4. Grover, H. J.; Hyler, W. S.; and Jackson, L. R.: Fatigue Strengths of Aircraft Materials Axial-Load Fatigue Tests on Notched Sheet Specimens of 24S-T3 and 75S-T6 Aluminum Alloys and SAE 4130 Steel with Stress-Concentration Factor of 1.5. NACA TN 2639, 1952.

5. Hardrath, H. F.; and Illg, W.: Fatigue Tests at Stresses Producing Failure in 2 to 10,000 cycles, 24S-T3 and 75S-T6 Aluminum Alloy Sheet Specimens with a Theoretical Stress-Concentration Factor of 4.0 Subjected to Completely Reversed Axial Load. NACA TN 3132, 1954.

6. Landers, C. B.; and Hardrath, H. F.: Results of Axial-Load Fatigue Tests on Electropolished 2024-T3 and 7075-T6 Aluminum Alloy Sheet Specimens with Central Holes. NACA TN 3631, 1956.

7. Illg, W.: Fatigue Tests on Notched and Unnotched Sheet Specimens of 2024-T3 and 7075-T6 Aluminum Alloys and of SAE 4130 Steel with Special Consideration of the Life Range from 2 to 10,000 Cycles. NACA TN 3866, 1959.

8. Grover, H. J.; Hyler, W. S.; and Jackson, L. R.: Fatigue Strengths of Aircraft Materials Axial-Load Fatigue Tests in Edge-Notched Sheet Specimens of 2024-T3 and 7075-T6 Aluminum Alloys and of SAE 4130 Steel with Notch Radii of 0.004 and 0.070 Inch. NASA TN D-111, 1959.

9. Naumann, E. C.; Hardrath, H. F.; and Guthrie, D. E.: Axial-Load Fatigue Tests of 2024-T3 and 7075-T6 Aluminum-Alloy Sheet Specimens Under Constant-and-Variable-Amplitude Loads. NASA TN D-212, 1959.

10. Smith, C. R.: S-N Characteristics of Notched Specimens. NASA CR-54503, 1966.

11. Harmsworth, C. L.: Low-Cycle Fatigue Evaluation of Titanium 6Al-4V-2Sn and 300-M Steel for Landing Gear Applications. AFML-TR-69-48, 1969.

12. Deel, O. L.; and Mindlin, H.: Engineering Data on New and Emerging Structural Materials. AFML-TR-70-252, 1970.

13. Topper, T. H.; and Morrow, JoDean, eds.: Simulation of the Fatigue Behavior of the Notch Root in Spectrum Loaded Notched Members (U). T & AM Report No. 333, Dept. of Theoretical and Appl. Mech., Univ. of Ill., Jan. 1970.

14. Bateh, E. J.; and McGee, W.: Axial Load Fatigue and Tensile Properties of 300 VAR Steel Heat Treated to 280-300 ksi. ER-10202, Lockheed-Georgia Co., 1969.

15. Pendelberry, S. L.; Simenz, R. F.; and Walker, E. K.: Fracture Toughness and Crack Propagation of 300 M Steel. FAA Tech. Report No. DS-68-18, 1968

16. Newcomer, Robert E.: Improved Aluminum Alloys-Final Report. Report MDC A1666, McDonnell Douglas Corp., 1972.

17. Anon.: Fracture Toughness and Tear Tests. ML-TDR-64-238, Air Force Materials Laboratory, Research and Tech. Division, 1964.

18. Lindh, D. V.; and Eichenberger, T. W.: The Behavior of Several Materials With and Without Notches Under the Influence of Biaxial Stresses of Various Ratios. The Boeing Co., 1963.

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APPENDIX B

REFERENCE ABSTRACTS

DATA SOURCE ABSTRACT CHECKLIST

For each report from which data are obtained check for, and record, the following items:

General Report Information

(1) Reference Number

(2) Materials

(3) Authors, Title, Publisher/Source, Publication Date

Test Information

(1) Type of Test (Fatigue, Fatigue-Crack Propagation, Fracture), Summary of Report Abstract

(2) Type of Test Machines, Load or Strain Control?

(3) Number of Specimens

(4) Stress Ratios

(5) Test Temperature and Environment

(6) Test Frequencies

(7) If Fatigue-Crack Propagation--

(a) Plane Strain or Plane Stress?

(b) Basic Data or "Digested" Data?

Specimen Data

(1) Melting Practice/Heat Treatment of Specimens

(2) Ductility

(3) Fabrication Methods

(4) Surface Finish

(5) Specimen Dimensions

(6) Chemical Composition

(7) Tensile Properties (TYS, TUS, Reduction of Area, Elongation, Elastic Modulus)

(8) Are There Stress-Strain Curves or Data? Are They Monotonic or Cyclic?

REFERENCE NUMBER 1

Materials: 2024-T3, 7075-T6, 4130 Steel

Grover, H. J.; Bishop, S. M.; and Jackson, L. R.: Fatigue Strengths of Aircraft Materials Axial-Load Fatigue Tests on Unnotched Sheet Specimens of 24S-T3 and 75S-T6 Aluminum Alloys and of SAE 4130 Steel. NACA TN 2324, 1951.

(1) Fatigue Tests: Determination of fatigue strengths of three materials at two different test frequencies. Includes study of effects of guides, polishing and multiple stress levels.

(2) Type of Test Machine: Krouse, constant-deflection.

(3) Number of Specimens: 95/24S-T3, 65/75S-T6, 59/4130.

(4) Stress Ratio: R = -1.00 to R = 0.70.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 90 cpm and 1100 cpm.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Cut from 0.090-inch aluminum sheet and from 0.075-inch sheet, with grain running long direction of blank. Machined to shape with zinc chromate primer coating on blank. After electropolishing vinylseal was applied. Vinylseal removed with acetone prior to testing.

(4) Surface Finish: Specimens electropolished to (1) leave no transverse scratches, (2) reproducibly round edges, (3) leave negligible residual stress, (4) avoid surface coldworking, and (5) polish notch roots.

(5) Specimen Dimensions: Gross length = 18 inches, test section length = 9 inches, gross width = 3 inches, test section width = 1 inch, radius = 12 inches.

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	Grain Direc.	TYS, ksi	TUS, ksi	Elong., %	E, ksi
24S-T3	With	54.0	73.0	18.20	10620
24S-T3	Cross	50.0	71.0	18.30	10450
75S-T6	With	76.0	82.5	11.40	10450
75S-T6	Cross	75.0	82.5	11.00	10550
SAE 4130	With	98.5	117.0	14.25	30400
SAE 4130	Cross	101.0	120.0	12.50	31300

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 2

Materials: 2024-T3, 7075-T6, 4130 Steel

Grover, H. J.; Bishop, S. M.; and Jackson, L. R.: Fatigue Strengths of Aircraft Materials Axial-Load Fatigue Tests on Notched Sheet Specimens of 24S-T3 and 75S-T6 Aluminum Alloys and of SAE 4130 Steel with Stress-Concentration Factors of 2.0 and 4.0. NACA TN 2389, 1951.

Test Information

(1) Fatigue Tests: Axial-load fatigue tests were conducted on notched specimens of three sheet materials with two stress-concentration factors and several levels of mean stress.

(2) Type of Test Machine: Krouse direct repeated-stress testing machine.

(3) Number of Specimens: 189/2024-T3, 181/7075-T6, and 184/4130 steel.

(4) Stress Ratio: R = -1.0 to 0.70.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 1100 - 1500 cpm.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were machined from sheet materials and notches were cut.

(4) Surface Finish: Specimens were electropolished to produce a surface having an 8-microinch profilometer value.

(5) Specimen Dimensions:

Notch Type	Gross Length, in.	Net Length, in.	Gross Width, in.	Net Width, in.	Root Radius, in.	K_t
Hole-Type	17	---	4.5	---	1.5	2.0
Edge-cut	17	---	2.25	1.5	0.3175	2.0
Fillet-type	17	5.0	2.25	1.5	0.1736	2.0
Edge-cut	17	---	2.25	1.5	0.057	4.0
Fillet-type	17	5.0	2.25	1.5	0.0195	4.0

2024-T3 and 7075-T6 specimens were 0.09-inch thick and 4130 steel specimens were 0.075-inch thick.

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi	Elong., %
2024-T3	54.0	73.0	18.2
7075-T6	76.0	82.5	11.4
4130	98.5	117.0	14.25

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 3

Materials: 2024-T3, 7075-T6, 4130 Steel

Grover, H. J.; Bishop, S. M.; and Jackson, L. R.: Fatigue Strengths of Aircraft Materials Axial-Load Fatigue Tests on Notched Sheet Specimens of 24S-T3 and 75S-T6 Aluminum Alloys and of SAE 4130 Steel with Stress-Concentration Factor of 5.0. NACA TN 2390, 1951.

Test Information

(1) Fatigue Tests: Axial-load fatigue tests were conducted on notched specimens of three sheet materials with one stress concentration factor and four mean stress levels.

(2) Type of Test Machine: Krouse direct repeated-stress test machine.

(3) Number of Specimens: 49/2024-T3, 47/7075-T6, and 42/4130.

(4) Stress Ratio: R = -1.0 to 0.70.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 1100 - 1500 cpm.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were machined from 0.09 inch thick 2024-T3 and 7075-T6 aluminum and from 0.075 inch thick 4130 steel. Notches were cut in a series of machining cuts.

(4) Surface Finish: Specimens were electropolished.

(5) Specimen Dimensions: Gross length = 15.5 inches, gross width = 2.25 inches, net width = 1.5 inches, root radius = 0.03125 inch (K_t = 5).

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi	Elong., %
2024-T3	54.0	73.0	18.2
7075-T6	76.0	82.5	11.4
4130	98.5	117.0	14.3

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 4

Materials: 2024-T3, 7075-T6, 4130 Steel

Grover, H. J.; Hyler, W. S.; and Jackson, L. R.: Fatigue Strengths of Aircraft Materials Axial-Load Fatigue Tests on Notched Sheet Specimens of 24S-T3 and 75S-T6 Aluminum Alloys and SAE 4130 Steel with Stress-Concentration Factor of 1.5. NACA TN 2639, 1952.

Test Information

(1) Fatigue Tests: Axial-fatigue tests were conducted on notched specimens of three sheet materials at four levels of mean stress.

(2) Type of Test Machine: Krouse direct repeated-stress test machine.

(3) Number of Specimens: 31/2024-T3, 31/7075-T6, and 24/4130.

(4) Stress Ratio: R = -1.0 to 0.5.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 1100 - 1500 cpm.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Notched specimens were machined from 0.09 inch 2024-T3 and 7075-T6 and 0.075 inch 4130 steel.

(4) Surface Finish: Specimens were electropolished.

(5) Specimen Dimensions: Gross length = 15.25 inches, gross width = 3 inches, net width = 1.5 inches, root radius = 0.76 inch (K_t = 1.5).

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi	Elong., %
2024-T3	54.0	73.0	18.2
7075-T6	76.0	82.5	11.4
4130	98.5	117.0	14.3

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 5

Materials: 2024-T3, 7075-T6

Hardrath, H. F.; and Illg, W.: Fatigue Tests at Stresses Producing Failure in 2 to 10,000 cycles, 24S-T3 and 75S-T6 Aluminum Alloy Sheet Specimens with a Theoretical Stress-Concentration Factor of 4.0 Subjected to Completely Reversed Axial Load. NACA TN 3132, 1954.

Test Information

(1) Fatigue Tests: Notched specimens of two sheet materials were subjected to completely reversed axial loads and fatigue strengths compared.

(2) Type of Test Machine: Subresonant fatigue machine or double-acting hydraulic jack (120,000 lb.).

(3) Number of Specimens: 30/2024-T3, 26/7075-T6.

(4) Stress Ratio: R = -1.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 1800 cpm or 14 - 48 cpm.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Longitudinal specimens were machined from 0.09-inch sheet and notches were cut with a milling cutter.

(4) Surface Finish: Surfaces were left unpolished except for removing burrs at the notches.

(5) Specimen Dimensions: Gross length = 17 inches, gross width = 2.25 inches, net width = 1.5 inches, root radius = 0.057 inch (K_t = 4.0).

(6) Chemical Composition: Not specified.

(7) Tensile Properties: Not specified.

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 6

Materials: 2024-T3, 7075-T6

Landers, C. B.; and Hardrath, H. F.: Results of Axial-Load Fatigue Tests on Electropolished 2024-T3 and 7075-T6 Aluminum Alloy Sheet Specimens with Central Holes. NACA TN 3631, 1956.

Test Information

(1) Fatigue Tests: Axial-load tests were conducted on two sheet materials at two stress ratios using specimens with central holes. Specimen widths and hole diameters were varied to study the effect of notch size.

(2) Type of Test Machine: Subresonant fatigue machine (20,000 lb.) or hydraulic machine.

(3) Number of Specimens: 507/2024-T3, 255/7075-T6.

(4) Stress Ratio: R = 0 or -1.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 1800 cpm or 180 cpm.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were machined from 0.09 inch sheet in the longitudinal direction. Central holes were made in three steps and deburred.

(4) Surface Finish: Specimens were electropolished.

(5) Specimen Dimensions:

	W = 4 in. L = 20 in.		W = 2 in. L = 20 in.		W = 0.5 in. L = 12 in.	
Material	Hole Diameter, Inch	K_t	Hole Diameter, Inch	K_t	Hole Diameter, Inch	K_t
2024-T3	0.125	2.91	0.0625	2.91	0.03125	2.82
"	0.25	2.82	0.125	2.82	0.0625	2.66
"	0.5	2.66	0.25	2.66	0.125	2.43
"	1.0	2.43	0.5	2.43	0.25	2.16
"	2.0	2.16	1.0	2.16		
7075-T6	0.125	2.91	0.0625	2.91	0.03125	2.82
"	0.25	2.82	0.125	2.82	0.125	2.43
"	2.0	2.16	1.0	2.16	0.25	2.16

(6) Chemical Composition: Not specified.

(7) Tensile Properties: Not specified.

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 7

Materials: 2024-T3, 7075-T6, 4130 Steel

Illg, W.: Fatigue Tests on Notched and Unnotched Sheet Specimens of 2024-T3 and 7075-T6 Aluminum Alloys and of SAE 4130 Steel with Special Consideration of the Life Range from 2 to 10,000 Cycles. NACA TN 3866, 1959.

Test Information

(1) Fatigue Tests: Notched and unnotched specimens of three alloys were tested with two stress concentrations and three mean stress levels.

(2) Type of Test Machine: Subresonant machine or double acting hydraulic jack.

(3) Number of Specimens: 145/2024-T3, 149/7075-T6, and 258/4130.

(4) Stress Ratio: R = -1.0 to 0.8.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 1900 cpm or 0.4 - 1.0 cpm.

Specimen Data

(1) Melting Practice/Heat Treatment: The 4130 steel was in the normalized condition or heat treated to tensile strength of 180 ksi.

(2) Ductility: Not specified.

(3) Fabrication Methods: Longitudinal specimens were machined and notches cut with a milling tool.

(4) Surface Finish: Burrs were removed at notches and unnotched specimens were electropolished.

(5) Specimen Dimensions:

Stress Concentration	Gross Length, in.	Net Length, in.	Gross Width, in.	Net Width, in.	Root Radius, in.
$K_t = 4.0$	17	---	2.25	1.5	0.057
$K_t = 2.0$	17	---	2.25	1.5	0.3175
$K_t = 1.0$	17.5	9.6	2.88	1.0	---

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi	Elong., %	E, 10^3 ksi
2024-T3	52.1	72.1	20.3	10.5
7075-T6	75.5	83.0	12.3	10.2
Normalized 4130	93.9	115.9	15.2	29.4
Hardened 4130	174.0	180.0	8.3	29.9

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 8

Materials: 2024-T3, 7075-T6, 4130 Steel

Grover, H. J.; Hyler, W. S.; and Jackson, L. R.: Fatigue Strengths of Aircraft Materials Axial-Load Fatigue Tests in Edge-Notched Sheet Specimens of 2024-T3 and 7075-T6 Aluminum Alloys and of SAE 4130 Steel with Notch Radii of 0.004 and 0.070 Inch. NASA TN D-111, 1959.

Test Information

(1) Fatigue Tests: Axial-load fatigue tests were conducted on notched specimens of three sheet materials to afford data on the variation of fatigue strength reduction with notch radius and on the usefulness of the stress concentration factor.

(2) Type of Test Machine: Krouse direct repeated-stress test machine.

(3) Number of Specimens: 36/2024-T3, 37/7075-T6, 35/4130.

(4) Stress Ratio: R = -1.0 to 0.08.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 1100 - 1500 cpm.

Specimen Data

(1) Melting Practice/Heat Treatment: The 4130 steel was normalized.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were machined from 0.09 inch 2024-T3 and 7075-T6 and 0.075 inch 4130 and notches were cut.

(4) Surface Finish: Specimens were electropolished.

(5) Specimen Dimensions: Edge-notched specimen- length = 14.25 inches, width = 1.516 inches, root radius = .004 inch (K_t = 4), notch depth = .0093 inch. Notched specimen- length = 14.25 inches, width = 4.1 inches, root radius = 0.07 inch, notch depth = 1.3 inches.

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi	Elong., %
2024-T3	54.0	73.0	18.2
7075-T6	76.0	82.5	11.4
4130	98.5	117.0	14.3

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 9

Materials: 2024-T3, 7075-T6

Naumann, E. C.; Hardrath, H. F.; and Guthrie, D. E.: Axial-Load Fatigue Tests of 2024-T3 and 7075-T6 Aluminum-Alloy Sheet Specimens Under Constant-and-Variable-Amplitude Loads. NASA TN D-212, 1959.

Test Information

(1) Fatigue Tests: Sheet specimens of two materials were tested using a constant or varied load amplitude. The value of the summation of cycle ratios, effects of load spectrum, block size, number of stress steps, and S-N curve reliability are discussed.

(2) Type of Test Machine: Fatigue testing machines (20,000 pound capacity).

(3) Number of Specimens: 41 constant amplitude/2024-T3, 34 constant amplitude/7075-T6.

(4) Stress Ratio : R = -1.0 to 0.6.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 1800 cpm.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were machined from 0.09 inch sheet material and notched by drilling a hole and then slotting.

(4) Surface Finish: Rolled surfaces were left as received but burrs were removed from notches.

(5) Specimen Dimensions: Length = 17.5 inches, gross width = 2.25 inches, net width = 1.5 inches, root radius = .058 inch (K_t = 4).

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi	Elong.,%
7075-T6	75.5	82.94	12.3
2024-T3	52.05	72.14	21.6

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 10

Materials: 7075-T6

Smith, C. R.: S-N Characteristics of Notched Specimens. NASA CR-54503, 1966.

Test Information

(1) Fatigue Tests: Tests were conducted on one material to show that a single fatigue test in the short life range plus mechanical properties of the material can be used to predict S-N characteristics of notched specimens.

(2) Type of Test Machine: Sonntag constant-load fatigue machine or Tatnall-Budd hydraulic fatigue machine.

(3) Number of Specimens: 225/7075-T6.

(4) Stress Ratio : R = -1 to 0.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 1750 cpm or 5 cps.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Notched and unnotched specimens were made in the longitudinal direction from 0.05 inch thick sheet.

(4) Surface Finish: Edges of unnotched specimens were finished with emery paper.

(5) Specimen Dimensions: Unnotched hourglass - length = 7.5 inches, gross width = 1.5 inches, net width = 0.5 inch. Notched - length = 7.5 inches, width = 1.5 inches, central hole diameter = 0.25 inch (K_t = 2.57).

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi	Elong., %	R.A., %
7075-T6	76.0	84.0	11.1	26.4

(8) Stress-Strain Curves: Typical stress-strain curve is given.

REFERENCE NUMBER 11

Materials: 300-M Steel, Ti-6Al-6V-2Sn

Harmsworth, C. L.: Low-Cycle Fatigue Evaluation of Titanium 6Al-4V-2Sn and 300-M Steel for Landing Gear Applications. AFML-TR-69-48, 1969.

Test Information

(1) Fatigue Tests: Typical landing gear forgings of two alloys were evaluated to obtain properties of interest in the design of landing gear. Data includes strain and stress cycled low cycle fatigue under reversed loading.

(2) Type of Test Machine: A Research Incorporated Universal Testing Machine (50,000 lb.) was used for constant strain tests and a Schenck Fatigue Machine (12,000 lb.) was used for stress cycled tests.

(3) Number of Specimens: 47/Ti-6Al-6V-2Sn, 60/300-M Steel.

(4) Stress Ratio: R = -1.0 or +0.1.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 30 cpm.

Specimen Data

(1) Melting Practice/Heat Treatment: The Ti-6Al-6V-2Sn forgings were solution annealed (1600° - 1650° F/1 hr), water quenched and aged (1000° F/6-8 hours). The 300-M steel specimens were heat treated after machining as follows: (a) H.T. in salt bath and (b) 1600° F in salt oil quench, (3) double draw at 575° F.

(2) Ductility: Not specified.

(3) Fabrication Methods: Steel specimens were rough machined, heat treated, and ground to final dimensions.

(4) Surface Finish: Test portion was polished with emery paper.

(5) Specimen Dimensions: Gross length = 5.5 inches, net length = 1.25 inches, gross diameter = 0.62 inch, net diameter = 0.25 inch, root radius = 0.02 inch (K_t = 2.4) or 0.01 inch (K_t = 3.0), flank angle = 60°.

(6) Chemical Composition: See report for analysis of each titanium forging.

REFERENCE NUMBER 11 (continued)

300-M, Percent by Weight

Si	1.68	Ni	1.93
Mn	0.70	Cr	0.79
P	0.01	Mb	0.39
S	0.01	Al	0.15
C	0.43	V	0.07

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi	Elong., %	R.A.,%
Ti-6-6-2 Forged Block	168.7	178.8	6.1	20.8
Ti-6-6-2 Forging No. 1	178.7	184.8	5.1	23.8
Ti-6-6-2 Forging No. 2	174.6	188.1	4.2	9.6
300-M Steel	242.1	294.0	7.7	44.0

(8) Stress-Strain Curves or Data: Stress-strain curves and data are given for both materials.

REFERENCE NUMBER 12

Materials: 300 M (see report for others).

Deel, O. L.; and Mindlin, H.: Engineering Data cn New and Emerging Structural Materials. AFML-TR-70-252, 1970.

Test Information

(1) Fatigue and Fracture Tests: Tests were conducted to evaluate newly developed structural materials of potential Air Force weapons system interest.

(2) Type of Test Machine: Krouse axial-load machine (5,000 or 10,000 lb. capacity) or MTS electrohydraulic servocontrolled machine.

(3) Number of Specimens: 5 Fracture/300 M, 59 Fatigue/300 M.

(4) Stress Ratio : R = 0.1.

(5) Test Temperature and Environment: Tests were conducted at room temperature, 300° F and 500° F in air.

(6) Test Frequency: 1725 or 2000 cpm.

Specimen Data

(1) Melting Practice/Heat Treatment: 300 M specimens were heat treated to 280 ksi as follows: 1600 F, quench in warm oil, temper 2 + 2 hours at 575 F.

(2) Ductility: Not specified.

(3) Fabrication: Not specified.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Unnotched fatigue - gross length = 5.5 inches, net length = 2.75 inches, gross diameter = 0.373 inch, net diameter = 0.25 inch, root radius = 0.013 inch (K_t = 3.0), flank angle = 60°.

(6) Chemical Composition:

300 M, Percent by Weight

C	Si	Mn	P	S	Ni	Cr	Mb	Al	V	Fe
0.43	1.68	0.70	0.01	0.01	1.93	0.79	0.39	0.15	0.07	Bal.

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi	Elong., %	E, 10^3 ksi
300 M	247.0	292.0	12.0	29.4

(8) Stress-Strain Curves: Typical tension and compression stress-strain curves are given for room and elevated temperatures.

REFERENCE NUMBER 13

Materials: 2024-T4, 4340 Steel

Topper, T. H.; and Morrow, JoDean, eds.: Simulation of the Fatigue Behavior of the Notch Root in Spectrum Loaded Notched Members (U). T & AM Report No. 333, Dept. of Theoretical and Appl. Mech., Univ. of Ill., Jan. 1970.

Test Information

(1) Fatigue Tests: Tests were conducted to develop the analysis portion of the fatigue problem in the design process.

(2) Type of Test Machine: Closed loop, servo controlled, axial, hydraulic test machine under strain and stress control.

(3) Number of Specimens: 81/2024-T4, 43/4340 Steel.

(4) Stress Ratio:: R = -1.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: Not specified.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Not specified.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Reduced test section was 0.6 inch long and 0.25 inch in diameter.

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi
2024-T4	44	69
4340	171	180

(8) Stress-Strain Curves: Full range stress-strain curves are given for 2024-T4.

REFERENCE NUMBER 14 (MCIC 74342)

Materials: 300 M

Bateh, E. J.; and McGee, W.: Axial Load Fatigue and Tensile Properties of 300 VAR Steel Heat Treated to 280-300 ksi. ER-10202, Lockheed-Georgia Co., 1969.

Test Information

(1) Fatigue Tests: Raw data from fatigue tests on one alloy.

(2) Type of Test Machine: MTS electrohydraulic servo controlled axial fatigue machine.

(3) Number of Specimens: Approximately 750/300 M.

(4) Stress Ratio : R = -1.0, -.333, or +.333.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 6 - 30 cps.

Specimen Data

(1) Melting Practice/Heat Treatment: The 300 M billets were austenitized, quenched, air-cooled, and tempered.

(2) Ductility: Not specified.

(3) Fabrication Method: Not specified.

(4) Surface Finish: Surface finish was of four types - plain, decarburized and shot peened, ground and shot peened, or rough machined.

(5) Specimen Dimensions:

K_t	Maximum Diameter, Inch	Minimum Diameter, Inch	Root Radius, Inch
2.0	0.5	0.25	0.040
3.0	0.5	0.25	0.0145
5.0	0.5	0.25	0.0047

(6) Chemical Composition: Not specified.

(7) Tensile Properties: Not specified.

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 15

Materials: 300 M

Pendelberry, S. L.; Simenz, R. F.; and Walker, E. K.: Fracture Toughness and Crack Propagation of 300 M Steel. FAA Tech. Report No. DS-68-18, 1968

Test Information

(1) Fracture and Crack Propagation Tests: Tests were conducted on one material in three product forms to study the effects of material thickness and strength level.

(2) Type of Test Machine: Lockheed-designed closed-hoop servohydraulic fatigue machine (150,000 lb. capacity), Lockheed-designed axial load resonant fatigue machine (250,000 lb. capacity), and a universal hydraulic testing machine (60,000-400,000 lb. capacity).

(3) Number of Specimens: 132 specimens were used to obtain both crack propagation and fracture data.

(4) Stress Ratio: R = 0.1 or 0.5.

(5) Test Temperature and Environment: Tests were conducted at room temperature in a moist air or salt spray environment.

(6) Test Frequency: 20 cps to precrack specimens.

(7) FCP Data: Presented in basic form.

Specimen Data

(1) Melting Practice/Heat Treatment: Specimens were normalized at 1700°F/1-1/2 hours, air cooled, austinitized at 1600°F/1-1/2 hours, oil quenched, and double-tempered at 500°F to 1050°F depending upon strength level desired.

(2) Ductility: Not given.

(3) Fabrication Methods: Specimens were machined from 0.125 inch sheet, 0.5 or 0.75 inch plate or forgings. Precracking was done by axial tension-tension fatigue generated from an EDM slot.

(4) Surface Finish: Specimens were left as machined.

(5) Specimen Dimensions:

Specimen Type	Thick-ness, inch	Gross Length, inch	Net Length, inch	Gross Width, inch	Net Width, inch	Slot Length, inch	Slot Width, inch
Surface Crack	.125	14	3.5	4	2.25	.08	.006
Surface Crack	.375	16	3.5	5	2.25	.08	.006
Surface Crack	.75	28	9.0	12	4.5	.08	.010
Through Crack	.125	15	---	5	---	.5	---
Through Crack	.375	28	9.0	12	5.0	.5	.010

(6) Chemical Composition: See report for analysis of each heat of material.

(7) Tensile Properties: See report for original materials' properties, results of heat treatment study and properties of control specimens after heat treatment.

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 16

Materials: X7475-T61, 2024-T81, 7075-T6(A)

Newcomer, Robert E.: Improved Aluminum Alloys-Final Report. Report MDC A1666, McDonnell Douglas Corp., 1972.

Test Information

(1) Fatigue-Crack Propagation and Fracture: Testing of three materials was evaluated to characterize properties of a new alloy.

(2) Type of Test Machine: Universal testing machine using loading rate of 60,000 lb/min for 3 and 5-inch crack length specimens and loading rate of 40,000 lb/min for specimens with 7-inch crack length.

(3) Number of Specimens: 4 fracture specimens and approximately 45 crack propagation specimens were used for each alloy.

(4) Stress Ratio: R = 0.1.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: Not specified.

(7) FCP Data: Given as basic data.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens used were center-cracked panels with elox slots.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Width = 15.5 inches for all specimens. 2024-T81 thickness = 0.1226 and 0.1215 inch, 7075-T6 thickness = 0.1243 and 0.1256 inch, and 7475-T61 thickness = 0.1117 and 0.1120 inch. Elox slot width = 0.010 inch and slot length = 2, 4, or 6 inches.

(6) Chemical Composition: Composition of 2024 not specified.

Material	Composition, weight %								
	Si	Fe	Mn	Cu	Mg	Zn	Cr	Ti	Others
7075	0.40*	0.50*	0.30*	1.2-2.0	2.1-2.9	5.1-6.1	0.18-0.35	0.20*	0.15*
X7475	0.10*	0.12*	0.06*	1.2-1.9	1.9-2.6	5.2-6.2	0.18-0.25	0.06*	0.15*

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi	Elong., %
2024-T81	65.0	70.5	10
7075-T6	78.5	85.0	16
7475-T61	75.0	80.0	15

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 17

Materials: Ti-8Al-1Mo-1V, AM-350 Stainless Steel, Inco 718, Ti-6Al-4V(A), PH14-8Mo Stainless Steel (B)

Anon.: Fracture Toughness and Tear Tests. ML-TDR-64-238, Air Force Materials Laboratory, Research and Tech. Division, 1964.

Test Information

(1) Fracture and Fatigue-Crack Propagation Tests: Tests were conducted on five sheet alloys with variables of grain direction, thickness, temperature, crack length, and stress rate to be examined. Exposure effects were also discussed.

(2) Type of Test Machine: Servovalve-controlled hydraulic-load-cylinder jigs were used for cycling and fracture testing.

(3) Number of Specimens: Approximately 52 fracture specimens/alloy. Six/alloy were exposed at 650 F for 1000 hours under 25 ksi for titanium alloys and 40 ksi for steel and nickel alloys.

(4) Stress Ratio: R = 0.20.

(5) Test Temperature and Environment: Fracture tests were conducted at room temperature, -110, 400, and 650 F in air.

(6) Test Frequency: Large panels were cycled at 120 cpm, small panels at 120 or 1200 cpm.

Specimen Data

(1) Melting Practice/Heat Treatment: AM-350 and PH14-8Mo panels were put through a transformation heat treatment. Inco 718 panels were put through an aging cycle. Ti-8Al-1Mo-1V was in the duplex annealed condition. Ti-6Al-4V was mill annealed.

(2) Ductility: Not specified.

(3) Fabrication Methods: Large 24 x 72-inch panels and 8 x 24-inch panels were sheared and/or milled to the appropriate size from sheets. 24 x 72-inch panels for transverse grain direction tests were made by fusion welding extensions to the basic material sheet widths by the tungsten inert-gas-shielded process. All panels were centrally notched except the exposure specimens. Notches were made by drilling a small center hole, sawing a rough slot, and extending it to final length with a jeweller's saw.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Ti-6Al-4V and PH14-8Mo 24 x 72-inch panels had a crack length of 3, 6, or 10 inches; 8 x 24-inch panels had a crack length of 1 or 3 inches. Thickness of all panels = 0.025, 0.050, 0.125, or 0.200 inch. Notch width = 0.005 inch. See report for other specimen dimensions.

(6) Chemical Composition: See report for chemical analysis of materials by heat.

REFERENCE NUMBER 17 (continued)

(7) *Tensile properties:* See report for properties of other materials.

Material	Grain Dir.	Thick., in.	TYS, ksi	TUS, ksi	Elong., %
Ti-6Al-4V	L	0.025	136.7	140.7	11.5
		0.050	135.8	142.2	14.4
		0.125	134.6	138.8	15.2
		0.200	129.3	138.5	13.7
PH14-8Mo	L	0.025	187.3	203.8	7.8
		0.050	196.5	211.8	10.0
		0.093	197.4	214.2	10.0
		0.125	194.5	207.5	8.6

(1) *Stress-Strain Curves:* Not given.

REFERENCE NUMBER 18

Materials: 7075-T6, Ti-6Al-4V(A), 18Ni Maraging Steel

Lindh, D. V.; and Eichenberger, T. W.: The Behavior of Several Materials With and Without Notches Under the Influence of Biaxial Stresses of Various Ratios. The Boeing Co., 1963.

Test Information

(1) Fracture Tests: Pressure vessels of three materials were biaxially stressed at several ratios with and without flaws to determine yielding behavior and effect of flaws on behavior.

(2) Type of Test Machine: A 150-kip test machine with a Sprague hydraulic bench and data recording system was used for the tests.

(3) Number of Specimens:

	Biaxial Stress	Testing in Comp.	Notched 4 in. Diam. Cylinder	Sheet Tear Spec.
7075-T6	15	5	14	4
Ti-6Al-4V	7	1	4	3
18Ni Maraging	8	2	3	4

(4) Stress Ratio: Biaxial stress ratios of 2:1, 1:1, and 1:0 were used.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: Not specified.

Specimen Data

(1) Melting Practice/Heat Treatment: The Ti-6Al-4V was in the annealed condition.

(2) Ductility: Not specified.

(3) Fabrication Methods: Tubular specimens were formed from sheet material to allow both internal pressure and axial loading. Notches were made in the center of the specimen using an electric-arc discharge machine.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Length = 18 inches, diameter = 5 inches, thickness = 0.020 inch, tip radius of notch $\leq$ 0.001 inch.

REFERENCE NUMBER 18 (continued)

(6) Chemical Composition:

7075-T6, weight %

Mn	Si	Cr	Zn	Ti	Cu	Fe	Mg	Al
0.13	0.13	0.26	5.42	0.01	1.68	0.23	2.72	Bal.

Ti-6Al-4V, weight %

Al	V	H_2	O	N_2	Ti
5.4	3.9	44 ppm	666 ppm	84 ppm	Bal.

18 Ni Maraging Steel, weight %

C	Mn	P	S	Si	Cr	Ni	Mo	Zr	Ca	Ti	Al	Co	Fe
0.019	0.011	0.004	0.010	0.061	0.010	18.69	5.07	0.007	0.005	0.72	0.067	8.97	Bal.

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi	Elong., %	E, 10^3 ksi
7075-T6	74.1	82.1	10.0	9.9
Ti-6Al-4V	130	136	8.5	17.7
18Ni Maraging Steel	290	295	1.5	21.2

(8) Stress-Strain Curves: Cyclic stress-strain curves are present for all materials in two grain directions.

REFERENCE NUMBER 19

Materials: 7075-T651(B), -T7351(A), 7079-T651, 2024-T851, 2020-T651, 2219-T851, 7001-T75

Nordmark, G. E.; Lifka, B. W.; and Kaufman, J. G.: Fracture Toughness, Fatigue-Crack Propagation and Corrosion Characteristics of Aluminum Alloy Plates for Wing Skins. Quarterly Report, Aluminum Co. of America, 1964.

Test Information

(1) Fracture Tests: Tests were performed on several aluminum alloys in full section specimen form.

(2) Type of Test Machine: Southwark testing machines (50,000 lb and 3,000,000 lb capacities).

(3) Number of Specimens: 24/7075-T6 and -T7351 (full section).

(4) Stress Ratio: R = 1/3.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 5 cps.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were cut from 1-3/8 inch plate in the longitudinal and long transverse directions. A minimum of 1/8-inch was machined from each as-rolled surface. 1/8-inch specimens were machined from the center of the thickness. Notches were machined on full section specimens and half of the 1/8 inch specimens. The others were fatigue cracked.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: 1 inch thick specimens - width = 20 inches, length = 64 inches, saw cut = 7 inches, root radius ≤0.0005 in. 1/8 inch thick specimens - width = 3 inches, length = 14 inches, saw cut = 1 inch, root radius ≤ 0.0005 in.

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi	Elong., %
7075-T651	78.5	85.4	15.0
7075-T7351	60.9	72.0	18.3

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 20

Materials: 2024-T3 (clad and bare) (A)

Anderson, W. E.: Fracture Toughness Data Summary. Report D6-9068, The Boeing Co., 1962.

Preliminary data compilation only--unable to abstract.

REFERENCE NUMBER 21

Materials: 7075-T6 (A), 2219-T87 (B) (See report for others.)

Eichenberger, T. W.: Fracture Resistance Data Summary. Report DA-20947, The Boeing Co., 1962.

Test Information

(1) Fracture Tests: Fracture resistance data is presented for both plane stress and plane strain conditions for several types of specimens. Parameters used to evaluate the data were K_c, K_{Ic}, G_c, and dP/dA.

(2) Type of Test Machine: Not specified.

(3) Number of Specimens: Approximately 25 notched round specimens and 40 center-cracked specimens of 2219-T87, 20 center-cracked and 60 tear test specimens of 7075-T6.

(4) Stress Ratio: Not specified.

(5) Test Temperature and Environment: Tests were conducted in range from -423 F to 1500 F in air.

(6) Test Frequency: Not specified.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Not specified.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: See report for individual specimen dimensions.

(6) Chemical Composition: Not specified.

(7) Tensile Properties: See report for tabulated properties.

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 22

Materials: 2219-T87 (A), Ti-5Al-2.5 Sn (B)

Masters, J. N.; Haese, W. P.; and Finger, R. W.: Investigation of Deep Flaws in Thin Walled Tanks. NASA CR-72606, 1970.

Test Information

(1) Fracture Tests: Tests were conducted to investigate the conditions controlling fracture instability and subcritical flaw growth of thin sections containing deep, part-through flaws. Both static and cyclic tests were performed at several temperatures and in varied environments.

(2) Type of Test Machine: Horizontal 350 kip machine was used for larger specimens.

(3) Number of Specimens: Approximately 110 static fracture specimens of 2219-T87 base metal. See report tabulation for other specimens.

(4) Stress Ratio: Not specified.

(5) Test Temperature and Environment: Tests were conducted at room temperature (65 - 75 F) in air, at -320 F in liquid nitrogen, and at -423 F in liquid hydrogen.

(6) Test Frequency: Maximum of 20 cpm.

Specimen Data

(1) Melting Practice/Heat Treatment: The Ti-5Al-2.5 Sn was purchased in the annealed condition.

(2) Ductility: Not specified.

(3) Fabrication Methods: The Ti-5Al-2.5 Sn plate material was put through a hot flattening cycle before fabricating. Smooth tensile, surface flaw, and center crack specimens were machined from plate and weldments of the same thickness except for thin-flawed specimens. Specimens were oriented with the axis of the flaw parallel to rolling direction in the titanium, and perpendicular to rolling direction in aluminum. Initial flaws were made with an electric discharge machine and extended using low stress fatigue.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: See report for individual specimen dimensions.

(6) Chemical Composition: See report for titanium composition.

2219-T87, weight %

Mn	Si	Cu	Mg	Zn	Ti	Fe	V	Zr
0.20-0.40	0.20	5.8-6.8	0.02	0.10	0.02-0.10	0.30	0.05-0.15	0.10-0.25

(7) Tensile Properties: See report for titanium values.

Material	Thickness, in.	Grain Dir.	TYS, ksi	TUS, ksi	Elong., %	R.A., %	E, 10^3 ksi
2219-T87	0.625	L	56.0	69.3	14	30	10.5
2219-T87	0.125	L	55.8	68.0	10	35	10.5

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 23

Materials: 7075-T6 (A), 7075-T73 (B)

Allen, F. C.: Effect of Thickness on the Fracture Toughness of 7075 Aluminum in the T6 and T73 Conditions. Damage Tolerance in Aircraft Structures, ASTM STP 486, 1971, pp. 16-38.

Test Information

(1) Fracture Test: Tests were conducted on one material in two conditions to determine the variation of fracture toughness with thickness.

(2) Type of Test Machine: Tests were done on an appropriate machine with a loading rate of 20,000 psi/min. Buckling restraints were used on 0.05 inch thick specimens.

(3) Number of Specimens: 60 centrally cracked specimens were used.

(4) Stress Ratio: R = 0.1 for crack development.

(5) Test Temperature and Environment: All tests were at room temperature in air.

(6) Test Frequency: Not specified.

Specimen Data

(1) Melting Practice/Heat Treatment: All material was received as 7075-T6 and portions were heat treated to the -T73 condition.

(2) Ductility: Not specified.

(3) Fabrication Methods: All specimens were machined from 0.75 inch raw stock. Cracks were developed from starter notches by fatigue loading. Grain direction was parallel to loading.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Thickness = 0.05, 0.10, 0.2, 0.312, 0.45, 0.6, or 0.75 inch; width = 2, 8, 22, or 32 inches; length = 3 times width. Crack dimensions varied.

(6) Chemical Composition: Not specified.

(7) Tensile Properties: See report for graphs of properties.

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 24

Materials: 2219-T87 (A), Ti-5Al-2.5Sn ELI

Eitman, D. A.; and Rawe, R. A.: Plane Stress Cyclic Flaw Growth of 2219-T87 Aluminum and 5Al-2.5Sn ELI Titanium Alloys at Room and Cryogenic Temperatures. NASA CR-54956, 1966.

Test Information

(1) Fracture and Fatigue-Crack Propagation Tests: Tests were conducted for two materials at various temperatures, stresses, and crack lengths to determine the effects of uniaxial and biaxial stresses on the flaw growth characteristics of typical cryogenic tank materials.

(2) Type of Test Machine: Uniaxial flaw growth tests were done on a 150,000 lb. capacity hydraulic fatigue machine. Biaxial specimens were cycled by pressurization with hydraulic oil or cryogenic fluid.

(3) Number of Specimens: 7 uniaxial static specimens/2219-T87, 6 uniaxial static specimens/Ti-5Al-2.5 Sn, 20 biaxial/2219-T87, 18 biaxial/Ti-5Al-2.5 Sn.

(4) Stress Ratio: R = 0.05 or 0.5.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air, at -320 F in liquid nitrogen, and at -423 F in liquid hydrogen.

(6) Test Frequency: 10-60 cpm.

(7) FCP Data: Given as basic data.

Specimen Data

(1) Melting Practice/Heat Treatment: The 2219 Al was in the T87 condition and the Ti-5Al-2.5 Sn was in the annealed condition.

(2) Ductility: Not specified.

(3) Fabrication Methods: All uniaxial specimens of 2219 were prepared with a transverse orientation; the Ti-5Al-2.5 Sn were longitudinal. Starter slots were machined and then fatigue tipped. Biaxial specimens were fabricated by shearing blanks of material to final circumferential dimensions, rolling to form cylinders, welding the seam (tungsten inert gas process), and trimming to length. Starter slots were then milled, crack detector wires were bonded to the cylinders, and the specimen was fatigued until the desired precrack length was reached.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Uniaxial - width = 16 inches, length = 42 inches, thickness = 0.060 or 0.020 inch, crack length $\sim$ 5.00 inches. Biaxial - diameter = 10 inches, length = 36 inches, thickness = 0.060 or 0.020 inch.

REFERENCE NUMBER 24 (continued)

(6) Chemical Composition:

2219-T87, weight %						
Cu	Mg	Si	Fe	Ti	Mn	Zn
5.8-6.8	0.01-0.03	0.07-0.17	0.17-0.37	0.05-0.08	0.22-0.33	0.04-0.07

Ti-5Al-2.5Sn, weight %		
Fe	C	N
0.14-0.19	0.011-0.020	0.007-0.015

(7) Tensile Properties:

Material	Grain Dir.	TYS, ksi	TUS, ksi	Elong., %	E, 10^3 ksi
2219-T87	L	58.2	69.7	9.8	9.8
Ti-5Al-2.5Sn	L	109.3	118.3	15.6	15.6

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 25

Materials: 2219-T87 (A), Ti-5Al-2.5 Sn (ELI)

Ferguson, C. W.: Hypervelocity Impact Effects on Liquid Hydrogen Tanks. NASA CR-54852, 1966.

Test Information

(1) Fracture Tests: Tests were conducted on two materials to determine the structural behavior of cryogenic tank wall materials under simulated meteoroid environments.

(2) Type of Test Machine: A 150,000 lb. capacity test fixture was used with a cryostat containing LH_2 for the uniaxial static fracture tests. Hypervelocity impact and biaxial tests were conducted with a biaxial test fixture and LH_2 pressurizing system.

(3) Number of Specimens: 10 uniaxial specimens of each alloy. See report for numbers of other specimens.

(4) Stress Ratio: Not specified.

(5) Test Temperature and Environment: Tests were conducted at -423 F in LH_2 environment.

(6) Test Frequency: Specimens were loaded monotonically to failure.

Specimen Data

(1) Melting Practice/Heat Treatment: 2219 Al was purchased in the T37 condition and aged to T87. The Ti-5Al-2.5 Sn was in the annealed condition.

(2) Ductility: Not specified.

(3) Fabrication Methods: Uniaxial test panels were machined from 0.125 or o.032 inch sheets of 2219-T87 and 0.015 or 0.036-inch sheets of Ti-5Al-2.5Sn. Fatigue-starter slots were machined in the center of the panels and grown by fatigue cycling.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Uniaxial specimens - width = 16, 14, or 12 inches, length = 42 inches, slot width ≈0.005 inch, slot length = 0.02 to 1.0 inch for titanium and 1 to 4 inches for aluminum, thickness = 0.032 or 0.125 inch for aluminum and 0.015 or 0.036 inch for titanium.

(6) Chemical Composition:

2219-T87, weight %

Zn	Ti	Mg	Mn	Fe	Cu	Al
0.05	0.07	0.02	0.27	0.27	6.25	Bal.

REFERENCE NUMBER 25 (continued)

Ti-5Al-2.5Sn (ELI), weight %							
Al	C	Fe	H	N	O	Sn	Ti
5.2	0.025	0.16	0.006-0.015	0.014	0.07	2.5	Bal.

(7) Tensile Properties:

Material	Grain Direction	Thickness, in.	TYS, ksi	TUS, ksi	Elong., %
2219-T87	L	0.032	59.3	70.4	8
2219-T87	L	0.125	57.6	68.7	10
Ti-5Al-2.5Sn	L	0.015	109.9	117.3	15
Ti-5Al-2.5Sn	L	0.036	108.3	116.4	14

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 26

Materials: 2014-T6

Orange, T. W.: Fracture Toughness of Wide 2014-T6 Aluminum Sheet at -320 F. NASA TN D-4017, 1967.

Test Information

(1) Fracture Tests: Test program was conducted to investigate the effect of specimen size on plane-stress fracture-toughness parameter K_c and to provide a base of data for comparing the effectiveness of several methods of analysis.

(2) Type of Test Machine: Specimens up to 3 inches wide were tested in a 20,000-pound-capacity hydraulic testing machine. Larger specimens were tested in a 400,000-pound-capacity screw-powered tensile machine. Guide plates were used with specimens having initial cracks of 2 inches or longer.

(3) Number of Specimens: Approximately 80.

(4) Stress Ratio: Not specified.

(5) Test Temperature and Environment: Tests were conducted at 70 F in air, -320 F in liquid nitrogen, and -423 F in liquid hydrogen.

(6) Test Frequency: Not specified.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were machined from unclad sheets 72 x 72 x 0.060 inches. Central notches were rough-machined to shape and notch roots finished by shaper-type process.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions:

Length, in.	Width, in.	Thickness, in.	Notch Length	Notch Width, in.	Notch Root Radii, in.
12	3	0.060	As required	0.080	$\leq$0.0005
24	6	0.060	As required	0.080	$\leq$0.0005
48	12	0.060	As required	0.080	$\leq$0.0005

(6) Chemical Composition:

2014, weight %											
Cu	Si	Mn	Mg	Fe	Zn	Cr	Ti	N	H	O	Al
4.45	0.92	0.69	0.57	0.60	0.05	0.04	0.02	0.0012	0.0005	<0.0005	Bal.

(7) Tensile Properties:

Grain Direction	Temp, F	TYS, ksi	TUS, ksi
L	70	65.0	72.3
L	-320	75.19	86.65
L	-423	80.29	99.67

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 27

Materials: Ti-6Al-4V (A), Ti-4Al-3Mo-1V, Ti-8Al-1Mo-1V, AM 350, Rene 41, ELC 301, PH 15-7Mo

Figge, I. E.: Residual Static Strength of Several Titanium and Stainless-Steel Alloys and One Superalloy at -109 F, 70 F, and 550 F. NASA TN D-2045, 1963.

Test Information

(1) Fracture Tests: Static-strength tests were conducted on several materials containing central fatigue cracks. A discussion of the unified notch-strength analysis method is included.

(2) Type of Test Machine: A hydraulic jack (120,000-pound capacity) with load rate of 30,000 lb/min was used. Guide plates were used on all specimens.

(3) Number of Specimens: 19/Ti-6Al-4V.

(4) Stress Ratio: Not specified.

(5) Test Temperature and Environment: Tests were conducted at 70 F, -109 F (block of dry ice used), and 550 F (ceramic heating slab used) in air.

(6) Test Frequency: Not specified.

Specimen Data

(1) Melting Practice/Heat Treatment: Ti-6Al-4V was in the mill-annealed condition (1475 F for 1 hour, furnace cooled to 1300 F, and air cooled).

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were machined with the grain direction parallel to the direction of loading. A crack starter of a 0.01-inch-wide slit was cut by a spark-discharge technique.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Length = 24 in., width = 8 in., thickness = 0.040 in.

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	Temp., F	TYS, ksi	TUS, ksi	Elong., %	E, 10^3 ksi
Ti-6Al-4V	-109	163.0	170.8	13.2	17.4
Ti-6Al-4V	70	137.3	144.4	12.5	16.4
Ti-6Al-4V	550	96.7	109.1	7.5	14.4

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 28

Materials: Ti-5Al-2.5Sn ELI (C), 2014-T6 (A), 2219-T87 (B)

Orange, T. W.; Sullivan, T. L.; and Calfo, F. D.: Fracture of Thin Sections Containing Through and Part-Through Cracks. NASA TN D-6305, 1971.

Test Information

(1) Fracture Tests: Current fracture mechanics theory is used to illustrate the effects of crack dimension and material properties on fracture stresses for several materials. Implications of the analysis for leak-before-burst design of pressure vessels and the applicability of plane-strain theory to surface cracks in thin metal sections are discussed.

(2) Type of Test Machine: A screw-powered (400,000-pound-capacity) tensile testing machine was used with buckling guides for the 2219-T87 specimens. All others were tested in hydraulic machines (20,000, 24,000, and 120,000-pound capacities).

(3) Number of Specimens: 19/5Al-2.5Sn, 10/2014-T6 Al, and 22/2219-T87 Al through-crack specimens. 37/Ti-6Al-2.5Sn and 12/2014-T6 surface-crack specimens.

(4) Stress Ratio: Not specified.

(5) Test Temperature and Environment. Tests were conducted at 70 F in air, -320 F in liquid nitrogen, and -423 F in liquid hydrogen.

(6) Test Frequency: Not specified.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Crack starters were made by electrical-discharge machining or were machine scribed. Cracks were fatigue sharpened in tension or extended in cyclic, unidirectional bending.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions:

Material	Length, in.	Width, in.	Thickness, in.
Ti-5Al-2.5Sn	12	1.0	0.06 or 0.11
Ti-5Al-2.5Sn	12	2.0	0.06 or 0.11
Ti-5Al-2.5Sn & 2014-T6	12	3.0	0.06 or 0.11
2219-T87	24	5.5	0.068
2219-T87	24	6.7	0.068

REFERENCE NUMBER 28 (continued)

(6) Chemical Composition:

Ti-5Al-2.5Sn, weight %								
Al	C	Fe	H	Mn	N	O	Sn	Ti
0.06 inch								
5.3	0.02	0.18	0.0040	0.01	0.007	0.098	2.5	Bal.
0.11 inch								
5.3	0.02	0.18	0.0034	0.01	0.007	0.091	2.5	Bal.

2014-T6, weight %													
Al	Cr	Cu	Fe	H	Mg	Mn	N	O	Si	Ti	Zn	V	Zr
Bal.	0.04	4.45	0.60	0.0005	0.57	0.69	0.0012	0.0005	0.92	0.02	0.05	--	--

2219-T87, weight %													
Al	Cr	Cu	Fe	H	Mg	Mn	N	O	Si	Ti	Zn	V	Zr
Bal.	--	5.85	0.19	--	0.012	0.25	--	--	0.12	0.09	0.09	0.08	0.11

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi	Elong., %	E, 10^3 ksi
Ti-5Al-2.5Sn (0.06 in.)	119	129.0	14	17
Ti-5Al-2.5Sn (0.11 in.)	105	114.0	18	17
2014-T6	65	72.3	--	10
2219-T87	55	67.7	11	11

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 29

Materials: 2024-T3 (A), 2024-T351

Feddersen, C. E.; Simonen, F. A.; Hulbert, L. E.; and Hyler, W. S.: An Experimental and Theoretical Investigation of Plane-Stress Fracture of 2024-T351 Aluminum Alloy. NASA CR-1678, 1970.

Test Information

(1) Fracture Tests: A study of plane-stress fracture behavior of one material in two forms and conditions. Influence of width, thickness, and crack-aspect ratio was determined. A discussion of data display and analysis technique is included.

(2) Type of Test Machine: All tests were done under load control in an electro-hydraulic testing machine (25-kip, 50-kip, 170-kip, or 700-kip load capacities) using buckling restraints.

(3) Number of Specimens: 6/2024-T3 0.05-inch sheet, 17/2024-T3 0.125-inch sheet, 7/2024-T351 0.5-inch plate.

(4) Stress Ratio: R = 0.1.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: Not specified.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were machined from bare sheet or plate. A saw cut was made to a length 0.8 inch less than desired crack length. Last 0.8 inch of flaw length was made by fatigue cycling. Photoelastic coating was applied to some specimens.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions:

Width, in.	Crack Length, in.	Thickness, in.
4	0.4, 1.2, 2.4	0.125
8	0.8, 2.4, 4.8	0.05, 0.125, 0.5
24	2.4, 7.2, 14.4	0.05, 0.125, 0.5

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	Thickness, in.	TYS, ksi	TUS, ksi	Elong., %
2024-T3	0.050	52.65	71.5	19.5
2024-T3	0.125	53.8	71.65	20.0
2024-T351	0.5	54.85	71.35	22.7

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 30

Materials: 2219-T81 Al, Ti-6Al-4V (ELI), René 41, 2014-T6 (A). Type 301 S.S., Type 310 S.S.

Christian, J. L.; and Hurlich, A.: Physical and Mechanical Properties of Pressure Vessel Materials for Application in a Cryogenic Environment. ASD-TDR-62-258, Part II, General Dynamics/Astronautics, 1963.

Test Information

(1) Fracture Tests: Tests were designed to determine fracture toughness of several materials for application in a cryogenic environment.

(2) Type of Test Machine: Standard universal testing machine with a cryostat.

(3) Number of Specimens: Approximately 30/alloy

(4) Stress Ratio : Not specified (0-60% of maximum stress).

(5) Test Temperature and Environment: Tests were conducted at 78 F in air, -320 F in liquid nitrogen, and -423 F in liquid hydrogen.

(6) Test Frequency: 6 cpm.

Specimen Data

(1) Melting Practice/Heat Treatment: See report for history of each alloy.

(2) Ductility: Not specified.

(3) Fabrication Methods: Center notches were cut with an electrical discharge machine. Notch length was approximately 30% of specimen width, except in notch-length study. Loading was parallel to the direction of rolling.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Width = 2, 4, 8, 13, or 18 inches; Length = 2 times width; see report for alloy sheet thicknesses.

(6) Chemical Composition: See report for analysis of alloys.

(7) Tensile Properties: See report for properties of alloys tested.

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 31

Materials: 7075-T651

Bonesteel, R. M.: Fracture Behavior of 1/4-in.-Thick 7075-T651 Al Containing Semielliptical Surface Flaws. 6-83-71-1, Lockheed Missiles and Space Co., 1971.

Test Information

(1) Fracture Tests: The behavior of center-through-crack specimens of one plate alloy was studied, as well as that of surface flawed specimens under sustained load and exposed to aqueous 3 1/2% NaCl solution.

(2) Type of Test Machine: Not specified for fracture tests (monotonically loaded). Environmental tests were performed in a modified creep test frame.

(3) Number of Specimens: 13 static fracture surface flawed, 7 fracture center-through cracked.

(4) Stress Ratio: Not specified.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air or aqueous 3 1/2% NaCl solution.

(6) Test Frequency: Not specified.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Blanks were sheared from 1/4-inch plate and tensile type specimens were machined with the axes transverse to the rolling direction. Surface flaws were introduced by EDM with axial or bending fatigue. Center-through-cracks were made by introducing a central slot or hole, enlarging it with a jeweler's saw, and axial fatigue.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions:

Gross Length, in.	Test Section Length, in.	Gross Width, in.	Test Section Width, in.	Thickness, in.
8	2.75	2.00	1.25	0.25
12	6.00	3.95	2.50	0.25

(6) Chemical Composition: Not specified.

(7) Tensile Properties: Not specified.

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 32

Materials: 2024-T3 , 7075-T6

Dubensky, R. G.: Fatigue Crack Propagation in 2024-T3 and 7075-T6 Aluminum Alloys at High Stresses. NASA CR-1732, 1971.

Test Information

(1) Fatigue Crack Propagation: Crack-growth rates were measured at high stresses in axial-load fatigue tests on sheet specimens of two aluminum alloys.

(2) Type of Test Machine: Combination subresonant and hydraulic fatigue machine (132,000 lb. capacity) using the hydraulic mode of operation.

(3) Number of Specimens: 16/7075-T6, 16/2024-T3.

(4) Stress Ratio: R=0, 0.33, 0.5, or 0.7.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 4-25 cpm.

(7) FCP Data: Data are in basic form.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were cut from sheet material and a crack starter notch 0.1 inch long by 0.01 inch wide was made by EDM.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Length = 35 in. width = 12 in., thickness = 0.09 in.

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi	Elong., %	E, 10^3 ksi
7075-T6	75.5	83.2	12	10.1
2024-T3	51.2	70.9	31	10.42

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 33

Materials: Type 304 S.S., 18% Ni. Maraging Steel (A), Hastelloy B, Type 718 Ni(C), 7039-T6 Al, René 41, Ti-6Al-4V ELI (B), Ti-5Al-2.5Sn ELI

Christian, J. L.; Yang, C. T.; and Witzell, W. E.: Physical and Mechanical Properties of Pressure Vessel Materials for Application in a Cryogenic Environment. ASD-TDR-62-258, Part III, General Dynamics/Astronautics, 1964.

Test Information

(1) Fracture Tests: Crack propagation tests were conducted to determine fracture toughness and strain-energy release rate for several materials. The effect of specimen width, notch length, loading rate, and material thickness are investigated.

(2) Type of Test Machine: Not specified.

(3) Number of Specimens: Approximately 60/alloy for each variable investigated.

(4) Stress Ratio: Not specified.

(5) Test Temperature and Environment: Tests were conducted at 75 F in air, -320 F in liquid nitrogen, and -423 F in liquid hydrogen.

(6) Test Frequency: 6 cpm.

Specimen Data

(1) Melting Practice/Heat Treatment: See report for history of each alloy.

(2) Ductility: Not specified.

(3) Fabrication Methods: Center notched tensile specimens were used. Notches were cut by an electrical discharge (Elektro-Jet) machine with tip radius $\leq$ 0.001 inch. Notch length was approximately 30% of specimen width.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions:

Width, in.	Length, in.	Crack Length, in.	Root Radius, in.
2	6	0.60	$\leq$0.001
4	10	1.25	$\leq$0.001
8	16	2.50	$\leq$0.001
13	26	4.00	$\leq$0.001
18	36	5.50	$\leq$0.001

(6) Chemical Composition: See report for individual analyses.

(7) Tensile Properties: See report for properties of each alloy.

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 34

Materials: 2024-T3 Al (A), Ti-8Al-1Mo-1V (B)

Walker, E. K.: A Study of the Influence of Geometry on the Strength of Fatigue Cracked Panels. AFFDL-TR-66-92, Northrop Norair, 1966.

Test Information

(1) Fracture Tests: Tests were designed to define and verify a synthesis of strength-limiting parameters for fatigue cracked panels, applicable to a wide range of conditions.

(2) Type of Test Machine: Load frame and hydraulic load cylinder (300,000 lb. capacity). Load control was attained by use of an electrohydraulic servo channel and feedback signal. Buckling restraints were used on about half of the specimens.

(3) Number of Specimens: 68/2024-T3 Al, 16/Ti-8Al-1Mo-1V.

(4) Stress Ratio: Not specified.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: Not specified.

Specimen Data

(1) Melting Practice/Heat Treatment: The Ti-8Al-1Mo-1V was duplex annealed.

(2) Ductility: Discussion of materials' ductility included.

(3) Fabrication Methods: Flat panels were cut from sheets and slotted with the slot perpendicular to the rolling direction. Initial slots were extended by a jeweler saw and grown by fatigue cracking to a length at least 3 times the thickness.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: 2024-T3 - width = 30 in., 20 in., 12 in., and 9 in., length = 2.5 times width, thk. = .080, .063, and .032 inch; Ti-8Al-1Mo-1V - width = 12 in. and 9 in., length = 2.5 times width, thk. = .045 in. and .020 in.

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	Thickness, in.	TYS, ksi	TUS, ksi	Elong., %	E, ksi x 10^3
2024-T3	0.032	52.0	71.1	18.0	10.3
2024-T3	0.063	51.9	68.2	19.2	10.3
2024-T3	0.080	53.3	71.1	19.8	10.3
Ti-8Al-1Mo-1V	0.045	132.6	143.9	14.3	18.0
Ti-8Al-1Mo-1V	0.020	135.5	145.8	12.0	16.0

(8) Stress-Strain Curves: Relationship between strain and stress variables is shown.

REFERENCE NUMBER 35

Materials: 2024-T3(A), -T6, and -T81; 5052-H34; 6061-T4; and 7075-T6 (B)

Gurin, P. J.: Crack Propagation Tests for Some Aluminum Alloy Materials. LR 10498, Lockheed Aircraft Corp., 1955.

Test Information

(1) Fracture Tests: Tests were conducted to investigate relative crack propagation properties of several aluminum alloys.

(2) Type of Test Machine: Southwark-Emery universal testing machine (300,000 lb. capacity).

(3) Number of Specimens: Approximately 125/2024-T3 and 7075-T6. See report for other alloys.

(4) Stress Ratio : Not specified.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: Not specified.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Initial cracks were made by drilling a .25-inch hole, saw cutting to .048 inch additional length, and extending the crack an additional .018 inch with a jeweler's saw.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Width = 9 inches or 20 inches; length = 8 inches to 40 inches. See report for alloy sheet thicknesses.

(6) Chemical Composition: Not specified.

(7) Tensile Properties: See report for properties of specific alloys.

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 36

Materials: 2024-T3(A), 2024-T4, 7075-T6(B)

McEvily, A. J.; Illg, W.; and Hardrath, H. F.: Static Strength of Aluminum-Alloy Specimens Containing Fatigue Cracks. NACA TN 3816, 1956.

Test Information

(1) Fracture Tests: Several specimen configurations of two alloys were fatigue-cracked and subjected to static tests to determine the residual static strengths.

(2) Type of Test Machine: Hydraulic testing machine (120,000-pound capacity) and Langley 1,200,000-pound-capacity test machine.

(3) Number of Specimens: See report for specimen numbers per alloy, form, and condition.

(4) Stress Ratio : Not specified.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 3 cpm, 6 cpm, and 1800 cpm.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were cut to varying widths with the longitudinal axis parallel to the grain direction. The specimens were then machined to produce an edge notch, 1/4-inch hole, 1-inch hole, 1/8-inch tangs with 1/4-inch hole, or 1/4-inch tangs with 1/4-inch hole.

(4) Surface Finish: Faces of the specimens were left as received.

(5) Specimen Dimensions:

Gross Width, in.	Net Width, in.	Gross Length, in.	Net Length, in.	Root Radius, in.	Center Hole Diameter, in.	Tang Thickness, in.
2.25	1.5	17.5	--	0.375	--	--
12	--	36	--	--	1.0	--
12	8.5	36	--	0.875	--	--
2	--	24	14	--	0.25	
4	2	24	9.5	--	0.25	0.125 or 0.25

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	Product Form	TYS, ksi	TUS, ksi	Elong., %
2024-T3	Sheet	52.7	71.9	19.5
2024-T4	Extrusion	52.7	67.2	16.7
2024-T4	Rolled Bar	46.2	64.8	20.9
7075-T6	Sheet	74.0	80.5	12.8
7075-T6	Extrusion	78.5	86.6	11.0
7075-T6	Extruded Bar	77.9	89.0	13.3

(8) Stress-Strain Curves: Typical curves shown for each material.

REFERENCE NUMBER 37

Materials: 2024-T3(A), 7075-T6(B)

Broek, D.: The Residual Strength of Aluminum Alloy Sheet Specimens Containing Fatigue Cracks or Saw Cuts. NLR-TR M.2143, National Aerospace Laboratory, Amsterdam, 1966.

Test Information

(1) Fracture Tests: Tests of aluminum alloy sheets to determine the effect of lower stress concentration at the tip of a saw cut versus that of a fatigue crack, and a fatigue crack grown at a large stress amplitude versus those grown at lower stresses.

(2) Type of Test Machine: Specimens were fatigued in a hydraulic Amsler pulsator (50 tons capacity) and tested in a hydraulic jack (50 tons capacity).

(3) Number of Specimens: 16 specimens per each alloy.

(4) Stress Ratio: Not specified. Mean stress = 11.36 ksi, stress amplitude = 3.55 ksi and 9.23 ksi.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: Not specified.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were cut from alclad sheet with a transverse crack or saw cut. Cracks were made with a jig saw (central hole of .276 inch diameter or central hole and stop holes of .079 inch diameter) or jeweller's fret saw and then fatigue cracked to .592 inch beyond saw cut.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Length = 26.76 inches, width = 11.81 inches, initial crack length = 0.985 inch or 2.36 inches for 7075-T6, and 1.77 or 3.54 inches for 2024-T3.

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi	Elong., %
2024-T3	51.8	67.8	18
7075-T6	73.1	78.6	12

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 38

Materials: 2024-T3(A), 7075-T6(B)

Broek, D.: The Effect of Finite Specimen Width on the Residual Strength of Light Alloy Sheet. TR M.2152, National Aero- and Astronautical Research Institute, Amsterdam, 1965.

Test Information

(1) Fracture Tests: Tests were conducted on two aluminum alloy specimens of varying widths to determine the validity of the energy fracture criterion developed for an infinite sheet.

(2) Type of Test Machine: Hydraulic jack (50 tons capacity) with a strain gauge dynamometer to provide load records.

(3) Number of Specimens: Approximately 42 for each alloy.

(4) Stress Ratio: Not specified.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: Not specified.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were cut from alclad sheet .079 inch thick. Central transverse cracks were made by a saw cut with a jeweller's fret saw and grown by fatigue cycling.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions:

Width, inches	Length, inches
23.6	47.3
11.8	23.6
5.9	11.8

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi	Elong., %
2024-T3	51.6	67.5	18
7075-T6	73.0	78.3	12

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 39

Materials: 2024-T3

Broek, D.: The Effect of the Sheet Thickness on the Fracture Toughness of Cracked Sheet. NLR-TR M.2160, National Aerospace Laboratory, Amsterdam, 1966.

Test Information

(1) Fracture Tests: Tests were conducted on aluminum alloy sheet specimens of varying thicknesses to determine the effect upon residual strength.

(2) Type of Test Machine: A hydraulic jack with strain gauge dynamometer to record load.

(3) Number of Specimens: 40/2024-T3.

(4) Stress Ratio: Not specified.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: Not specified.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were cut longitudinally from four thicknesses of alclad sheet. Center cracks were made with a jeweller's fret saw.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Width = 11.8 inches, length = 26.8 inches, thickness = 0.039, 0.079, 0.118, or 0.157 inch.

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Thickness, in.	TYS, ksi	TUS, ksi	Elong., %
0.039	45.0	63.8	19
0.079	51.8	67.8	18
0.118	53.3	68.1	19
0.157	52.1	68.7	20

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 40

Materials: 2024-T3

Broek, D.: Static Tests on Cracked Panels of 2024-T3 Alclad Sheet Materials from Different Manufacturers. NLR-TN M.2164, National Aerospace Laboratory, The Netherlands, 1966.

Test Information

(1) Fracture Tests: Tests on one material from five manufacturers were used to determine the effects on residual strength and their cause.

(2) Type of Test Machine: Hydraulic jack (50 tons capacity) with a strain gauge dynamometer.

(3) Number of Specimens: Approximately 50.

(4) Stress Ratio: Not specified.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: Not specified.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were cut from alclad sheets in the longitudinal direction. A transverse saw cut was made with a jeweler's fret saw in the center of each specimen.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Width = 5.9 inches, length = 15 inches, thickness = 0.079 or 0.094 inch, saw cut length = 0.79, 1.18, 1.57, or 3.15 inches.

(6) Chemical Composition: See report for composition of each producer's material.

(7) Tensile Properties:

Producer	TYS, ksi	TUS, ksi	Elong., %
B	56.0	66.2	19.0
F	56.4	65.9	22.0
G	51.8	67.8	18.0
E	53.0	68.0	21.0
D	50.5	68.8	22.5

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 41

Materials: 7075-T7351

Feddersen, C. E.; and Hyler, W. S.: Fracture and Fatigue-Crack Propagation Characteristics of 7075-T7351 Aluminum Alloy Sheet and Plate. Report No. G-8902, Battelle Memorial Institute, Columbus Laboratories, 1970.

Test Information

(1) Fracture Tests: Tests on one aluminum alloy were conducted to provide information relative to the damage tolerance of the alloy.

(2) Type of Test Machine: Electrohydraulic servo-controlled machines (25 to 500 kip capacities).

(3) Number of Specimens: Approximately 95.

(4) Stress Ratio: R = 0.1 to 0.5.

(5) Test Temperature and Environment: Tests were conducted at 70 F in air with a relative humidity of 50 ± 10 percent.

(6) Test Frequency: 10-25 cps.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were sectioned with the rolling direction in the direction of loading. The initial flaw was made by drilling a hole 0.25 inch in diameter. The flaw was then machined to the desired dimensions. Cracks were extended by fatigue cracking.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Thickness = 1/16, 1/4, 1/2, 1 or 1-1/4 inches.

Width, in.	Length, in.	Root Radius, in.
8	32	0.005
16	48	0.005
36	96	0.005

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Thickness, in.	TYS, ksi	TUS, ksi
0.061	58.24	69.7
0.257	60.46	71.96
0.50	62.1	72.7
1.0	61.07	71.6
1.257	61.77	71.6

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 42

Data contained in previously defined Reference Number 42 are actually part of Reference Number 124. See that reference for data abstract.

REFERENCE NUMBER 43

Materials: 7049-T73, 7175-T736, 7475-T61(A), 7475-T761(B), Alclad 7475-T61(C), 2124-T851

Babilon, C. F.; Wygonik, R. H.; Nordmark, G. E.; and Lifka, B. W.: Mechanical Properties, Fracture Toughness, Fatigue, Environmental Fatigue Crack Growth Rates and Corrosion Characteristics of High-Toughness Aluminum Alloy Forgings, Sheet and Plate. Fifth Technical Management Report, ALCOA, 1972.

Test Information

(1) Fatigue, Fatigue Crack Propagation and Fracture Tests: Tests were conducted on several alloys in different forms. Not all tests were completed at this time.

(2) Type of Test Machine : Test procedures were described in First and Third Technical Management Reports (August, 1971, and February, 1972).

(3) Number of Specimens: 19 fracture specimens/7475-T61 sheet and 7475-T761 sheet. See report for others.

(4) Stress Ratio: R = 0 for axial stress fatigue tests.

(5) Test Temperature and Environment: Fracture tests were conducted at room temperature in air. Environments used in other tests were lab air, dry air, humid air, and salt fog.

(6) Test Frequency: See former reports.

Specimen Data

(1) Melting Practice/Heat Treatment: 7475 material is Alcoa Process 467 in the -T61 and -T761 conditions.

(2) Ductility: Not specified.

(3) Fabrication Methods: See former reports.

(4) Surface Finish: See former reports.

(5) Specimen Dimensions: Center slotted fracture-toughness panels--length = 44 inches, width = 16 inches, center hole diameter = 0.5 inch.

(6) Chemical Composition: See report for composition of each sample.

(7) Tensile Properties: See report for properties of all alloys.

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 44

Materials: Ti-6Al-4V(A), 4340 Steel (B), Maraging 250 (C), 9Ni-4Co-0.45C(D), AM 355(E), PH-13-8Mo(F), Ti-6Al-6V-2Sn (G)

Anon.: Thick Section Fracture Toughness. ML-TDR-64-236, Boeing-North American, 1964.

Test Information

(1) Fracture Tests: Eight alloys suitable for thick section application on supersonic transport were tested to determine fracture toughness over service temperature range and conditions.

(2) Type of Test Machine: 120-kip Baldwin, 300-kip Baldwin, and a Boeing-made 1000-kip hydraulic machine.

(3) Number of Specimens: 20 center notch panel specimens/Ti-6Al-4V. See report for others.

(4) Stress Ratio: Not specified.

(5) Test Temperature and Environment: Tests were conducted at -110 F in liquid nitrogen, room temperature, 400 F, and 650 F in air.

(6) Test Frequency: 120 to 600 cpm.

Specimen Data

(1) Melting Practice/Heat Treatment: The heat-treat study showed solution treated at 1650 F for 1 hour, water quenched, aged at 1100 F for 4 hours, and air-cooled Ti-6Al-4V material to be in the optimum condition for testing.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were fabricated from forged blocks 3 x 9 x 24 inches. Three thicknesses of specimens were center notched and fatigue-cycled to produce the desired crack length.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions:

Thickness, in.	Width, in.	Length, in.	Grain Direction	Crack Length, in.
3/16	3.0	9.0	L&T	1.0
3/8	6.0	24.0	L	2.0
1	9.0	24.0	L	3.0

(6) Chemical Composition: See report for other alloys' analysis.

Ti-6Al-4V, percent by weight						
Fe	C	V	Al	H_2	O	N_2
0.18	0.08	4.1	6.5	69	1210 ppm	33

(7) Tensile Properties: See report for other alloys.

Material	Grain Direction	TYS, ksi	TUS, ksi	Elong., %	R.A., %
Ti-6Al-4V	L	147.1	160.1	13	44
Ti-6Al-4V	T	152.2	165.3	14	38

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 45

Materials: Ti-5Al-2.5 Sn

Sullivan, T. L.: Uniaxial and Biaxial Fracture Toughness of Extra-Low-Interstitial 5Al-2.5Sn Titanium Alloy Sheet at 20 K. NASA TN D-4016, 1967.

Test Information

(1) Fracture Tests: Tests were conducted on one alloy to determine the effect of sheet width and notch length on the fracture toughness value. A correlation between flat sheet and through-cracked cylindrical pressure vessels is included.

(2) Type of Test Machine: Hydraulically actuated (20,000 lb. capacity) and screw-actuated (400,000 lb. capacity) testing machines.

(3) Number of Specimens: 45/Ti-5Al-2.5 Sn.

(4) Stress Ratio: Not specified.

(5) Test Temperature and Environment: Tests were conducted at -423 F in liquid hydrogen.

(6) Test Frequency: Not specified.

Specimen Data

(1) Melting Practice/Heat Treatment: The material was mill-annealed to 1325 F for four hours and furnace cooled.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were fabricated from .02 inch sheet in the longitudinal direction. Sharp notches were made by electrical discharge machining a through-central slot and fatiguing to the desired length. After fabrication the specimens were stress-relieved by heating to 1100 F for two hours.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions:

Width, inch	Length, inch	Notch Length
3	12	1/8 to 1/3 width
6	24	
12	48	

(6) Chemical Composition:

Ti-5Al-2.5 Sn wt. %

C	Fe	N_2	Al	H_2	O_2	Sn	Mn
0.022	0.03	0.014	5.1	0.006-0.009	0.08	2.5	<0.006

(7) Tensile Properties:

Temp., F	TYS, ksi	TUS, ksi	E, 10^3 ksi
70	104.9	110.1	16.2
-320	172.8	180.3	18.1
-423	203.5	225.6	17.7

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 46

Materials: Ti-8Al-1Mo-1V

Figge, I. E.: Residual-Static-Strength and Slow-Crack-Growth Behavior of Duplex-Annealed Ti-8Al-1Mo-1V Sheet. NASA TN D-4358, 1968.

Test Information

(1) Fracture Tests: Tests were conducted on one alloy to investigate the effect of specimen width on the residual strength. The effects of prior stress and temperature histories and slow-crack-growth behavior are also investigated.

(2) Type of Test Machine : Subresonant (20,000-lb-capacity) and a combination hydraulic and subresonant machines were used to propagate cracks. A hydraulic jack (120,000-lb-capacity) or fatigue and static test machine (1,000,000 lb) were used for static tests with a load rate of 30,000 lbf/min.

(3) Number of Specimens: 65/Ti-8Al-1Mo-1V.

(4) Stress Ratio: R = 0 for prior-stress-history study.

(5) Test Temperature and Environment: Static tests were conducted at 80 F in air. Cracks for the prior-temperature-history study were grown at -109 F, room temperature, or 550 F.

(6) Test Frequency: 40-1800 cpm.

Specimen Data

(1) Melting Practice/Heat Treatment: The material was duplex-annealed by (a) heat to 1450 F/8 hrs., (b) furnace cool, (c) heat to 1450 F/15 minutes, (d) air cool.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were cut from .05 inch thick sheet in two directions. A slit .01 inch wide was cut by a spark-discharge technique and grown by fatigue cycling to the desired length.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions:

Width, inch	Length, inch	Grain Direction
2	12	L
4	12	L
8	24	L&T
20	40	L
20	48	L

(6) Chemical Composition:

Ti-8Al-1Mo-1V, Wt. %							
C	Mo	V	Al	N	H	Ti	Fe
0.08	0.75-1.25	0.75-1.25	7.5-8.5	0.05	0.015	Bal.	0.3

(7) Tensile Properties:

Temp., F	Grain Dir.	TYS, ksi	TUS, ksi	E, 10^3 ksi	Elong., %
80	L	133.6	152.0	18.3	12.5
80	T	135.3	149.2	16.9	11.2
-109	L	162.7	178.0	17.7	15.3
550	L	93.7	115.5	14.1	12.0

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 47

Materials: 2219-T87 Al(B), Ti-5Al-2.5 Sn (ELI)(A)

Tiffany, C. F.; Lorenz, P. M.; and Hall, L. R.: Investigation of Plane-Strain Flaw Growth in Thick-Walled Tanks. NASA CR-54837, 1966.

Test Information

(1) Fracture Tests: Tests were performed on two materials to generate plane-strain fracture toughness data, establish how and under what conditions uniaxial data can be applied to cryogenic pressure vessel design, and verify the applicability of uniaxial data to cryogenic pressure vessel design.

(2) Type of Test Machine: Not specified.

(3) Number of Specimens: 8 static specimens/Ti-5Al-2.5 Sn, 6 static specimens/2219-T87.

(4) Stress Ratio: Not specified.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air, -320 F in liquid nitrogen and -423 F in liquid hydrogen.

(6) Test Frequency: 1 cpm.

Specimen Data

(1) Melting Practice/Heat Treatment: The titanium material was in the annealed condition. The aluminum material was heat treated from the T37 to T87 condition.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were fabricated with through-the-thickness cracks for static tests. The flaws were started with an EDM and extended by fatigue.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Width = 14 inches, length = 30 inches, thickness = 0.188 inch for through-cracked specimens.

(6) Chemical Composition:

Ti-5Al-2.5Sn, percent by weight						
C	Mn	Al	Zr	Sn	Fe	Ti
0.025	0.002	5.2	0.007	2.5	0.16	Bal.

(7) Tensile Properties:

Material	Temp., F	Grain Dir.	TYS, ksi	TUS, ksi	Elong., %
Ti-5Al-2.5Sn	70	L	110.7	116.4	16.7
Ti-5Al-2.5Sn	-320	L	180.3	191.5	14.5
Ti-5Al-2.5Sn	-423	L	213.7	216.8	5.0

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 48

Materials: 7075-T6(A), 2024-T3

Hudson, C. M.: Effect of Stress Ratios on Fatigue-Crack Growth in 7075-T6 and 2024-T3 Aluminum-Alloy Specimens. NASA TN D-5390, 1969.

Test Information

(1) Fracture Tests: Crack-growth tests were conducted on two aluminum alloys at several stress ratios.

(2) Type of Test Machine: Subresonant (20,000-pound capacity), hydraulic (100,000 and 120,000-pound capacities), and a combination unit (105,000 or 132,000-pound capacities). Lubricated buckling guides were used.

(3) Number of Specimens: 27/7075-T6 static tests, 17/2024-T3 static tests.

(4) Stress Ratio: -1.0 to 0.8.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 30 to 1800 cpm depending upon machine used.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were cut from sheet material 0.09 inch thick. A center notch 0.10 inch long by 0.01 inch wide was cut by an electrical discharge process.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Width = 12 inches, length = 35 inches, thickness = 0.09 inch.

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi	E, 10^3 ksi	Elong., %
7075-T6	75.9	83.2	10.1	12
2024-T3	51.2	70.9	10.4	21

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 49

Materials: 7079-T6(B), 7075-T6(A)

Bateh, E. J.; and Edwards, W. T.: Evaluation of Tear Resistance of 7079 Aluminum Alloys (Sheet, Extrusions, and Forging). SMN 86, Lockheed Aircraft Corp., 1962.

Test Information

(1) Fracture Tests: Tests were conducted on two alloys in three forms. A comparison of tear resistance strengths is included.

(2) Type of Test Machine: Universal testing machine with constant load of 4000 lb/min.

(3) Number of Specimens: 21/7075-T6 extrusion, 21/7079-T6 extrusion, 43/7079-T6 sheet.

(4) Stress Ratio: Not specified.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: Not specified.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: The extrusions were machined into plates for testing. A saw cut was made in the center of each specimen equivalent to 0.3 times the width.

(4) Surface Finish: Sheet specimens were bare, clad, or chem-milled.

(5) Specimen Dimensions:

Product Form	Width, in.	Length, in.	Thickness, in.
Extrusion	12	24	0.125 or 0.25
Extrusion	16	40	0.125 or 0.25
Extrusion	16	24	0.125 or 0.25
Sheet	9	24	0.125 or 0.06
Sheet	12	24	0.125 or 0.06
Sheet	12	36	0.125 or 0.06
Sheet	16	36	0.125 or 0.06

(6) Chemical Composition: Not specified.

(7) Tensile Properties: Not specified.

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 50

Materials: Ti-6Al-4V (SR-A, STA-B)

DeSaw, F. A.; Mishler, H. W.; Monroe, R. E.; and Lindh, D. V.: Development of a Manufacturing Method for the Production of Aircraft Structural Components of Titanium by High-Frequency Resistance Welding. AFML-TR-71-222, Battelle's Columbus Laboratories, 1971.

Test Information

(1) Fatigue Tests: Properties of the butt and tee sections of one alloy were evaluated and compared with the extruded tee sections and aluminum tee sections.

(2) Type of Test Machine: SF-10-U, SF-1-U, SF-01-U.

(3) Number of Specimens: 25 base metal fatigue specimens.

(4) Stress Ratio: -1.0, +0.06.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 1800 cpm.

Specimen Data

(1) Melting Practice/Heat Treatment: Titanium material was in the mill-annealed, stress-relieved, or STA condition.

(2) Ductility: Not specified.

(3) Fabrication Methods: Tee and butt sections were fabricated from 2" and 4" wide strips sheared from 3 ft x 8 ft sheets. High frequency resistance welding was used to produce butt, tee, and double-stem sections.

(4) Surface Finish: Butt sections were chemical milled, tee sections were milled with a milling cutter.

(5) Specimen Dimensions: Base metal specimen--length = 9.25 inches, test section length = 3.25 inches, diameter = 0.510 inch. See report for other specimen dimensions.

(6) Chemical Composition: See report for analysis by heat number.

(7) Tensile Properties:

Material	Condition	Grain Dir.	TYS, ksi	TUS, ksi	Elong., %
Base Metal	SR	T	136.5	140.9	13.0
Base Metal	STA	T	148.0	152.3	12.7

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 51

Materials: Ti-6Al-4V (A), Ti Beta III

Bjeletich, J. G.: Development of Engineering Data on Thick-Section Electron-Beam-Welded Titanium. Interim Technical Report Nos. 1, 2, 3, 4, 5, and 7, LMSC-D177632, Lockheed Missiles and Space Col, June 1971-July 1972.

Test Information

(1) Fatigue Tests: Tests were conducted to develop basic property data for the design of electron-beam-welded structures by establishing new or revised specifications.

(2) Type of Test Machine: Closed-loop, servo-actuated hydraulic test machine.

(3) Number of Specimens: 6/base metal Ti-6Al-4V.

(4) Stress Ratio: R = 0.1.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 4Hz-18Hz.

Specimen Data

(1) Melting Practice/Heat Treatment: All Ti-6Al-4V 1-inch material was from heat A41642-1, all 2-inch material from heat HC-442-1B. Ingots were rolled at 2000°-2050°F, hot flattened at 1650°F, and annealed at 1325°F. Ti Beta III material was from heat K-50776. Slabs were hot rolled to plate size, solution treated at 1350°F, water quenched, and aged at one of four temperatures for 8 hours.

(2) Ductility: Not specified.

(3) Fabrication Methods: Plates and slabs were cut into panels of convenient size. Panels for welding were milled flat along one edge. Electron beam welding was used and reduced section specimens were removed.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Axial fatigue-gross length = 6.0 inches, test section length = 2.25 inches, diameter = 0.25 inch.

(6) Chemical Composition:

Material	Heat No.	Percent by Weight C	N	Fe	O_2	H_2	Al	V	Sn	Zr	Mo
Ti-6Al-4V	A41642-1	.023	.016	.13	.15	.0008	6.48	4.29	--	--	--
Ti-6Al-4V	HC-442-1B	.017	.012	.20	.14	.0018	6.34	4.13	--	--	--
Ti-Beta III	K50776	.020	.014	.03	.13	.0074	--	--	4.7	5.8	10.2

(7) Tensile Properties: Ti Beta III not reported yet.

Material	Grain Dir.	TYS, ksi	TUS, ksi	Elong., %	R.A., %
Ti-6Al-4V	L	132.3	140.0	15	18
Ti-6Al-4V	T	141.0	148.5	14	22

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 52

Materials: 2014-T651(A), 4340 Steel (B)

Orange, T. W.: A Semiempirical Fracture Analysis for Small Surface Cracks. NASA TN D-5340, 1969.

Test Information:

(1) Fracture Tests: Surface crack test data from the literature is analyzed to yield a toughness parameter for each material relating fracture stress to crack size.

(2) Type of Test Machine: Not specified.

(3) Number of Specimens: 15/2014-T651, 12/4340 steel.

(4) Stress Ratio: Not specified.

(5) Test Temperature and Environment: Tests were conducted at 70 F and -423 F.

(6) Test Frequency: Not specified.

Specimen Data:

(1) Melting Practice/Heat Treatment: The 2014 alloy was in the T651 condition. The 4340 steel was tempered at 475 F for 2 hours.

(2) Ductility: Not specified.

(3) Fabrication Methods: Not specified.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: 2014--width = 1.0 inch, thickness = 0.375 inch; 4030--width = 1.0 inch, thickness = 0.25 inch.

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi
2014-T651	81.9	94.5
4340	230.6	278.4

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 53

Material: 2014-T6

Pierce, W. S.: *Effects of Surface and Through Cracks on Failure of Pressurized Thin-Walled Cylinders of 2014-T6 Aluminum.* NASA TN D-6099, 1970.

Test Information

(1) Fracture Tests: Tests were conducted on one alloy to determine the effects of surface cracks on the failure stresses of pressurized cylinders.

(2) Type of Test Machine: Helium gas was used to pressurize the system to failure within a cryostat.

(3) Number of Specimens: 20/2014-T6 alloy.

(4) Stress Ratio : Not specified.

(5) Test Temperature and Environment: Tests were conducted at -320 F in liquid nitrogen.

(6) Test Frequency: Not specified.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Cylinders were fabricated from unclad extruded tubing. Longitudinal crack starters were made by EDM and fatigue sharpened by pressure cycling.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Length = 17 inches, diameter = 5.63 inches, wall thickness = 0.060 inch, slit width = 0.005 inch.

(6) Chemical Composition:

2014, wt. %

Cu	Fe	Si	Mn	Mg	Zn	Ni	Cr	Ti	Sn	Al
4.32	0.35	0.80	0.73	0.40	0.06	0.005	0.01	0.025	0.001	Bal

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi
2014-T6, 70 F, Trans. Dir.	63.3	71.5

(8) Stress-Strain Curves: Surface strain as function of hoop stress.

REFERENCE NUMBER 54

Materials: 2014-T62(A). Ti-6Al-4V (ELI)(B)

Hall, L. R.: Plane-Strain Cyclic Flaw Growth in 2014-T62 Aluminum and 6Al-4V (ELI) Titanium. NASA CR-72396, 1968.

Test Information

(1) Fracture Tests: Plane-strain flaw-growth rates were determined for two alloys. Three methods of determining flaw-growth rates are included.

(2) Type of Test Machine: Not specified.

(3) Number of Specimens: 82/2014-T62, 79/Ti-6Al-4V(ELI).

(4) Stress Ratio: R = 0 to 0.5.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air, at -320 F in liquid nitrogen, and at -423 F in liquid hydrogen.

(6) Test Frequency: 20 cpm at room temperature and -320 F, 2 cpm at -423 F.

Specimen Data

(1) Melting Practice/Heat Treatment: 2014 aluminum was purchased in the O condition and solution heat-treated and aged to T62. Ti-6Al-4V was in the annealed condition.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimen blanks were machined to produce flat and parallel surfaces. Surface flaws were produced by EDM and low-stress fatigue. See report for welding procedures.

(4) Surface Finish: No finish other than machining for base metal specimens.

(5) Specimen Dimensions: Surface Flaw Fracture Specimens

Material	Temp., F	Gross Length, in.	Net Length, in.	Gross Width, in.	Net Width, in.	Test Area Thickness, in.
2014	70	27.0	10.0	9.0	4.5-6.0	0.9
2014	-320	24.0	--	6.0	--	0.6
2014	-423	24.0	--	6.0	--	0.45
Ti-6Al-4V	70& -320	10.0	2.5	3.5	2.0,3.0	0.375
Ti-6Al-4V	-423	10.0	2.0	3.0	1.1	0.375

REFERENCE NUMBER 54 (continued)

(6) Chemical Composition:

2014, weight %									
Cu	Si	Mn	Mg	Fe	Cr	Zn	Ti	Other	Al
3.9-5.0	0.50-1.20	0.40-1.20	0.20-0.80	1.0	0.10	0.25	0.15	0.15	Bal.

Ti-6Al-4V, weight %							
Fe	V	C	N(ppm)	O(ppm)	H(ppm)	Al	Ti
0.06	4.0	0.023	90	1110	50	5.9	Bal.

(7) Tensile Properties:

Material	Grain Dir.	TYS, ksi	TUS, ksi	Elong., %	R.A., %
2014	L	62.3	68.8	10.5	20
2014	T	62.9	69.0	9.0	16
Ti-6Al-4V	L	126.8	130.8	14.6	37
Ti-6Al-4V	T	123.1	126.6	16.0	44

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 55

Materials: 7075-T6511(A), 4330V(B)

Packman, P. F.; Pearson, H. S.; Owens, J. S.; and Marchese, G. B.: The Applicability of a Fracture Mechanics-Nondestructive Testing Design Criterion. AFML-TR-68-32, Lockheed-Georgia Co., 1968.

Test Information

(1) Fracture Tests: Tests were conducted to investigate the applicability of a combined fracture mechanics-nondestructive inspection procedure as a design approach for aircraft structures.

(2) Type of Test Machine: Baldwin Universal testing machine and a Riehle Amtek closed-loop fatigue machine.

(3) Number of Specimens: Approximately 100/each alloy.

(4) Stress Ratio: R = 0.22 for aluminum precracking, R = 0.24 for steel precracking.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 2.5 and 3 cps.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Test cylinders were made from cold-drawn steel tubing and extruded aluminum tubing. The cylinders were precracked in fatigue.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Cylinders--length = 32 in., diameter = 3 in., thickness = 0.25 in. Round center notched--gross length = 5 in., net length = 2 in., gross diameter = 1.25 in., net diameter = 1.05 in., root radius = 0.001 in., flank angle = 60 degrees.

(6) Chemical Composition: Aluminum composition not given.

4330V Steel, weight %

C	Mo	Ni	Mn	Cr	Si	V	Fe
0.306	0.35	1.79	0.83	0.87	0.34	0.08	Bal.

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi
7075-T6511	83.0	89.5
4330V	189.3	224.0

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 56

Materials: AISI 4130 Steel

Maynor, H. W., Jr.; and Waldrop, R. S.: Crack Toleration Ability of a High-Strength Biaxially Stressed Cylindrical Pressure Vessel Containing a Surface Crack. Final Report No. 9, Auburn Univ., 1971.

Test Information

(1) Fracture Tests: Cylindrical pressure vessels with surface cracks were tested to determine certain constants of the equation for the critical stress-intensity factor.

(2) Type of Test Machine: Hydraulic system for crack extension and pressurization to burst.

(3) Number of Specimens: 10 biaxial specimens, 7 uniaxial specimens.

(4) Stress Ratio: Not specified.

(5) Test Temperature and Environment: Tests were conducted at room temperature.

(6) Test Frequency: Not specified.

Specimen Data

(1) Melting Practice/Heat Treatment: Vessels were oil-quenched from 1600 F and double-tempered (oil) for 2 hours at 350 F.

(2) Ductility: Not specified.

(3) Fabrication: Vessels were deep drawn to desired dimensions and surface slots drilled with a milling machine and dental tool. Slots were extended by fatigue methods.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Vessels--length = 12.25 inches, diameter = 3 inches, thickness = 0.06 inch. Uniaxial--gross length = 12 inches, net length = 7 inches, gross width = 3 inches, net width = 1.5 inch.

(6) Chemical Composition:

4130, Weight %								
C	Mn	P	S	Si	Ni	Cr	Mo	Fe
0.29	0.5	0.007	0.023	0.31	0.06	0.9	0.19	Bal.

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi	Elong., %
4130	207.03	254.42	5

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 57

Materials: 4340 Steel (A), 18Ni-7Co-5Mo (B). 18Ni-9Co-5Mo (C)

Kerlins, V.; and Pendleberry, S. L.: The Effect of Crack Type and Material Thickness on the Fracture Strength of 4340 Steel. SM-43113, Douglas Aircraft Co., 1963

Test Information

(1) Fracture Tests: Determination of fracture strength for several alloy specimens with shallow cracks. Partial report only was obtained so further test information is unavailable.

Specimen Data

(1) Melting Practice/Heat Treatment: The 18Ni-7Co-5Mo steel was heat treated at 900 F/3 hours or 900 F/12 hours. The 18Ni-9Co-5Mo steel was heat treated at 900 F/3 hours or 875 F/8 hours.

(2) Ductility: Not specified.

(3) Fabrication Methods: Not specified.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions:

Material	Width, in.	Thickness, in.
18Ni-7Co-5Mo	4.0	0.75
18Ni-9Co-5Mo	1.0	0.07
18Ni-7Co-5Mo	1.0	0.07
4340	1.5	0.04
4340	1.5	0.07
4340	1.5	0.11
4340	1.0	0.125
4340	1.0	0.16

(6) Chemical Composition: See report for analysis of 4340 steel by heat.

(7) Tensile Properties:

Material	Heat Treatment	Thickness, in.	TYS, ksi	TUS, ksi	Elong., %
18Ni-7Co-5Mo	900 /3 hr	0.75	260.0	265.8	---
18Ni-7Co-5Mo	900 /12 hr	0.75	268.0	273.0	---
18Ni-7Co-5Mo	900 /3 hr	0.07	305.8	309.0	---
18Ni-9Co-5Mo	900 /3 hr	0.07	304.3	308.3	---
18Ni-9Co-5Mo	875 /8 hr	0.07	311.1	314.1	---
4340	7C1505	0.04	188.8	235.6	5.0
4340	7C1505	0.07	208.4	239.1	5.0
4340	7C1505	0.11	199.3	245.2	5.3
4340	38787	0.125	209.4	254.5	7.3
4340	X12475	0.125	200.8	238.7	7.0
4340	38787	0.16	214.9	255.1	7.7
4340	X12475	0.16	212.6	247.7	8.0

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 58

Materials: 300M Steel (A), See report for others.

Bockrath, G. E.; Wysocki, E. V.; and McGovern, D. J.: Design Criteria for Pressure Vessels. MDC-G0934, McDonnell Douglas Astronautics Co., 1971.

Test Information

(1) Fracture Tests: Static and cyclic test data are utilized to determine the allowable operating stresses and ultimate design and proof-test factors for a given pressure cyclic life.

(2) Type of Test Machine: Not specified.

(3) Number of Specimens: 9/300M static fracture. See report for others.

(4) Stress Ratio: R = 0 to 1.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: Not specified.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Not specified.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Width and thickness only given for each specimen. See report for details.

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi	Elong., %
300M	232	280	7

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 59

Materials: D6AC Steel (A), 18Ni (300) Marage (B), Ti-6Al-4V (C)

Tiffany, C. F.; and Lorenz, P. M.: An Investigation of Low-Cycle Fatigue Failures Using Applied Fracture Mechanics. ML-TDR-64-53, The Boeing Co., 1964.

Test Information

(1) Fracture Tests: Basic principles of fracture mechanics were applied to the investigation of cyclic flaw growth characteristics of 3 alloys.

(2) Type of Test Machine: Not specified.

(3) Number of Specimens: 37/D6AC, 14/Ti-6Al-4V, and 8/18Ni (300) Maraging Steel (static fracture specimens).

(4) Stress Ratio: Not specified.

(5) Test Temperature and Environment: D6AC and 18Ni(300) steel were tested at room temperature in air. Ti-6Al-4V was tested at -320 F in liquid nitrogen.

(6) Test Frequency: 1800 cpm for crack growth.

Specimen Data

(1) Melting Practice/Heat Treatment: D6AC was purchased in hot-rolled, annealed, pickled, and oiled condition and was stress-relieved at 1225 F/8 hours. Rough blanks were austenitized at 1550 F/1 hour, salt quenched to 400 F, and held 10-15 minutes, rinsed in boiling water, air-cooled below 150 F, and double tempered at specified temperature/2 hours. The Ti-6Al-4V was in the annealed condition and stress-relieved at 1300 F/1 hour. The 18Ni(300) steel was purchased in the annealed, pickled, and oiled condition, then aged at specified temperature/3 hours.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were finish-machined after heat treatment and flaws were produced by fatigue extension.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions:

Material	Specimen Type	Gross Length, in.	Net Length, in.	Gross Width or Diameter, in.	Net Width or Diameter, in.	Thickness, in.
D6AC & Ti-6Al-4V	Round bar	4.0	2.75	0.5	0.354	--
D6AC & Ti-6Al-4V	Surface flawed flat	27.0	14.0	8.0	6.0	0.25
18Ni(300)	Surface flawed flat	27.0	14.0	8.0	6.0	0.29
18Ni(300)	Through the thickness	19.0	--	6.0	--	0.25

REFERENCE NUMBER 59 (continued)

(6) Chemical Composition:

Ti-6Al-4V, weight %

C	Al	V	Fe	Ti
0.02	6.1	4.1	0.17	Bal.

18Ni(300), weight %

C	Mn	Ph	S	Si	Ni	Cr	Mo	Al	Co	Ti	Fe
0.27	0.05	0.006	0.009	0.01	18.8	0.10	4.95	0.05	8.98	0.63	Bal.

Ladish D6AC (2 heats), weight %

C	Mn	Ph	S	Si	Ni	Cr	Mo	V	Fe
0.44	0.84	0.006	0.006	0.24	0.56	1.10	1.00	0.08	Bal.
0.57	0.78	0.008	0.007	0.24	0.56	1.09	0.98	0.09	Bal.

(7) Tensile Properties:

Material	Temp., F	Grain Direction	TYS, ksi	TUS, ksi	Elong., %	R.A., %
D6AC	70	L	247.0	278.7	9.5	40.5
Ti-6Al-4V	-320	L	212.3	224.0	8.0	19.7
18Ni(300)	70	L	283.8	275.5	16.0	--

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 60

Materials: D6AC Steel (A), Ti-6Al-4V (B)

Randall, P. N.: Severity of Natural Flaws as Fracture Origins and a Study of the Surface Cracked Specimen. AFML-TR-66-204, TRW Systems, 1966.

Test Information

(1) Fracture Tests: Tests were performed on two alloys to determine the severity of natural flaws.

(2) Type of Test Machine: Baldwin Hydraulic, Tatnall-Krouse.

(3) Number of Specimens: 61/D6AC, 59/Ti-6Al-4V.

(4) Stress Ratio: Not specified.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 600 cpm.

Specimen Data

(1) Melting Practice/Heat Treatment: The D6AC was normalized at 1700 F and double tempered at 1300 F. After finish machining it was austenitized 45 min. at 1650 F, salt quenched at 400 F, cooled in air to 100 F, returned to salt bath at 400 F/1 hour, and tempered at 1050 F or 550 F for 4 hours. The Ti-6Al-4V material was purchased in the annealed condition, solution treated at 1775 F or 1750 F/1 hr., quenched at 40 F or 80 F, and aged at 925 F or 1000 F/4 hours.

(2) Ductility: Not specified.

(3) Fabrication Methods: Button-head flat tensile & surface-cracked specimens were machined from both materials. Normal, abnormal, and twin cracks were produced. Cracks were also produced in hydrogen embrittled areas for the steel and oxygen-contaminated weld nuggets for titanium.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Surface-cracked specimen - length = 5.0 in., width = 1.4 in., thk. = 0.25 in.

(6) Chemical Composition: D6AC, wt. %

C	Si	P	Mn	S	Ni	Cr	Mo	V	Fe
0.45	0.24	0.007	0.6	0.006	0.52	1.11	0.99	0.13	Bal.

REFERENCE NUMBER 60 (continued)

Ti-6Al-4V, wt.%

Al	V	Fe	C	N	H	O	Ti
6.2	4.2	0.15	0.025	0.013	0.0074	0.195	Bal.

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi
D6AC (High)	249	289
D6AC (Low)	212	230
Ti-6Al-4V (High)	160	174
Ti-6Al-4V (Low)	154	162

(8) Stress-Strain Curves: Average curves for each strength of material are given.

REFERENCE NUMBER 61

Materials: *18Ni-9Co-5Mo (A)*

Corn, D. L.; and Mixon, W. V.: Interim Report on the Effects of Crack Shape on Fracture Toughness. SM-44671, Douglas Aircraft Co., 1964.

Test Information

(1) Fracture Tests: One alloy was tested using partial thickness crack specimens to determine the effect of crack eccentricity on fracture toughness.

(2) Type of Test Machine: Not specified.

(3) Number of Specimens: 38/18Ni-9Co-5Mo.

(4) Stress Ratio: Not specified.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: Not specified.

Specimen Data

(1) Melting Practice/Heat Treatment: Material was obtained in the annealed condition (1500 F/1 hour & air cooled). The 0.1" and 0.25" material was given an additional anneal of 1500 F/1 hour. All specimens were aged at 900 F/ 3 hours and air cooled.

(2) Ductility: Not specified.

(3) Fabrication Methods: Two heats were tested in three thicknesses: 0.07", 0.1", 0.25" (the 0.1" was made by grinding the 0.25"). Cracks of different eccentricity were made by varying the shape of the starter notch.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Douglas drawing X 2868174.

(6) Chemical Composition: 18Ni-9Co-5Mo, wt. %

	Ni	Co	Mo	Ti	Mn	C	P	S	N
Heat 24252	18.62	8.87	4.77	0.59	0.017	0.013	0.003	0.007	0.007
Heat 24349	18.63	9.18	4.61	0.72	0.035	0.016	0.003	0.011	---

(7) Tensile Properties:

Material	Thk., inches	TYS, ksi	TUS, ksi
18Ni-9Co-5Mo	0.25	302.9	306.4
18Ni-9Co-5Mo	0.07	305.3	308.8

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 62

Materials: Ti-6Al-4V (A), D6AC

Collipriest, J. E.: Part-Through-Crack Fracture Mechanics Testing. IR & D Summary Report SD71-319, North American Rockwell Corp., 1971.

Test Information

(1) Fracture Tests: Tests were conducted on two alloys with emphasis on non-ideal crack behavior and special test methodology required for proper assessment of material behavior.

(2) Type of Test Machine: Electro-hydraulic, feedback-controlled.

(3) Number of Specimens: 7/Ti-6Al-4V (Study 4).

(4) Stress Ratio: Not specified.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: Not specified.

Specimen Data

(1) Melting Practice/Heat Treatment: The titanium was purchased in the annealed condition.

(2) Ductility: Not specified.

(3) Fabrication Methods: Material was obtained in 6-inch-wide strips parallel to the rolling direction. Crack starters were ELOX machined and developed by bending and tension fatigue.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Thk. = 0.20 in., test section width = 3 in.

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Ti-6Al-4V

Grain Dir.	TYS, ksi	TUS, ksi	Elong., %
L	132.8	138.8	17.7
T	139.2	141.9	19.0

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 63

Materials: Ti-6Al-4V (A)

Schwartzberg, F. R.; Gibb, R. H.; and Beck, E. J.: Experimental Study of Pop-In Behavior of Surface Flaw-Type Cracks. Final Report, NASA CR-108457, 1970.

Test Information

(1) Fracture Tests: Titanium alloy was evaluated to determine whether flaw growth occurring during proof testing results from pop-in or slow growth.

(2) Type of Test Machine: Marquardt model TM-1 servo-controlled, electro-hydraulic universal testing machine (50,000 lb. capacity).

(3) Number of Specimens: 19/0.09-inch, 15/0.06-inch, 11/0.03-inch at room temperature. 29/0.09-inch, 23/0.06-inch, 18/0.03-inch at -320.

(4) Stress Ratio: Not specified.

(5) Test Temperature and Environment: Tests were conducted at room temperature in 50% relative humidity air and at -320 F in liquid nitrogen.

(6) Test Frequency: 14 cpm.

Specimen Data

(1) Melting Practice/Heat Treatment: Material was received in the solution-treated and aged condition. Specimens were stress-relieved after final machining (1000 F/4 hours).

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were prepared from parent material and welded panels. Flaw starters were placed using the EDM technique, specimens were cleaned with acetone, and cracks were extended by fatigue cycling.

(4) Surface Finish: Specimens were deburred with 600-grit metallographic polishing paper.

(5) Specimen Dimensions: Gross length = 13.0 in., net length = 9.3 in., gross width = 3.1 in., net width = 2.3 in., thk. = 0.09, 0.06, or 0.03 in.

(6) Chemical Composition:

		Ti-6Al-4V, wt. %						
Heat No.	Gage, in.	C	Fe	N_2	Al	V	H_2	O_2
G-6570	0.09	0.022	0.09	0.010	6.0	4.0	0.008	0.11
G-8202	0.063	0.023	0.09	0.013	5.9	3.9	0.008	0.12
K-2312	0.063	0.026	0.07	0.015	6.0	4.0	0.007	0.11
K-2312	0.032	0.026	0.07	0.015	6.0	4.0	0.008	0.11

(7) Tensile Properties:

Thk., in.	TYS, ksi	TUS, ksi	Elong., %
0.090	158.0	166.0	10.0
0.060	159.3	168.5	8.3
0.030	150.4	161.6	8.5

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 64

Materials: Ti-6Al-4V

Hoeppner, D. W.; Pettit, D. E.; Feddersen, C. E.; and Hyler, W. S.: Determination of Flaw Growth Characteristics of Ti-6Al-4V Sheet in the Solution-Treated and Aged Condition. NASA CR-65811, 1968.

Test Information

(1) Fracture Tests: Tests were conducted to determine the feasibility of employing cryogenic proof testing to screen out small defects in LM tankage, establish the size defect eliminated by proof testing, determine whether undetected flaws will grow to critical length in operation, evaluate the influence of specific environments, and determine if thickness of the LM tankage material effects its flaw tolerance.

(2) Type of Test Machine: Baldwin Universal testing machine (200,000-lb. capacity).

(3) Number of Specimens: 41/room temperature parent material (all thicknesses), 24/cryogenic parent material (two thicknesses).

(4) Stress Ratio: R = 0.1.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air, aqueous, salt-spray, and Aerozine 50 environments and at -320 F in liquid nitrogen.

(6) Test Frequency: Not specified.

Specimen Data

(1) Melting Practice/Heat Treatment: Material was furnished in the solution-treated and aged condition.

(2) Ductility: Not specified.

(3) Fabrication Methods: The parent material was sheared into blanks with the longest dimension parallel to the grain direction. The specimen edges were polished, specimens were washed and stress relieved at 1000 F/4 hours-air cool. An EDM notch was introduced and a fatigue crack grown.

(4) Surface Finish: Ends of the specimen were grit blasted.

(5) Specimen Dimensions: Gross length = 16 in., net length = 6.25 in., gross width = 4.75 in., net width = 3.0 in., thk. = 0.02, 0.04, or 0.063 in.

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Thk., in.	TYS, ksi	TUS, ksi	Elong., %
0.02	162.0	171.3	8.5
0.04	161.8	170.3	10.4
0.063	160.4	168.5	11.1

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 65

Materials: 2219-T87 (A), Ti-5Al-2.5Sn

Hall, L. R.; and Finger, R. W.: Investigation of Flaw Geometry and Loading Effects on Plane Strain Fracture in Metallic Structures. NASA CR-72659, 1971.

Test Information

(1) Fracture Tests: Tests were conducted to evaluate the effects on fracture and flaw growth of weld-induced residual stresses, combined bending and tension stresses, and stress fields adjacent to circular holes in two alloys.

(2) Type of Test Machine: Not specified.

(3) Number of Specimens: 36 fracture/alloy with flaws protruding from holes, 12 fracture/alloy with surface flaws.

(4) Stress Ratio: R = 0.06 for fatigue cracking.

(5) Test Temperature and Environment: Tests were conducted at 70 F in air, -320 F in liquid nitrogen, and -423 F in liquid hydrogen.

(6) Test Frequency: 1800 cpm.

Specimen Data

(1) Melting Practice/Heat Treatment: Aluminum material was purchased in the T87 condition. Titanium material was purchased in the mill annealed condition.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were machined from hot rolled plate and precracked by growing fatigue cracks from starter slots under low stress fatigue loading.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Dimensions specified with data.

(6) Chemical Composition: Specification limits only given for 2219. See report for composition of Ti-5Al-2.5Sn (ELI).

(7) Tensile Properties:

Material	Cond.	Thk., inches	Grain Dir.	TYS, ksi	TUS, ksi	Elong., %
2219	T87	1.0	T	56	69	8
"	"	2.5	L	57	69	12
"	"	2.5	T	55	69	10
Ti-5Al-2.5Sn	MA	0.375	L	113	122	15
"	Reanneal	0.375	L	114	119	14
"	1550/16 hr.	0.80	L	108	114	14

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 66

Materials: 2024-T351

Dunsby, J. A.: Fatigue Tests on Notched Specimens of 2024-T351 Aluminum Alloy Under a Low Altitude Aircraft Load Spectrum. Aeronautical Report LR-504, NRC No. 13029, National Aeronautical Establishment, National Research Council of Canada, 1968.

Test Information

(1) Fatigue Tests: Experiments were conducted on notched specimens of one alloy simulating a fatigue load distribution encountered by aircraft operating continuously at low altitude.

(2) Type of Test Machine: Servo-controlled electro-hydraulic test machine (50,000 lb. capacity).

(3) Number of Specimens: 5/constant amplitude tests.

(4) Stress Ratio: R = 0.2 to 0.65.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 15.5 Hz.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were milled from clad plate in the longitudinal direction.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Length = 14 in., gross width = 7 in., net width = 4 in., root radius = 7/32 in. (K_t = 3.5).

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	Grain Dir.	TYS, ksi	TUS, ksi	Elong., %
Clad 2024-T351	L	55.4	70.1	18.3
Clad 2024-T351	T	45.2	68.5	18.8

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 67

Materials: D6AC Steel

Feddersen, C. E.; Moon, D. P.; and Hyler, W. S.: Crack Behavior in D6AC Sheet -- An Evaluation of Fracture Mechanics Data for the F-111 Aircraft. MCIC Report 72-04, Battelle's Columbus Laboratories, 1972.

Test Information

(1) Fracture and Fatigue-Crack Propagation Tests: Multilaboratory tests were conducted to determine the fracture toughness, fatigue-crack propagation, and sustained-load crack behavior in an effort to assess crack behavior in accordance with the principles of elastic fracture mechanics.

(2) Type of Test Machine: Not specified.

(3) Number of Specimens: See report for compilation of each data type.

(4) Stress Ratio: R = 0.08 to 0.5.

(5) Test Temperature and Environment: Tests were conducted at room temperature and elevated temperatures in a variety of environments.

(6) Test Frequency: 0.1 - 3.0 Hz.

Specimen Data

(1) Melting Practice/Heat Treatment: The material was used in the rolled plate or forged condition from a number of heat lots. See report for description of eight heat treatments used to produce high, medium, or low toughness levels.

(2) Ductility: Not specified.

(3) Fabrication Methods: Following heat treatment specimen blanks were cut and machined to thickness. Final machining was done by the individual laboratories.

(4) Surface Finish: Blanks were shot-peened, cadmium plated, and painted.

(5) Specimen Dimensions: See data compilation for specimen thickness and width used in each study.

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Product Form	Toughness Level	TYS, ksi	TUS, ksi	Elong., %	R.A., %
Plate	High	211	232	13	49
"	Medium	218	239	13	45
"	Low	212	232	14	43
Forging	Medium	214	233	13	45

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 68

Materials: 2024-T3

Schijve, J.; and DeRijk, P.: The Fatigue Crack Propagation in 2024-T3 Alclad Sheet Materials From Seven Different Manufacturers. NLR-TR M.2162, Reports and Transactions, National Aerospace Laboratory NLR, The Netherlands, vol. XXXIII, 1968.

Test Information

(1) Fatigue Crack Propagation Tests: Results were compared and crack growth data correlated with material properties.

(2) Type of Test Machine: Constant-amplitude tests were carried out on a vertical Schenck pulsator, program tests on a horizontal Schenck pulsator.

(3) Number of Specimens: 20/manufacturer for each group of similarly tested specimens.

(4) Stress Ratio: R= 0.004 to 0.47

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 3200 cpm.

Specimen Data

(1) Melting Practice/Heat Treatment: Material was obtained in the T3 condition. Materials from one manufacturer was given an additional temperature cycle and another had an artificial aging cycle.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were cut and provided with a small central notch for crack initiation.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Length = 15.7 in., width = 6.3 in., thickness = 0.079 in.

(6) Chemical Composition:

2024, wt. %

Material	Cu	Mg	Mn	Si	Fe	Zn	Cr[(a)]	Ti
A	4.90	1.63	0.70	0.14	0.23	0.08	455	0.03
B	4.45	1.69	0.58	0.16	0.23	0.07	566	0.02
C	5.07	1.77	0.58	0.26	0.29	0.10	392	0.01
D	4.50	1.61	0.71	0.21	0.33	0.20	657	0.04
E	4.49	1.70	0.68	0.24	0.37	0.02	799	0.02
F	4.72	1.55	0.63	0.16	0.32	0.06	1189	0.02

(a) Relative values.

(7) Tensile Properties:

2024-T3

Material	Grain Dir.	TYS,ksi	TUS,ksi	Elong., %
A	L	52.2	65.7	20
B	L	56.1	66.2	19
C	L	48.9	66.7	23
D	L	50.3	68.7	22.5
E	L	52.9	67.9	21
F	L	50.1	65.8	22
G	L	51.8	67.7	18

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 69

Materials: Ti-6Al-4V (A), Ti-6Al-6V-2Sn, Ti-8Al-1Mo-1V

Brockett, R. M.; and Gottbrath, J. A.: Development of Engineering Data on Titanium Extrusion for Use in Aerospace Design. AFML-TR-67-189, Lockheed-California Co., 1967.

Test Information

(1) Fatigue and Fracture Toughness Tests: Three titanium alloys were tested to determine the effects of temperatures used in extrusion processing.

(2) Type of Test Machine: Lockheed designed fatigue test machines.

(3) Number of Specimens: 74 fatigue specimens/Ti-6Al-4V.

(4) Stress Ratio: R = - 1 to 0.98.

(5) Test Temperature and Environment: Fatigue tests were conducted in air at room temperature and 400° F.

(6) Test Frequency: 1800 cpm.

Specimen Data

(1) Melting Practice/Heat Treatment: Material was obtained from two vendors in the annealed condition with air cooling.

(2) Ductility: Discussion of materials ductility is included.

(3) Fabrication Methods: Specimens were cut from thick and thin extrusions.

(4) Surface Finish: Extrusions were descaled and pickled.

(5) Specimen Dimensions:

Spec. Type	Gross Length, in.	Gross Width, in.	Net Width, in.	Thk., in.	Root Rad., in.
Smooth Fatigue	7.5	1.5	0.75	0.100	---
Notched Fatigue	7.5	1.5	---	0.100	0.125

(6) Chemical Composition: Ti-6Al-4V, wt. %

Al	V	O	N	C	Fe	H(ppm)
6.31-6.6	4.3-4.38	0.15-0.17	0.008-0.011	0.02-0.044	0.17-0.19	43-60

(7) Tensile Properties:

Extr. Type	Material	Grain Dir.	TYS, ksi	TUS, ksi	Elong., %
Thin	Ti-6Al-4V	L	127.8	143.4	14.7
"	Ti-6Al-4V	T	128.3	144.1	14.1
Thick	Ti-6Al-4V	L	127.5	141.8	14.0
"	Ti-6Al-4V	T	131.0	143.2	14.0

(8) Stress-Strain Curves: Typical tensile and compressive curves are given.

REFERENCE NUMBER 70

Material: Ti-6Al-4V (A,B)

Anon.: Room and Elevated Temperature Fatigue Characteristics of Ti-6Al-4V. Titanium Metals Corp. of America, 1957.

Test Information

(1) Fatigue Tests: Tests were conducted to obtain basic design information and to study the effects of heat treatment on the fatigue properties of one alloy.

(2) Type of Test Machine: Krouse direct repeated stress testing machine.

(3) Number of Specimens: 21 unnotched annealed and 16 notched annealed at room temperature. See report for others.

(4) Stress Ratio: R = - 1.0, -0.26, and +0.25.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air for three heat treatment conditions and at 750° F for two heat treatment conditions.

(6) Test Frequency: 1750 cpm.

Specimen Data

(1) Melting Practice/Heat Treatment: Material was tested in three conditions: (a) mill annealed (1300° F, 2 hrs., air cooled), (b) 1550° F., 1 hr., water quenched + 900° F, 24 hrs., air cooled, (c) 1750° F, 1 hr., water quenched +900° F, 24 hrs., air cooled.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were machined from bar stock, heat treated, and machined to final dimensions. A circumferential notch was tooled in by a lathe for notched specimens.

(4) Surface Finish: Unnotched specimens were polished in a longitudinal direction. Notch roots were polished with abrasive charged copper wire.

(5) Specimen Dimensions: Unnotched - gross length = 5.5 in., net length = 2.75 in., net diam. = 0.203 in. Notched - gross length = 5.5 in., net length = 2.75 in., gross diam. = 0.331 in., net diam. = 0.252 in., root radius = 0.01 in. (K_t = 3.3), flank angle = 60°.

(6) Chemical Composition: Ti-6Al-4V, wt. %

Al	V	Fe	N	C	O	H
6.18	3.81	0.216	0.026	0.023	0.097	0.008

(7) Tensile Properties:

Material	Heat Treatment	TYS, ksi	TUS, ksi	Elong., %	R.A., %
Ti-6Al-4V	A	128.5	136.5	14.5	37.5
Ti-6Al-4V	B	141.5	152.5	14.0	34.7
Ti-6Al-4V	C	158.0	170.5	12.0	37.2

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 71

Materials: Ti-6Al-4V (A), Ti-5Al-2.5Sn

McClaren, S. W.; Cook, O. H.; and Pascador, G.: Processing, Evaluation, and Standardization of Titanium Alloy Castings. AFML-TR-68-264, Vought Aeronautics Division, LTV Aerospace Corp., 1969.

Test Information

(1) Fatigue Tests: Tests were conducted to evaluate the Mono-Graf investment shell casting process and compare it with a similar forged aircraft component for two titanium alloys.

(2) Type of Test Machine: Not specified -- little test information given.

(3) Number of Specimens: 61 fatigue specimens/Ti-6Al-4V.

(4) Stress Ratio : R = 0.1, -1.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: Not specified.

Specimen Data

(1) Melting Practice/Heat Treatment: Materials were purchased in the annealed condition (1550 F/2-4 hr., air cooled).

(2) Ductility: Not specified.

(3) Fabrication Methods: Castings were made by the Mono-Graf process, cleaned with solvents, defects were repaired by welding, and were heat treated. Specimens were taken from a thick base section (> 1/2 in.) or thin flange and web sections (< 1/2 in.).

(4) Surface Finish: Surface was cleaned chemically.

(5) Specimen Dimensions: Unnotched -- gross length = 3.0 in., gross width = 1.0 in., net width = 0.25 in., thk. = 0.07 in. Notched (K_t = 3) -- gross length = 3.0 in., net length = 1.12 in., gross width = 0.75 in., net width = 0.33 in., notch depth = 0.04 in., root radius = 0.016 in.

(6) Chemical Composition: See report for analysis by heat.

(7) Tensile Properties:

Material	Section Size	TYS, ksi	TUS, ksi	Elong., %	R.A., %	E, 10^3 ksi
Ti-6Al-4V	Thick	114.6	134.6	7.8	22.6	16.7
Ti-6Al-4V	Thin	120.3	141.9	7.3	---	16.6
Ti-5Al-2.5Sn	Thick	105.7	115.5	5.9	19.6	17.2
Ti-5Al-2.5Sn	Thin	109.9	124.3	8.4	---	17.5

(8) Stress-Strain Curves: Typical tensile curves are given.

REFERENCE NUMBER 72

Materials: Ti-6Al-4V (A), Marage 250, 17-4 PH, D6AC, A356-T61, CH 70-T63

Jones, R. L.; and Pratt, W. M.: The Mechanical and Stress Corrosion Properties of Premium Quality Cast Aerospace Alloys. FGT-5742 (M-140), General Dynamics, Fort Worth Division, 1972.

Test Information

(1) Fatigue and Fracture Tests: Tests were conducted on castings of six materials from four foundries to determine properties for aerospace applications.

(2) Type of Test Machine: SF-1-U (cantilever bending) was used for fracture tests. Baldwin SF-10-U was used for most fatigue tests.

(3) Number of Specimens: 82 fatigue specimens/Ti-6Al-4V. See report for others.

(4) Stress Ratio: R = -0.3, 0.1.

(5) Test Temperature and Environment: Fatigue tests were conducted at room temperature in air and at -65 F.

(6) Test Frequency: 1800 cpm.

Specimen Data

(1) Melting Practice/Heat Treatment: The Ti-6Al-4V material was annealed (2 hrs at 1000 F, 8 hrs at 1550 F).

(2) Ductility: Not specified.

(3) Fabrication Methods: After heat treatment, specimens were machined and notches were made on a lathe.

(4) Surface Finish: Notches were not polished.

(5) Specimen Dimensions: Round tens.-comp. fatigue (K_t = 2, 3, 4, or 5) - gross length = 4.25 in., gross diam. = 0.315, 0.357, or 0.43 in., net diam. = 0.220, 0.252, or 0.3 in., flank angle = 60°, root radius = 0.0035 to 0.043 in.

(6) Chemical Composition: See report for analysis of other alloys.

Ti-6Al-4V, wt.%

C	H	Fe	O	V	N_2	Al	Ti
.024	0.0009	0.136	0.17	3.98	0.014	6.20	Bal.

(7) Tensile Properties: See report for other alloys.

Material	TYS, ksi	TUS, ksi	Elong., %	R.A., %
Ti-6Al-4V	118.05	128.6	9.5	10.4

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 73 (M-105)

Materials: Ti-6Al - 4V

VanOrden, J. M.; and Soffa, L. L.: Ti-6Al-4V Beta Forging Fatigue Tests--Model AH56A. LR 22236 (M-105), Lockheed-California Co., 1969.

Test Information

(1) Fatigue Tests: Tests were conducted on a large forged billet as part of a design substantiation program to determine the effects of specimen location, notch acuity and range ratio.

(2) Type of Test Machine: Axial-loaded resonant fatigue machine.

(3) Number of Specimens: Approximately 110 fatigue specimens.

(4) Stress Ratio: R = 0.1, - 0.5.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: Not specified, assume 30 cps.

Specimen Data

(1) Melting Practice/Heat Treatment: Forged billet was prepared from a round ingot which was cogged, upset (1900° F), and recogged (1775° F).

(2) Ductility: Not specified.

(3) Fabrication Methods: Billet was cut into slabs and specimens were machined.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Gross length = 5.25 in., test area length = 1 in., gross diam. = 0.62 in., net diam. = 0.3 in., root radius = 0.01 in., (K_t = 3) or 0.03 in., (K_t = 2), flank angle = 60°.

(6) Chemical Composition: Ti-6Al-4V, wt. %

C	Fe	Al	V	Ti	H(ppm)	O	N
0.04	0.16-0.17	5.55-5.87	4.05-4.20	Rem.	30-131	0.144-0.195	0.005

(7) Tensile Properties:

Grain Dir.	TYS, ksi	TUS, ksi	Elong., %	R.A., %
L	128.3	137.2	16	36.9
T	125.7	135.1	13	30.2
S	125.5	135.0	11.3	27.6

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 74

Materials: Ti-6Al-4V (A,B,C), Ti-6Al-6V-2Sn

Marrocco, A.: Evaluation of Annealed Ti-6Al-4V and Ti-6Al-6V-2Sn Extrusions. M & P-1-TR-70-1 (M-130), Grumman Aircraft Engineering Corp., 1970.

Test Information

(1) Fatigue Tests: Notched and unnotched data was obtained for two alloys representing a variety of extruded shapes and thicknesses.

(2) Type of Test Machine: Sonntag SF-1U fatigue machine under axial loading.

(3) Number of Specimens: 54 fatigue specimens/Ti-6Al-4V.

(4) Stress Ratio: R = 0.1.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: Not specified, assume 30 cps.

Specimen Data

(1) Melting Practice/Heat Treatment: Material was supplied in the annealed condition.

(2) Ductility: Not specified.

(3) Fabrication Methods: Conventional machining techniques were used to remove specimens. All fatigue specimens were taken from the longitudinal direction.

(4) Surface Finish: See specimen drawing for description.

(5) Specimen Dimensions: Unnotched - length = 6.5 to 7.5 inches, gross width = 1.5 inches, net width = 0.25 inch. Notched - length= 7.5 inches, gross width = 1.5 inches, net width = 0.5 inch, keyhole notch radius = 0.031 inch, notch width = 0.045 inch, notch depth = 0.5 inch.

(6) Chemical Composition: Ti-6Al-4V, Wt. %

Al	V	Fe	C	N	O	H (ppm)
6.6	4.4	0.09	0.02	0.011	.180	80

(7) Tensile Properties: Ti-6Al-4V

Heat No.	Grain Dir.	TYS, ksi	TUS, ksi	Elong., %	E, 10^3 ksi
W84-6	L	127.5	141.1	15.7	17.17
302418	L	131.9	144.3	14.2	17.48
Unknown	L	128.6	147.0	13	16.75

(8) Stress Strain Curves: Not given.

REFERENCE NUMBER 75

Materials: PH 15-7Mo, AM 350, AISI 301, Ti-4Al-3Mo-1V, Ti-6Al-4V (A), Ti-8Al-1Mo-1V

Illg, W.; and Castle, C. B.: Fatigue of Four Stainless Steels and Three Titanium Alloys Before and After Exposure to 550°F (561°K) Up to 8800 Hours. NASA TN D-2899, 1965.

Test Information

(1) Fatigue Tests: Tests were conducted on seven alloys before and after exposure to determine the effect upon fatigue life.

(2) Type of Test Machine: Subresonant-type axial fatigue.

(3) Number of Specimens: 70 pre-exposure/Ti-6Al-4V.

(4) Stress Ratio: R = -0.79 to -0.22.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 1800 cpm.

Specimen Data

(1) Melting Practice/Heat Treatment: Titanium material was in the annealed condition.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were machined from sheet material and deburred by chamfering.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Unnotched -- gross length = 12.625 in., gross width = 2.0 in., net width = 0.75 in. Notched -- length = 12.625 in., gross width = 2.25 in., net width = 1.5 in., root radius = 0.058 in. (K_t = 4).

(6) Chemical Composition: See report for other alloys.

Ti-6Al-4V, wt.%

C	Fe	N_2	H_2	Al	V	Ti
0.026	0.15	0.013	0.011	6.1	4.0	Bal.

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi	Elong., %
Ti-6Al-4V	142	149	12

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 76

Materials: Ti-6Al-4V (A), IMI 679

Simenz, R. F.; and Macoritto, W. L.: Evaluation of Large Ti-6Al-4V and IMI 679 Forgings. AFML-TR-66-57, Lockheed-California Co., 1966.

Test Information

(1) Fatigue and Fracture Tests: Tests were conducted on large titanium forgings to provide a basis for their use in advanced weapon systems.

(2) Type of Test Machine: Not specified.

(3) Number of Specimens: 31 fatigue specimens/Ti-6Al-4V.

(4) Stress Ratio: R = 0.1.

(5) Test Temperature and Environment: Tests were conducted at room temperature and 550° F in air.

(6) Test Frequency: Not specified.

Specimen Data

(1) Melting Practice/Heat Treatment: The Ti-6Al-4V was heat treated as follows: 1750° F/1 hr., within 6 seconds water quenched, age at 1000° F/4 hrs., air cool.

(2) Ductility: Discussion of ductility included.

(3) Fabrication Methods: The Ti-6Al-4V forgings were machined to 2.5 in. prior to heat treatment. Specimens were machined from various sections of the forging.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions:

Type	Gross Length, in.	Net Length, in.	Gross Dia., in.	Net Dia., in.	Notch root Radius, in.	Flank Angle
Smooth Fatigue	5.0	2.8	0.625	0.2	---	---
Notched Fatigue (K_t=3)	5.0	1.0	0.3	0.2	0.01	60°

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi	Elong., %	R.A., %
Ti-6Al-4V	155.6	169.0	10.0	30.5

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 78

Materials: Ti-6Al-4V (A-H), Ti-4Al-3 Mo-1V, Ti-13V-11Cr-3Al, Ti-6Al-6V-2Sn

Sommer, A. W.; and Martin, G. R.: Design Allowables for Titanium Alloys. AFML-TR-69-161, North American Rockwell Corp., 1969.

Test Information

(1) Fracture and Fatigue Tests: Tests were conducted to develop design information on four titanium alloys for use in MIL-HDBK-5.

(2) Type of Test Machine: Fatigue tests were run on an Amsler Vibraphone fatigue machine (22,000 lb. capacity, 60-300 cps), a Baldwin-Sonntag fatigue machine (10,000 lb. capacity, 30 cps), or a Krouse Direct Stress fatigue machine (5,000 lb. capacity). Amsler machine was believed to be used for Ti-6Al-4V tests but report does not specify clearly.

(3) Number of Specimens: 50 fatigue/Ti-6Al-4V.

(4) Stress Ratio: R= - 1.0, -0.3, 0, + 0.3.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: Believed to be 100 cps for Ti-6Al-4V.

Specimen Data

(1) Melting Practice/Heat Treatment: Ti-6Al-4V material used in fatigue tests was solution treated and aged (solution treated 1725° F for 10 minutes, w.q., aged 1000° F for 4 hrs. and air cooled).

(2) Ductility: Not specified.

(3) Fabrication Methods: Close machining tolerances were used to provide a minimum of distortion and surface defects. On smooth fatigue specimens the reduced section edges were left sharp. Notches were made by light finishing cuts or light grinding.

(4) Surface Finish: Surface roughness per MIL-STD-10 (FA6-219).

(5) Specimen Dimensions:

Spec. Type	Gross Length, in.	Gross Width, in.	Test Section Width, in.	Root Radius, in.	Flank Angle
Smooth Fatigue	5.75	0.875	0.375	---	---
Notched Fatigue (K_t=3)	5.75	1.0	0.500	0.0212	60°

REFERENCE NUMBER 78 (continued)

(6) Chemical Composition:

Ti-6Al-4V, wt. %

C	Fe	N	Al	V	H(ppm)	O
0.03	0.16	0.011	6.1	4.2	72	0.107

(7) Tensile Properties:

Material	Grain Dir.	Thk., in.	TYS, ksi	TUS, ksi
Ti-6Al-4V	L	0.25-0.3	149.7	161.4
Ti-6Al-4V	L	0.25-0.63	161.7	175.9
Ti-6Al-4V	L	≥ 1.00	146.2	152.9

(8) Stress-Strain Curves: Typical full range tensile stress - strain curve is shown.

REFERENCE NUMBER 79

Materials: Ti-6Al-4V (A-F)

Beck, E.: *Effect of Beta Processing and Fabrication on Axial Loading Fatigue Behavior of Titanium.* AFML-TR-69-108, Martin-Marietta Corp., 1969.

Test Information

(1) Fatigue Tests: A single heat of material was forged at conventional and beta forging temperatures, annealed, and tested under axial-load. Surface effect studies were also conducted.

(2) Type of Test Machine: IVY-12, Baldwin Sonntag SF-IOU, and Baldwin Sonntag SF-1U.

(3) Number of Specimens: 130 smooth fatigue and 110 notched fatigue.

(4) Stress Ratio: R = -1.0, 0.053, or 0.5.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 20-30 cps.

Specimen Data

(1) Melting Practice/Heat Treatment: A cogged preform shape was forged in two steps, blocker and finish. Cogging was done at 1750 F. Forging conditions were as follows: (a) conventionally at 1750 F, (b) Beta at 1880 F, (c) Beta at 1950 F, (d) Beta at 2100 F, (e) Two-stage, blocked at 2100 F and finished at 1750 F. After forging, material was annealed (1300 F/2 hr, AC) except for two forgings which were solution-treated and aged (1725 F/1 hr., H_2O quench, 1000 F/4 hr., A.C.).

(2) Ductility: Not specified.

(3) Fabrication Methods: Round bar specimens were machined and finished according to ASTM, STP-91, Section IV. Notch roots were polished.

(4) Surface Finish: For surface effect studies specimens were (a) lathe-turned (63 rms) (b) chemically milled (polished and reduced chemically from 0.285 in. to 0.250 in., 15-25 rms) (c) ground (20-30 rms) or (d) shot peened (glass shot to intensity of 0.10 A ± 0.01).

REFERENCE NUMBER 79 (continued)

(5) Specimen Dimensions:

Specimen Type	Gross Length, inches	Test Section Diam., inches	Root Radius, inches	Flank Angle
Smooth Fatigue	5.3	0.25	---	--
Notched Fatigue ($K_t = 3$)	6.25	0.48	0.016	60°

(6) Chemical Composition:

Ti-6Al-4V, wt. %						
Al	V	Fe	C	N_2	H_2	O_2
6.2	4.3	0.09	0.01	0.01	0.0057	0.182

(7) Tensile Properties:

Condition of Forging	Heat Treatment	TYS, ksi	TUS, ksi	Elong., %	R.A., %	E, 10^3 ksi
Conventional	Ann.	127.1	138.9	11.7	35.3	16.6
1880 F	Ann.	129.4	142.5	9.7	18.2	16.7
1950 F	Ann.	132.6	143.9	9.6	12.3	16.7
2100 F	Ann.	125.2	137.8	9.7	19.7	16.8
2 stage	Ann.	130.5	141.8	12.9	31.1	16.7
1880 F	STA	146.4	160.9	6.1	11.8	16.4

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 80

Materials: Ti-6Al-4V

Bass, Colin D.: Evaluation of Ti-6Al-4V Castings. AFML-TR-69-116, WPAFB, 1969.

Test Information

(1) Fatigue Tests: Tests were conducted on premium castings of one alloy and found to be competitive with wrought titanium.

(2) Type of Test Machine: Amsler High Frequency Vibrophore with 2-ton dynamometer, or 20-ton Schenck fatigue machine.

(3) Number of Specimens: 42 room temperature fatigue specimens.

(4) Stress Ratio: R = 0.1, -1.0.

(5) Test Temperature and Environment: Tests were conducted at room temperature and 500 F in air.

(6) Test Frequency: 4000-5000 cpm, or 1800 cpm.

Specimen Data

(1) Melting Practice/Heat Treatment: 9.5 X 1.0 X 0.5 inch bars were annealed (1450 ± 25 F/1 hour in Argon, cooled to 800 F at rate equal to cooling in air, air cooled to room temperature) or solution-treated and aged (1750 ± 25 F/1.5 hours, water quenched, 1000 ± 25 F/6 hours, air cooled).

(2) Ductility: Not specified.

(3) Fabrication Methods: Bars were machined to desired size after heat treatment.

(4) Surface Finish: Specimens were polished.

(5) Specimen Dimensions:

Specimen Type	Gross Length, inch	Test Area Length, inch	Gross Diam., inch	Net Diam., inch	Root Radius, inch	Flank Angle
Smooth	2.625	0.813	0.195	---	---	---
Notched (K_t = 3)	2.625	0.813	0.277	0.195	0.009	60°

REFERENCE NUMBER 80 (continued)

(6) Chemical Composition:

Ti-6Al-4V, wt. %						
Al	V	Fe	O	N	C	H
6.15	4.29	0.16	0.185	103 ppm	83 ppm	17 ppm

(7) Tensile Properties:

Material	Heat Treatment	TYS, ksi	TUS, ksi	Elong., %
Ti-6A'-4V	Annealed	123	136	7.2
Ti-6Al-4V	STA	153	165	3.0

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 81

Materials: Ti-6Al-4V (A,B), 301 S.S., AM-355, 300 Maraging

McClaren, S. W.; and Best, J. H.: Low Cycle Fatigue Design Data on Materials in a Multi-Axial Stress Field. RTD-TDR-63-4094, LTV Vought Aeronautics, 1968.

Test Information

(1) Fatigue tests: Biaxial characteristics of four materials are evaluated under static and fatigue conditions, and the relationship between uniaxial and biaxial properties presented.

(2) Type of Test Machine: Low cyclic-rate hydraulic test system with solenoid controls.

(3) Number of Specimens: 40 uniaxial fatigue/Ti-6Al-4V.

(4) Stress Ratio: R = 0.1 or 0.5.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 60 cpm.

Specimen Data

(1) Melting Practice/Heat Treatment: The Ti-6Al-4V material was melted by consumable electrode method, forged and rolled to sheet size, annealed, and pickled.

(2) Ductility: Not specified.

(3) Fabrication Methods: Uniaxial fatigue specimens were fabricated from 0.05 inch sheet.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Gross length = 10.0 in., test area length = 4.8 in., gross width = 1.5 in., net width = 0.5 in., thk. = 0.036 in.

(6) Chemical Composition:

Ti-6Al-4V, Wt. %

C	Al	V	Ti
0.055	6.00	4.09	Balance

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi	E, 10^3 ksi
Ti-6Al-4V	147.5	177.0	16.7

(8) Stress- Strain Curves: Typical stress-strain curves are given.

REFERENCE NUMBER 82

Materials: 2024-T4 (A-D), 7075-T6 (E-G), 2014-T6

Lazan, B. J.; and Blatherwick, A. A.: Fatigue Properties of Aluminum Alloys at Various Direct Stress Ratios. Part I - Rolled Alloys, WADC Technical Report 52-307, Part I, Univ. of Minnesota, 1952.

Test Information

(1) Fatigue Tests: Tests were conducted on three alloys to illustrate and analyze the effects of: (a) stress ratios in the range from static tension to reversed axial stress, (b) stress magnitude which causes failure in range from 10^3 to 10^7 cycles, and (c) severity of circumferential notches having four different theoretical stress concentration factors.

(2) Type of Test Machine: Axial stress fatigue machine L_1 (±5000 lb. capacity) and a Sonntag SF - 1U machine.

(3) Number of Specimens: Approximately 42/each specimen type/each alloy.

(4) Stress Ratio: R =-1 to +0.85.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 30 or 60 Hz, assumed 45 Hz.

Specimen Data

(1) Melting Practice/Heat Treatment: Material was furnished as heat-treated rods in the T4 or T6 condition.

(2) Ductility: Not specified.

(3) Fabrication Methods: Unnotched specimens were rough machined, lathe turned, and finish machined. Notch contours were cut by rough machining and finish grinding.

(4) Surface Finish: Smooth specimens were polished in three steps: (a) 180 mesh aluminum oxide abrasive grain tape, (b) 400 mesh tape and (c) 900 mesh tape. Type X notched specimens received no further polishing after grinding. Types W and AB notched specimens were polished with a compound until all circumferential scratches were removed.

(5) Specimen Dimensions: Gross length = 7.625 in., test area length = 3.625 in., diameter = 0.4 in., root radius = 0.1 in.(K_t=1.6), 0.032 in., (K_t=2.4), or 0.01 in., (K_t=3.4), flank angle = 60°.

(6) Chemical Composition:

Material	Cu	Fe	Si	Mn	Mg	Zn	Cr	Ti
	Percent by Weight							
2024-T4	4.17-4.25	0.30	0.13-0.14	0.63	1.42-1.49	0.7	0.01-0.02	0.02
7075-T6	1.55-1.63	0.32-0.34	0.15	0.03	2.32-2.40	5.51-5.60	0.26	0.05

(7) Tensile Properties:

Material	TYS,ksi	TUS,ksi	Elong., %	E,10^3ksi
2024-T4	48.6	72.8	21.4	10.6
7075-T6	70.9	82.3	16.5	10.4

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 83

Materials: 2024-T4 (A-B), 7075-T6 (C-D), 2014-T6

Lazan, B. J.; and Blatherwick, A. A.: Fatigue Properties of Aluminum Alloys at Various Direct Stress Ratios. Part II - Extruded Alloys, WADC Technical Report 52-307, Part II, Univ. of Minnesota, 1952.

Test Information

(1) Fatigue Tests: Tests were conducted on three extruded alloys at various stress levels to analyze the effect of stress ratio, stress magnitude, and stress concentration.

(2) Type of Test Machine: Axial stress machine (±5000 lb capacity) - see Ref. 82.

(3) Number of Specimens: 31/2024-T4, 23/7075-T6.

(4) Stress Ratio: R = -1 to +0.74.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 60 Hz.

Specimen Data

(1) Melting Practice /Heat Treatment: Following extrusion into bars, the material was solution treated to the T4 or T6 condition.

(2) Ductility: Not specified.

(3) Fabrication Methods: Refer to Ref. 82.

(4) Surface Finish: Refer to Ref. 82 smooth and X type specimens.

(5) Specimen Dimensions: Gross length = 7.625 in., test section length = 3.625 in., diameter = 0.4 in., root radius = 0.01 in. (K_t=3.4), flank angle = 60°.

(6) Chemical Composition: Percent by weight

Material	Cu	Fe	Si	Mn	Mg	Zn	Cr	Ti
2024-T4	4.3	0.22	0.14	0.61	1.54	0.01	0.01	0.01
7075-T6	1.57	0.20	0.12	0.02	2.46	5.63	0.23	0.02

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi	Elong.,%	E,10^3ksi
2024-T4	65.7	85.1	11.1	10.2
7075-T6	84.2	92.4	9.6	10.0

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 84

Materials: Ti-6Al-4V (A-L), Ti-13V-11Cr-3Al, Ti-2.5Al-16V, Ti-4Al-3Mo-1V

Anon.: Determination of Design Data for Heat Treated Titanium Alloy Sheet. vol. 3 - Tables of Data Collected, ASD-TDR-335 vol. 3, Lockheed-Georgia Co., 1962.

Test Information (From Vol. 2b)

(1) Fatigue Tests: Mechanical and physical property data were obtained for selected solution treated and aged titanium alloys in sheet form.

(2) Type of Test Machine: Lockheed designed axial-load, tuning fork type fatigue machine (15,000 lb. capacity), or Lockheed machine with load applied by hydraulic jack in series with a double bridge Cox and Stevens load cell.

(3) Number of Specimens: Approximately 276 specimens/Ti-6Al-4V at room temperature.

(4) Stress Ratio: R = -1, 0, or 0.54.

(5) Test Temperature and Environment: Tests were conducted in air at room temperature, 400 F, 600 F, 800 F, or 900 F.

(6) Test Frequency: 4 or 30 Hz.

Specimen Data

(1) Melting Practice/Heat Treatment: Sheets of Ti-6Al-4V were solution treated and aged as follows: 1675 F/20 min., W. Q., 900 F/4 hrs., A.C., or 1690 F/12 min., W.Q., 900 F/4 hrs., A.C.

(2) Ductility: Not specified.

(3) Fabrication Methods: Fatigue specimens were sheared from the sheets in the longitudinal direction and rough machined to final dimensions.

(4) Surface Finish: Specimens were deburred and cleaned with methyl ethyl ketone.

(5) Specimen Dimensions: Length = 18 in., gross width = 3 in., net width = 1.0 in., root radius = 0.031 in. (K_t = 2.82).

(6) Chemical Composition: See Volume 2a for analysis of each sheet.

(7) Tensile Properties:

Material	Heat No.	TYS, ksi	TUS, ksi	Elong., %	E, 10^3 ksi
Ti-6Al-4V	31372	167	177	8.6	16.5
"	32163	153	172	7.4	16.4
"	32167	162	176	7.6	16.8

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 85

Materials: D6AC Steel

Jones, R. L.: Mechanical Properties of D6AC Steel Forging, Billet and Plate. FGT 3075, General Dynamics, Fort Worth Division, 1964.

Test Information

(1) Fatigue Tests: Tests were conducted to determine design allowables in the 220-240 ksi heat treat range for one alloy.

(2) Type of Test Machine: BLH Model SF-1-U, BLH Model SF-10-U or BLH IV-4F.

(3) Number of Specimens: Approximately 230/forging, 30/forged plate, and 25/rolled plate.

(4) Stress Ratio: R = -1, 0, 0.1, or 0.5.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 30, 0.02, or 0.035 Hz.

Specimen Data

(1) Melting Practice/Heat Treatment: The 220-240 ksi heat treat level was produced as follows: (a) normalize 1650 F/30 min. (b) austenitize 1625-1650 F/30 min. (c) quench into furnace at 950 F/1 hr. (d) quench into 400 F molten salt/15 min. (e) cool to R.T. (f) temper at 400 F/1 hr. (g) double temper 1000 F/2 hr.

(2) Ductility: Discussion and graph of ductility is included.

(3) Fabrication Methods: Specimens were rough machined after heat treatment and finish machined in a lathe.

(4) Surface Finish: Fatigue notch radii were polished using a levigated alumina slurry and dacron cord, smooth specimens were polished with a cloth wheel.

(5) Specimen Dimensions: Gross length = 5 in., gross diam. = 0.252 in., root radius = 0.013 (K_t = 3) or 0.004 (K_t = 5) in.

(6) Chemical Composition: No analysis given, states materials were within specified ranges.

(7) Tensile Properties:

Form	Grain Dir.	TYS, ksi	TUS, ksi	Elong., %	R.A., %
Forging	L	215	237	13.4	49.6
Forging	T	212	233	12.0	37.0
Forging	S	218	238	10.5	38.5
Forged Plate	T	210	229	12.5	43.4
Rolled Plate	L	205	235	14.0	49.1

(8) Stress-Strain Curves: Typical stress-strain curves are given.

REFERENCE NUMBER 87

Materials: 7075-T651

Anon.: Unpublished fatigue data on 7075-T651 aluminum bar from Beckman Instruments, Inc., October 13, 1972.

Test Information

(1) Fatigue Tests: Tension/tension fatigue tests were conducted on aluminum bar at five K_t values.

(2) Type of Test Machine: Riehle machine functionally similar to the MTS controls.

(3) Number of Specimens: Approximately 100/each K_t value.

(4) Stress Ratio: R = 0 or 0.1

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: Assumed 1 cps unless indicated 5 cps.

Specimen Data

(1) Melting Practice/Heat Treatment: Material was in the T651 condition.

(2) Ductility: Not specified.

(3) Fabrication Methods: Not specified.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Specimens were stated to be 0.75 in. bar specimens. Unnotched specimens had a major diameter of 0.5 in. or 0.3 in. Notched specimens had a major diameter of 0.5 in., minor diameter of 0.4 in., and root radius of 0.26 in. (K_t = 1.3), 0.032 in. (K_t = 2.43), 0.016 in. (K_t = 3.1), or 0.074 in. (K_t = 1.79).

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi	Elong., %	R.A., %
Old heat	73.9	83.8	12.1	33.0
New heat	78.3	88.1	11.3	31.8

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 88

Materials: 300 M VAR Steel

Jaske, C. E.: The Influence of Chemical Milling on Fatigue Behavior of 300 M VAR Steel. Final Report, Battelle Memorial Institute, Columbus Laboratories, April 1969.

Test Information

(1) Fatigue Tests: Tests were conducted to determine the fatigue behavior of a steel with different surface finishes.

(2) Type of Test Machine: Electrohydraulic closed-loop system under load control (25,000-pound capacity).

(3) Number of Specimens: 9 control specimens and 27 chemical milled specimens/each of three stress ratios.

(4) Stress Ratio: R = - 1, - 1/3, or + 1/3.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 1 to 45 Hz.

Specimen Data

(1) Melting Practice/Heat Treatment: Material from 3 forgings was heat treated as follows - (a) preheat 1000° F/1 hr., (b) austenize 1600° F salt/3/4 hr., (c) quench in agitated 1000° F salt/1/2 hr., (d) quench in agitated 80°-180°F oil/25 min., (e) cool to below 150° F, (f) snap draw 400° F salt/1 hr., (g) cool and wash, (h) temper 600°F/2 hr., (i) cool to below 150° F, (j) temper 600° F/2 hr.

(2) Ductility: Not specified.

(3) Fabrication Methods: Control specimens were ground and shot peened. Remaining specimens were chemically milled prior to heat treatment and shot peened.

(4) Surface Finish: Shot peened to an intensity of 0.009 - 0.011 A2 full coverage using cast steel SAE 230 shot.

(5) Specimen Dimensions: Gross length = 5.39 in., test area length = 2.39 in., test area diam. = 0.25 in.

(6) Chemical Composition: Not specified.

(7) Tensile Properties: Not specified.

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 89

Materials: 300 M VAR Steel

Jaske, C. E.: The Influence of Variation in Decarburization Level Upon Fatigue Life of 300 M VAR Steel. Letter Report to the Bendix Corp., Battelle Memorial Institute, Columbus Laboratories, Sept. 30, 1968.

Test Information

(1) Fatigue Tests: Tests were conducted on deeply decarburized forging material and compared to normal decarburized forging and billet material.

(2) Type of Test Machine: Electrohydraulic closed-loop system under sinusoidal load control (20,000 lb. capacity).

(3) Number of Specimens: 8 control/billet and forging material, 26/decarburized forging.

(4) Stress Ratio: R = 0 or - 1.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 0.1 - 40 Hz.

Specimen Data (Found in Lab. Record Book No. 26111)

(1) Melting Practice/Heat Treatment: Control specimens were processed by Bendix sequence C with decarburization to 0.003 in. average and 0.006 in. maximum depth. Other specimens were austinitized in the gantry furnace to produce decarburization level of 0.015 in. to 0.020 in.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were ground to final dimension (RMS 63), heat treated, stress relieved and shot peened.

(4) Surface Finish: See (3) above.

(5) Specimen Dimensions: Gross length = 5.39 in., test area length = 2.39 in., test area diam. = 0.25 in.

(6) Chemical Composition: Not specified.

(7) Tensile Properties: Not specified.

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 90

Materials: Ti-6Al-4V

Gamble, R. M.: The Effect of Microstructure on the Tensile Properties, Low Cycle Fatigue Life, and Endurance Limit of Annealed Titanium Alloy 6Al-4V. *M.S. Thesis, Univ. of Fla.*, 1972.

Test Information

(1) Fatigue Tests: The fatigue life in the range from 1 to 10^7 cycles of one titanium alloy was studied as a function of material microstructure.

(2) Type of Test Machine: Model TT-D Instron machine having ±20 kips load cell was used for low cycle tests. The tests were strain controlled.

(3) Number of Specimens: 15 low cycle specimens/fine microstructure material, 21 low cycle specimens/coarse microstructure material.

(4) Stress Ratio: R = 0 or -1.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 0.12 - 1.06 cps.

Specimen Data

(1) Melting Practice/Heat Treatment: Fine grained specimens were from commercial hot rolled bar stock annealed at 1300° F for two hours and air cooled. Coarse grained specimens were taken radially from a cylindrical forging. The material was forged at 1750° F, water quenched, and annealed at 1300° F for two hours and air cooled.

(2) Ductility: Not specified.

(3) Fabrication Methods: Not specified.

(4) Surface Finish: Test section was polished in the longitudinal direction with 600 grit silicon carbide paper.

(5) Specimen Dimensions: Gross length = 3.5 in., test section length = 0.45 in., test section diameter = 0.29 inch.

(6) Chemical Composition: Stated to be within limits of AMS specification 4928C.

(7) Tensile Properties:

Microstructure	TYS, ksi	TUS, ksi	E, 10^3 ksi	R.A., %
Fine	148	160	16.0	44
Coarse	127	137	17.4	25

(8) Stress-Strain Curves: Average tensile curve and a comparison of cyclic and monotonic curves for both microstructures are given.

REFERENCE NUMBER 91

Materials: 2024 - T3 (B), 7075 - T6 (A,C)

Smith, I.; Howard, D. M.; and Smith, F. C.: Cumulative Fatigue Damage of Axially Loaded Alclad 75S-T6 and Alclad 24S-T3 Aluminum Alloy Sheet. NACA TN 3293, 1955.

Test Information

(1) Fatigue Tests: Cumulative-fatigue-damage tests were made on two aluminum alloys at stress amplitudes of 16 and 17 ksi, 16 and 30 ksi, 16 and 60 ksi, 30 and 40 ksi, and 30 and 60 ksi.

(2) Type of Test Machine: Lever-type fatigue machines designed by the National Bureau of Standards.

(3) Number of Specimens: 607/0.064 inch 7075-T6, 198/0.032 inch 2024-T3 and 7075-T6.

(4) Stress Ratio: R = - 1.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 16.7 Hz.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility. Not specified.

(3) Fabrication Methods: Specimens were machined from alclad 7075 - T6 rolled sheet 0.064 and 0.032 in. thick, and from 2024-T3 sheet 0.032 in. thick. Corners of the reduced section were rounded, lightly by hand.

(4) Surface Finish: Specimens were left as machined but inspected for stress-raisers.

(5) Specimen Dimensions: Length = 7.375 in., gross width = 1.5 in., test section width = 0.5 inch.

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	Thickness, in.	TYS, ksi	TUS, ksi	E, 10^3 ksi
7075-T6	0.064	76.1	77.8	10.2
7075-T6	0.032	70.8	78.3	10.1
2024-T3	0.032	50.1	66.8	10.5

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 92

Materials: 2024 - T3 (B), 7075-T6 (A)

Hudson, C. M.; and Hardrath, H. F.: Effects of Changing Stress Amplitude on the Rate of Fatigue-Crack Propagation in Two Aluminum Alloys. NASA TN D-960, 1961.

Test Information

(1) Fatigue-Crack Propagation Tests: Sheet specimens were subjected to constant-amplitude and two-step axial loads to study the effects of a change in stress on fatigue crack propagation of two alloys.

(2) Type of Test Machine: Subresonance fatigue machine (loads to 10 kips), hydraulic fatigue machine (loads to 20 kips), and a hydraulic jack (loads above 20 kips).

(3) Number of Specimens: 8 constant amplitude/7075-T6 and 7 constant amplitude/2024-T3.

(4) Stress Ratio: R = 0.02 to 0.1.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 1800 cpm, 1200 cpm, or 20-50 cpm depending upon machine used.

(7) FCP Data: The number of cycles given is the mean of the number of cycles required to produce cracks of equal length on both sides of the specimens.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: A 1/16" hole was drilled at the center of each specimen and a 1/32" deep notch was cut into each side of the hole.

(4) Surface Finish: Surface area was polished with No. 600 alundum powder.

(5) Specimen Dimensions: Length = 35 inches, width = 12 inches, thickness = 0.090 inch.

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	TYS,ksi	TUS, ksi	Elong., %	E,10^3ksi
2024-T3	52.05	72.14	21	10.47
7075-T6	75.50	82.94	12	10.22

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 93

Materials: 2024-T3 (A), 7075-T6 (B)

McEvily, A. J.; and Illg, W.: The Rate of Fatigue-Crack Propagation in Two Aluminum Alloys. NACA TN 4394, 1958.

Test Information

(1) Fatigue Crack Propagation Tests: Tests were conducted to provide a check on theoretical predictions and to evaluate empirical constants in the expression for the rate of fatigue crack propagation.

(2) Type of Test Machine: Subresonant fatigue machine (20,000 lb capacity), hydraulic fatigue machine (100,000 lb. capacity), and hydraulic jack (120,000 lb. capacity).

(3) Number of Specimens: 30/2024-T3, 33/7075-T6.

(4) Stress Ratio: R = 0.02 to 0.18.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 1800 cpm, 1200 cpm, 50 cpm, or 20 cpm.

(7) FCP Data: Test results give the number or cycles required to extend the crack from 0.2 inch. Crack lengths given are the averages of two specimens.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Blanks were sheared from sheet material parallel to the rolling direction. A 1/16-inch diameter hole was drilled at the center of each blank, and a 1/32-inch deep notch was cut in each side.

(4) Surface Finish: One face of each specimen was polished to a bright finish with No. 600 aluminum oxide powder.

(5) Specimen Dimensions: Length = 17.5 or 35 inches, width = 2 or 12 inches and thickness = 0.102 inch.

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi	Elong, %	E, 10^3 ksi
2024-T3	51.2	71.3	22.3	10.61
7075-T6	77.9	82.9	11.8	10.60

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 94

Materials: 7075-T76511 (A), 7075-T73511 (B), 2024-T8511 (C), 2219-T8511 (D), Ti-6Al-4V (E)

Anon.: Unpublished fracture toughness data on 7075-T76511, 7075-T73511, 2024-T8511, 2219-T851, and Ti-6Al-4V from Martin Marietta Aluminum, Dec. 1972 and Jan 1973.

Test Information

(1) Fracture Tests: Tests were conducted on three aluminum alloys and one titanium alloy employing a compact tension specimen.

(2) Type of Test Machine: Not specified.

(3) Number of Specimens: 95/7075-T76511, 5/7075-T73511, 6/2024-T8511, 44/2219-T8511, 38/Ti-6Al-4V.

(4) Stress Ratio: Not specified.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: Not specified.

Specimen Data

(1) Melting Practice/Heat Treatment: Final condition only is specified for aluminum alloys. Ti-6Al-4V was annealed (1300 F/2 hr.).

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were taken from extruded products. Orientation of the specimen is identified in the specimen number (LW, WL, TW, etc.).

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: See drawings of compact-tension specimens for complete dimensions.

(6) Chemical Composition: Not specified for aluminum alloys. See reference for composition by heat for Ti-6Al-4V.

REFERENCE NUMBER 94 (continued)

(7) Tensile Properties:

Material	Grain Direction	TYS, ksi	TUS, ksi	Elong., %
7075-T76511	L	69.3	77.7	11.2
" "	T	64.8	72.4	10.2
" "	S	62.6	71.9	9.1
7075-T73511	L	66.5	74.3	12.0
" "	T	60.6	69.0	11.0
" "	S	65.3	74.5	8.0
2024-T8511	L	66.5	71.0	7.0
" "	T	61.8	67.8	6.0
" "	S	61.6	67.7	3.0
2219-T8511	L	46.8	63.3	11.8
2219-T8511	T	44.0	61.8	8.6
Ti-6Al-4V	L	126.2	136.5	13.8
Ti-6Al-4V	T	127.7	137.4	13.5

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 95

Materials: AM 355, A286, Ti-6Al-4V (A), Inconel 718

Miller, James: Low-Cycle-Fatigue Under Biaxial Strain Controlled Conditions. J. Materials, JMLSA, vol. 7, no. 3, Sept. 1972, pp. 307-314.

Test Information

(1) Fatigue Tests: Low cycle strain controlled fatigue tests were conducted at three ratios of biaxial stress on four materials. The results support the effective strain criterion for crack initiation.

(2) Test Machine: Universal dynamic testing machine or a new fixture developed to convert uniaxial load to an equibiaxial load on a disk specimen.

(3) Number of Specimens: 8 uniaxial/Ti-6Al-4V.

(4) Stress Ratio: R = -1.0 or 0.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 5-10 cpm.

Specimen Data

(1) Melting Practice/Heat Treatment: Heat treatment of Ti-6Al-4V was as follows: 704C/1 hour, oil quenched. See report for others.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were machined from disk forgings in three types -- uniaxial, equibiaxial, and intermediate. Uniaxial specimens were cut in the radial and tangential directions.

(4) Surface Finish: Test section finish was 16 μ in. rms.

(5) Specimen Dimensions: Test section diameter = 5.1 mm.

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi	R.A., %	E, 10^3 ksi
Ti-6Al-4V	169	168-169	34-38	16

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 96

Materials: 420 Steel (A), 422 Steel (B), 7075-T6 (C, D), 2024-T3 (E)

Pearson, H. S.: Tear Resistance Properties of Types 420 and 422 Corrosion Resistant Steel, 7075-T6 and 2024-T3 Aluminum Alloy. ER 2332, Lockheed Aircraft Corp., 1957.

Test Information

(1) Fracture Tests: Tear resistance tests were made on four materials. Gross stress versus crack length curves are shown and data tabulated.

(2) Type of Test Machine: Riehle Universal testing machine (30,000 lb. capacity) and Baldwin Universal testing machine (400,000 lb. capacity).

(3) Number of Specimens: 8/420, 20/422, 16/7075-T6, and 16/2024-T3.

(4) Stress Ratio: Not specified.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: Not specified.

Specimen Data

(1) Melting Practice/Heat Treatment: (a) 420 steel sheet -- austenitized by heating at 1830 F ± 15 F/20 minutes, suspended in air to cool, tempered 600 F ± 10 F/3 hours (b) 422 steel sheet -- austenitized at 1875 F/3-5 minutes, air cooled, tempered at 1025-1050 F/3-5 minutes (c) 7075-T6 and 2024-T3 -- heat treated by vendor.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were sheared to size and a slot milled in the center of each panel normal to the longitudinal center line. A true crack was initiated in each end of the slot by using a Brinell hardness tester and a washer for the steel materials. A rivet gun was used to crack the aluminum materials.

(4) Surface Finish: Not specified.

REFERENCE NUMBER 96 (continued)

(5) Specimen Dimensions:

Material	Length, inches	Width, inches	Thickness, inch
420 Steel Sheet	12.0	6.0	0.046
422 Steel Sheet	48.0	18.0	0.023
" " "	24.0	8.0	0.023
" " "	12.0	4.0	0.023
7075-T6 Clad Sheet	36.0	17.0	0.025
" " "	18.0	8.0	0.025
" Extrusion	12.0	6.0	0.060
2024-T3 Clad Sheet	36.0	17.0	0.025
" " "	18.0	8.0	0.025

(6) Chemical Composition: Composition not specified for all alloys.

422 Steel, wt. %

C	Mn	P	S	Si	Ni	Cr	Mb	V
0.25	0.52	0.025	0.010	0.56	0.73	12.40	1.00	0.29

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi	Elong., %
420 Steel Sheet	175.1	227.0	6.7
422 Steel Sheet	177.0	218.0	7.0
7075-T6 Clad Sheet	67.3	75.6	8.2
7075-T6 Extrusion	80.9	90.8	7.2
2024-T3 Clad Sheet	47.2	65.4	15.8

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 97

Materials: AM350 (A), AM 355(B), Ti-4Al - 3Mo-1V (C), Ti-6Al-4V (D), PH15-7 Mo (E), 17-7 PH (F), 301 (G), M257 (H), Inconel 718 (I)

Schwartz, R. D.: Crack Propagation of a Number of High Strength Materials. Report No. 13961, Lockheed Aircraft Corp., 1961.

Test Information

(1) Fracture Tests: Crack propagation tests were conducted on numerous materials in various heat treat conditions and configurations. Tabular data, crack growth characteristic curves, and strength-weight versus crack length curves are included.

(2) Type of Test Machine: Universal testing machine (300,000 or 400,000 lb. capacity).

(3) Number of Specimens: 34/AM350, 22/AM355, 32/PH15-7 Mo, 8/17-7PH, 5/301, 18/Ti-4Al-3Mo-1V, 32/Ti-6Al-4V, 2/M 257, and 12/Inconel 718.

(4) Stress Ratio: Not specified.

(5) Test Temperature and Environment: Tests are conducted at room temperature -65 F, or 600 F in air.

(6) Test Frequency: Not specified.

Specimen Data

(1) Melting Practice/Heat Treatment: See Tables 1 - 5 of report for heat treatments of materials.

(2) Ductility: Not specified.

(3) Fabrication Methods: Six specimen configurations consisting of plain sheet with three transverse hat section stringers, butt joint, lap joint, and honeycomb panels were produced. Fatigue cracks were initiated from "Elox" cuts made by an electrical arc cutting process.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: See Figures 1-6 for specimen configurations and dimensions.

(6) Chemical Composition: See Tables 1-5 for composition of materials.

(7) Tensile Properties: See Tables 6-30 for properties of materials.

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 98

Materials: 2014-T6

Pierce, William S.: Crack Growth in 2014-T6 Aluminum Tensile and Tank Specimens Cyclically Loaded at Cryogenic Temperatures. NASA TN D-4541, 1968.

Test Information

(1) Fatigue Crack Propagation: Tests were conducted to determine the cryogenic low-cycle fatigue crack behavior of one aluminum material through-notched uniaxial tensile and biaxial pressure vessel specimens.

(2) Type of Test Machine: Tensile fatigue machine (20,000 lb. capacity), or gaseous nitrogen alternately pressurized and vented.

(3) Number of Specimens: 15 tensile specimens and 14 tank specimens.

(4) Stress Ratio: R = 0.07 to 0.23.

(5) Test Temperature and Environment: Tests were conducted at -320 F in gaseous nitrogen.

(6) Test Frequency: 3 cpm (0.05 Hz).

(7) FCP Data: Data is given as basic data.

Specimen Data

(1) Melting Practice/Heat Treatment: Tensile specimens were made from tubing, annealed, and reheat-treated to the T6 condition.

(2) Ductility: Not specified.

(3) Fabrication Methods: Tensile specimens were machined from unclad 2014-T6 extruded tubing. All specimens were transverse in direction. Tank specimens were machined from the same tubing.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Notched tensile specimen -- length = 12 inches, width = 3 inches, notch width = 0.08 inch, flank angle = 60°. Notched tank specimens -- outside diam. = 5.63 inches, wall thickness = 0.06 inch, notch width = 0.08 in., flank angle = 60°.

(6) Chemical Composition:

2014-T6, wt. %

Cu	Fe	Si	Mn	Mg	Zn	Ni	Cr	Ti	Sn
4.32	0.35	0.80	0.73	0.40	0.06	0.005	0.01	0.025	0.001

(7) Tensile Properties:

Material	Specimen Type	Temperature, F	TYS, ksi	TUS, ksi
2014-T6	Uniaxial	70	63.3	75.0
"	"	-320	75.0	86.0
"	"	-423	81.6	99.7
"	Biaxial	-320	85.8	--
"	"	-423	93.8	--

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 99

Materials: 2014-T6

Pierce, William S.; and Sullivan, Timothy L.: Factors Influencing Low-Cycle Crack Growth in 2014-T6 Aluminum Sheet at -320°F(77°K). NASA TN D-5140, 1969.

Test Information

(1) Fatigue-Crack Propagation Tests: Tests were conducted to determine the low-cycle crack growth characteristics of through-center-cracked aluminum specimens. The effects of initial stress intensity ratio, maximum gross stress applied, and cyclic rate are studied.

(2) Type of Test Machine: Servocontrolled closed-loop fatigue machine (20,000 lb. capacity).

(3) Number of Specimens: 54/2014-T6.

(4) Stress Ratio: R = 0 to 0.75.

(5) Test Temperature and Environment: Tests were conducted at -320 F in liquid nitrogen.

(6) Test Frequency: 0.05 to 0.5 Hz.

(7) FCP Data: Data is presented in basic form.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were machined from 0.06 inch sheet with the center crack normal to the sheet rolling direction.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Length = 12.0 inches, width = 3.0 inches, thickness = 0.06 inch, crack length = 0.3 inch.

(6) Chemical Composition:

2014, wt. %

Cu	Si	Mn	Mg	Fe	Zn	Cr	Ti
4.45	0.92	0.69	0.57	0.60	0.05	0.04	0.02

(7) Tensile Properties:

Material	Temperature, F	TYS, ksi	TUS, ksi	E, 10^3 ksi
2014-T6	70	65.0	72.3	10.4
2014-T6	-320	75.2	86.7	11.5

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 100

Materials: 7075 (A), 7175 (B), Alclad 7175 (C)

Anon.: Unpublished fatigue-crack-propagation and fracture toughness data on 7075 and 7175 aluminum from Kaiser Aluminum and Chem. Corp. Center for Technology, Jan. 22, 1973.

Test Information

Description of test procedures was not furnished. See data sheets for test temperature.

Specimen Data

(1) Melting Practice/Heat Treatment: Conditions of material include T6511, T73, T7351, T7651, T6, T651, T76511, T7352, and T73511. Actual heat treatment not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Material forms used for specimen fabrication were plate, hand forging, extrusion, and stepped extrusion.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: See data sheets for specimen width and thickness.

(6) Chemical Composition: See data sheets for composition of each lot of material.

(7) Tensile Properties: See data sheets for mechanical properties of each lot of material.

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 101

Materials: PH 15-7Mo, AM 350, AISI 301, Ti-6Al-4V (A, B), Ti-4Al-3Mo-1V, Ti-8Al-1Mo-1V, Clad RR 58, Clad 2024 (C).

Illg, W.; and Imig, L. A.: Fatigue of Four Stainless Steels, Four Titanium Alloys, and Two Aluminum Alloys Before and After Exposure to Elevated Temperatures For Up to Three Years. NASA TN D-6145, 1971.

Test Information

(1) Fatigue Tests: Unnotched, notched, spotwelded, and fusion-welded fatigue sheet specimens were tested before and after exposure to elevated temperatures to determine its effect.

(2) Type of Test Machine: Axial-load, subresonant-type, fatigue testing machine.

(3) Number of Specimens: 70 pre-exposure/Ti-6Al-4V, 77 pre-exposure/2024-T81, see report for others.

(4) Stress Ratio: R = -0.584 to 0.624.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 30 Hz.

Specimen Data

(1) Melting Practice/Heat Treatment: The Ti-6Al-4V material was annealed (1475 F/1 hour, furnace cooled at 1300 F) and the 2024 material was solution treated and aged to the T81 condition (solution treat 910-930 F, water quench, cold work, precipitation heat treat 375 F/11-13 hours).

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were machined from sheet materials. Notches were cut by drilling successively larger holes.

(4) Surface Finish: Fatigue critical areas were chamfered to remove burred material.

(5) Specimen Dimensions: Unnotched -- length = 12.6 inches, gross width = 2.0 inches, net width = 0.75 inch; notched -- length = 12.6 inches, gross width = 2.25 inches, net width = 1.5 inches, root radius = 0.058 inch (K_t = 4.0). Thickness = 0.04 inch for Ti-6Al-4V and 0.063 inch for 2024.

REFERENCE NUMBER 101 (continued)

(6) Chemical Composition: See report for others.

Ti-6Al-4V, wt. %		2024, wt. %	
Al	6.1	Cr	0.1
C	0.026	Cu	3.8-4.9
Fe	0.15	Fe	0.05
H_2	0.011	Mg	1.2-1.8
N_2	0.013	Mn	0.3-0.9
Ti	Balance	Si	0.05
V	4.0	Zn	0.25

(7) Tensile Properties: See report for others.

Material	TYS, ksi	TUS, ksi	Elong., %
Ti-6Al-4V	142.0	149.0	12
2024-T81	57.5	64.6	7

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 102

Materials: 2024-T3

Schijve, J.: The Fatigue Life of Unnotched and Notched 2024-T3 Alclad Sheet Materials From Different Manufacturers. NLR TR 68093C, National Aerospace Laboratory, The Netherlands, 1968.

Test Information

(1) Fatigue Tests: Constant-amplitude and programme-fatigue tests were performed on unnotched, central-hole, and riveted lap joint specimens. Comparisons were made among results of different manufacturers and scatter was studied.

(2) Type of Test Machine: Amsler high-frequency pulsator (10 ton capacity).

(3) Number of Specimens: 81 unnotched constant-amplitude, 78 central-hole.

(4) Stress Ratio: R = 0.037 to 0.53.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 67 Hz.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Not specified.

(4) Surface Finish: Surfaces were not polished.

(5) Specimen Dimensions: Unnotched - length = 12.6 inches, gross width = 1.57 inches, net width = 0.59 inch, thickness = 0.079 inch. Notched - length = 12.6 inches, width = 1.57 inches, hole diameter = 0.39 inch, thickness = 0.079 inch.

(6) Chemical Composition: Not given for material from manufacturer G.

Manufacturer	2024, Wt. % A	C	E	F
Cu	4.9	5.07	4.49	4.72
Mg	1.63	1.77	1.7	1.55
Mn	0.7	0.58	0.68	0.63
Si	0.14	0.26	0.24	0.16
Fe	0.23	0.29	0.37	0.32
Zn	0.08	0.1	0.02	0.06
Cr (a)	455	392	799	1189
Ti	0.03	0.01	0.02	0.02

(a) Relative values.

(7) Tensile Properties:

Manufacturer	2024-T3 A	C	E	F	G
TYS, ksi	52.2	48.9	52.9	50.1	51.8
TUS, ksi	65.7	66.7	67.8	65.8	67.7
Elong., %	20	23	21	22	18

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 103

Materials: Ti-6Al-4V

VanOrden, J. M.: Evaluation of Alloy Spark-Sintered Ti-6Al-4V Ingot and Forged Bar. Report No. 24376, Lockheed-California Co., 1971.

Test Information

(1) Fatigue Tests: Constant amplitude fatigue tests were performed on two forms of one alloy prepared by alloy powder spark sintering. Macro and microstructural features were examined.

(2) Type of Test Machine: Hydraulic servo-jack machine (10 kip).

(3) Number of Specimens: 16/ingot, 12/forged bar.

(4) Stress Ratio: R = 0.1.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 30 cps.

Specimen Data

(1) Melting Practice/Heat Treatment: Forged bars were fabricated from spark sintered billets. The forged bars and Ingot A were annealed (1300 F/2 hr., air cooled). Ingot B was solution heat treated and aged (1725 F/1 hr., water quench, 1000 F/4 hr., air cool).

(2) Ductility: Not specified.

(3) Fabrication Methods: Not specified.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: See Reference 73 for LCC Drawing X-8398-5. Length = 3.0 inches, major diameter = 0.3 inch, minor diameter =0.2 inch, root radius = 0.01 inch (K_t = 3.0), flank angle = 60°.

(6) Chemical Composition:

Ti-6Al-4V, Wt %

O_2	N_2	H_2	C	Si	Fe	Mn	Ni	Al	V	Ti
0.084	0.0082	0.0073	0.011	0.03	0.08	0.005	0.005	6.18	4.22	Rem.

(7) Tensile Properties:

Material	Product	Condition	TYS,ksi	TUS, ksi,	Elong., %	R.A., %
Ti-6Al-4V	Ingot A	Annealed	137.6	144.8	7.0	15.0
"	Ingot B	STA	145.6	155.8	6.7	14.8
"	Forged Bars	Annealed	152.5	158.7	12.2	33.0

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 104

Materials: 2024-T3 (A), 7075-T6 (B)

Wilks, I. E.; and Howard, D. M.: Effect of Mean Stress on the Fatigue Life of Alclad 24S-T3 and Alclad 75S-T6 Aluminum Alloy. WADC-TR-53-40, National Bureau of Standards, 1953.

Test Information

(1) Fatigue Tests: Axial load fatigue tests were conducted on center notched specimens of two materials to determine the effect of mean stress.

(2) Type of Test Machine: Brueggeman lever fatigue machine (1000 pound capacity).

(3) Number of Specimens: 99/2024-T3, 91/7075-T6.

(4) Stress Ratio: R = -100 to +7.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 20 Hz.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimen coupons from alclad 2024-73 and 7075-T6 were gangmilled and holes were match drilled and hand reamed. Hole edges were rounded by twisting a tapered rubber eraser in the hole.

(4) Surface Finish: Specimens were left as machined.

(5) Specimen Dimensions: Length = 6.5 inches, width = 0.8 inch, hole diameter = 0.125 inch (K_t=2.6), thickness = 0.032 inch.

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	TYS,ksi	TUS,ksi	E, 10^3ksi
2024-T3	50.07	66.80	10.47
7075-T6	70.80	78.10	10.10

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 105

Materials: D6AC (A, B), 4340 (C, D, E, F, G, H)

Heitzmann, R. J.: Effect of Decarburization and Surface Defects on the Notched Fatigue Strength of Steel. ADR 02-09-67.1, Grumman Aircraft Engineering Corp., 1967.

Test Information

(1) Fatigue Tests: Transverse fatigue properties of two vacuum-melted steels are studied at three tensile strength levels to develop notched fatigue curves.

(2) Type of Test Machine: Sonntag SF-1-U or Krouse Fatigue Machine.

(3) Number of Specimens: 92/D6AC, 54/4340.

(4) Stress Ratio: R = 0.1.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 1800 cpm, or 120 to 240 cpm.

Specimen Data

(1) Melting Practice/Heat Treatment: Vacuum melted forged bars of 4340 and D6AC and hot rolled plate of D6AC were heat treated as follows:

4340	D6AC
a. Austenitize at 1575 F/1 hour	a. Austenitize 1650 F/1 hour
b. Oil quench	b. Quench to AusBay Furnace and hold at 970 F/1 hour
c. Double temper at 750 F/2 hours (200-220 ksi) or 475 F/2 hours (260-280 ksi)	c. Oil quench
d. Stress relieve (260-280 ksi) at 425 F/2 hours after machining	d. Double temper at 1030 F/2 hours (220-240 ksi) or 600 F/2 hours (260-280 ksi)
	e. Stress relieve at 925 F/2 hours (220-240 ksi) or 525 F/2 hours (260-280 ksi) after machining

4340 was decarburized as follows: (a) Austenitize at 1575 F/1/2 hour (0.003 inch depth) or 1575 F/1 hour (0.006 inch depth) in molten salt bath (b) quench in oil (c) snap temper at 375 F/2 hours (d) double temper at 475 F/2 hours.

(2) Ductility: Not specified.

(3) Fabrication Methods: Transverse specimens were rough machined, heat treated, finish machined, and stress relieved.

REFERENCE NUMBER 105 (continued)

(4) Surface Finish: Specimens were polished to remove discoloration and scratches. Certain specimens were shot peened or scratches were introduced to the surface.

(5) Specimen Dimensions:

Specimen Type	Gross Length, inches	Gross Width or Diameter, inches	Net Width or Diameter, inches	Notch Root Radius, inches	K_t
Flat Edge Notched	7.76	2.75	1.0	0.15	1.97
" " "	8.0	3.25	1.8	0.09	3.0
" " "	10.5	3.0	1.01	0.095	2.9
Round Unnotched	4.0	0.435	0.2	--	1.0
Round Notched	4.0	0.435	0.357	0.013	3.0

(6) Chemical Composition:

	4340 Forged Bar	D6AC Forged Bar	D6AC Hot Rolled Plate
	Composition, Wt. %		
C	0.41	0.47	0.48
Mn	0.84	0.80	0.75
Si	0.34	0.22	0.27
Ni	1.80	0.55	0.59
Cr	0.72	1.09	1.08
Mb	0.23	0.99	1.00
V	--	0.10	0.09
P	0.004	0.006	0.006
S	0.004	0.005	0.005

(7) Tensile Properties:

Material	Heat Treat	TYS, ksi	TUS, ksi	Elong., %	R.A., %
D6AC	260-280 ksi	225.2	261.2	9.0	33.3
D6AC	220-240 ksi	208.7	230.3	14.0	46.4
4340	260-280 ksi	221.6	273.5	10.3	32.3
4340	260-280 ksi	216.2	263.3	10.6	42.1
4340	200-220 ksi	185.0	202.2	8.3	--
4340	decarburized	219.0	265.0	10.0	38.9
4340	decarburized	221.3	260.1	9.8	36.1
4340	decarburized + shot peened	222.0	264.5	10.0	40.5

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 106

Materials: Ti-6Al-4V

Marrocco, A. G.: Evaluation of Ti-6Al-4V 'Pancake' Forgings, Effect of Surface Condition. EMG-87, Grumman Aircraft Engineering Corp., 1969.

Test Information

(1) Fatigue Tests: Forged "pancakes" of one material were evaluated to determine the effects of surface condition on the fatigue characteristics of the material.

(2) Type of Test Machine: Sonntag SF 1U fatigue machine.

(3) Number of Specimens: 28/Ti-6Al-4V.

(4) Stress Ratio: R = 0.1.

(5) Test Temperature and Environment: Tests were concluded at room temperature in air.

(6) Test Frequency: 30 Hz.

Specimen Data

(1) Melting Practice/Heat Treatment: The material was alpha-beta forged and annealed at 1300 F/2 hours and air cooled.

(2) Ductility: Not specified.

(3) Fabrication Methods: Two specimens were machined from each of 14 forgings.

(4) Surface Finish: Nine specimens were from forgings left as machined with a 63 rms finish, nine specimens were from forgings with ECM surfaces, and ten specimens were from ECM forgings and were saturation shot peened.

(5) Specimen Dimensions: Dimensions not specified. As machined forgings were 0.19 inch thick, ECM forgings were 0.2 inch thick.

(6) Chemical Composition: Ti-6Al-4V, Wt. %

Al	V	Fe	C	N	O	H	Ti
6.48	4.37	0.21	0.028	0.007	0.14	0.0060	Balance

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi	Elong., %	E, 10^3 ksi
Ti-6Al-4V	141.6	148.1	18	16.76

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 107

Materials: Ti-6Al-4V

Marrocco, A. G.: Evaluation of 'Mill Polished' Titanium Sheet (Effect of Surface Belt Grinding). EMG-86, Grumman Aircraft Engineering Corp., 1969.

Test Information

(1) Fatigue Tests: The effects of abrasive belt grinding on the fatigue characteristics of one material are evaluated.

(2) Type of Test Machine: Sonntag SF-1U fatigue machine.

(3) Number of Specimens: 50 total in various surface finishes.

(4) Stress Ratio: R = 0.1.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 30 Hz.

Specimen Data

(1) Melting Practice/Heat Treatment: Material was in the annealed condition.

(2) Ductility: Not specified.

(3) Fabrication Methods: A 0.07 inch thick sheet of material was sheared into four panels, the panels were given various surface treatments, and specimens were machined transverse to the grain direction.

(4) Surface Finish: One panel was left as received, one panel was ground by an abrasive belt to 0.059 inch, one panel was pickled in a nitric-hydrofluoric acid bath for 10 minutes, and the fourth panel was chemically milled in a 10 percent hydrofluoric acid bath.

(5) Specimen Dimensions: Unnotched specimens per TGS 1089.

(6) Chemical Composition: Ti-6Al-4V, Wt. %

Al	V	Fe	C	N	H	O	Ti
6.2	4.1	0.13	0.03	0.013	80 (ppm)	0.12	Balance

(7) Tensile Properties:

Material.	Grain Direction	TYS,ksi	TUS, ksi	Elong., %
Ti-6Al-4V	L	141	148	11.9
Ti-6Al-4V	T	144	150	11.8

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 108

Materials: Ti-6Al-4V (A), Ti-6Al-6V-2Sn

Marrocco, A. G.: Evaluation of Ti-6Al-4V and Ti-6Al-6V-2Sn Forgings. EMG-82, Grumman Aircraft Engineering Corp., 1968.

Test Information

(1) Fatigue Tests: Fatigue properties of two titanium alloys' forgings were evaluated. A comparison was made between conventional forging practices and beta forging.

(2) Type of Test Machine: Sonntag SF - 1U fatigue machine.

(3) Number of Specimens: 15/Ti-6Al-4V, 19/Ti-6Al-6V-2 Sn.

(4) Stress Ratio: R = 0.1.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 30 Hz.

Specimen Data

(1) Melting Practice/Heat Treatment: The Ti-6Al-4V Forgings were beta forged and annealed. The Ti-6Al-6V-2Sn forgings were alpha-beta or beta forged and were annealed or solution-treated and aged.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were machined from forgings in unnotched or notched configuration.

(4) Surface Finish: Burrs were removed and specimen sides were polished.

(5) Specimen Dimensions: Specimens were machined per TGS 1004 or 1040-2 (see Reference 74).

(6) Chemical Composition:

	Composition, wt. %								
Material	Al	V	Sn	Fe	Cu	C	N	H (ppm)	O
Ti-6Al-4V	6.3	4.0	--	0.11	--	0.019	0.017	51	0.15
Ti-6Al-6V-2 Sn	5.7	5.5	2.1	0.74	0.56	0.015	0.017	46	0.16

(7) Tensile Properties:

Material	Forging Process	Condition	TYS, ksi	TUS, ksi	Elong., %	E, 10^3 ksi
Ti-6Al-4V	Beta	Ann.	132.7	143.6	12.7	17.74
Ti-6Al-6V-2 Sn	Beta	Ann.	143.0	152.4	14.1	15.92
Ti-6Al-6V-2 Sn	Alpha-Beta	Ann.	151.5	159.9	15.0	17.48
Ti-6Al-6V-2 Sn	Beta	STA	173.0	184.6	7.1	16.86
Ti-6Al-6V-2 Sn	Alpha-Beta	STA	176.5	184.3	8.7	16.71

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 109

Materials: 2024-T3 (A), 2024-T8 (B), 7178-T6

Schijve, J.; and Jacobs, F. A.: Fatigue Tests on Unnotched and Notched Specimens of 2024-T3 Alclad, 2024-T8 Alclad and 7178-T6 Extruded Material. NLR TR 68017U, National Aerospace Laboratory, The Netherlands, 1968.

Test Information

(1) Fatigue Tests: Constant amplitude and programme fatigue tests were conducted on unnotched specimens, specimens with a central hole, riveted lap joints, specimens with unloaded rivets and specimen with a bonded doubler. Comparison is made between alloys, their notch sensitivity, effect of cladding and $\Sigma n/N$ values.

(2) Type of Test Machine: Amsler high-frequency pulsator (10 ton capacity).

(3) Number of Specimens: 28 notched/2024-T3 and 2024-T8.

(4) Stress Ratio : R = 0.037 to 0.495.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 4000 cpm (66.7 Hz).

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: The 2024-T8 and 7178-T6 materials were found to have low ductilities.

(3) Fabrication Methods: Notched and unnotched specimens were machined from 0.08 inch materials. Notches were formed by drilling a central hole.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Unnotched - length = 12.8 inches, gross width = 1.6 inches, net width = 0.6 inch, K_t = 1.08. Notched - length = 12.8 inches, width = 1.6 inches, hole diameter = 0.4 inch, K_t= 2.43.

(6) Chemical Composition:

	Composition, Wt. %				
Material	Cu	Zn	Mg	Mn	Cr
2024	4.5	--	1.7	0.7	---
7178	2.0	6.8	2.7	---	0.3

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi	Elong., %
2024-T8	65.8	69.2	6.5
2024-T3	55.4	67.2	17.0
7178-T6	82.7	89.7	9.0

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 111

Materials: 7075-T651 (A), 7075 TMT, X 7075 TMT

Ostermann, F.: Improved Fatigue Resistance of Al-Zn-Mg-Cu(7075) Alloys Through Thermomechanical Processing. AFML-TR-71-121, Air Force Materials Laboratory; 1971.

Test Information

(1) Fatigue Tests: Fatigue properties of commercial and high purity aluminum in an age-hardened condition are compared to those of a conventional heat treat condition.

(2) Type of Test Machine: Schenck Pulsator (2-ton capacity).

(3) Number of Specimens: 22/7075-T651. See report for others.

(4) Stress Ratio: R = -1.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 40 Hz.

Specimen Data

(1) Melting Practice/Heat Treatment: The commercial, rolled bar stock was tested in the T651 condition. The high purity material was vacuum melted, chill cast, homogenized at 870 F for 20 hours, and annealed at 775 F. A thermomechanical treatment was given both commercial and high purity bars by solution annealing at 860 F/1 hour, water quenching, aging at 212F/1 hour, swaging at room temperature, and aging at 248 F/16 hours.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were machined according to specifications in Reference 82.

(4) Surface Finish: Specimens were polished.

(5) Specimen Dimensions: Length = 3 inches, test area length = 1.5 inches; gross diameter = 0.465 inch, net diameter = 0.2 inch.

(6) Chemical Composition:

	Composition, Wt. %								
Material	Al	Cu	Mg	Z	Si	Mn	Cr	Fe	Ti
C 7075	Remainder	1.56	2.42	5.53	0.11	0.04	0.19	0.26	0.05
X 7075	Remainder	1.59	2.64	5.53	<0.01	<0.01	0.29	0.01	0.19

(7) Tensile Properties:

Material	TYS, ksi	TUS,ksi	Elong., %	R.A., %
C7075-T651	74.9	83.1	16.5	32
C7075TMT	87.2	91.0	10.0	29
X7075TMT	85.3	91.8	12.7	34

(8) Stress-Strain Curves: True stress-true strain curves are given for the three materials.

REFERENCE NUMBER 112

Materials: 2014-T6, 7075-T6 (A, B), 7075-T73 (C, D), 7079-T6, X7080-T7, CH70-T7.

Nordmark, G. E.; Lifka, B. W.; Hunter, M. S.; and Kaufman, J. G.: Stress-Corrosion and Corrosion-Fatigue Susceptibility of High-Strength Aluminum Alloys. AFML-TR-70-259, ALCOA Research Laboratories, 1970.

Test Information

(1) Fatigue Tests: The stress-corrosion-fatigue performance of several high strength aluminum alloys was investigated by tests of hydraulic cylinders and other specimens prepared from forgings or castings.

(2) Type of Test Machines: Krouse fatigue machine (5 kip).

(3) Number of Specimens: 14/7075-T6 tested in ambient air and 15/7075-T73 tested in ambient air. See report for others.

(4) Stress Ratio: R = 0.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air or salt fog.

(6) Test Frequency: 1100 cpm (18.3 Hz).

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were machined from rolled rod forging stock, die forgings made from a portion of the forging stock, or premium strength castings (CH70 only). Flat, hourglass specimens, cylinders, or C-rings were used for testing.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Length = 11 inches, gross width = 1 inch, net width = 0.5 inch, thickness = 0.125 inch.

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	Form	TYS, ksi	TUS, ksi	Elong., %
7075-T6	Rolled Rod	67.8	79.4	15.0
7075-T6	Die Forging	69.6	79.8	17.0
7075-T73	Rolled Rod	56.6	69.5	15.5
7075-T73	Die Forging	66.4	76.9	14.5
7079-T6	Rolled Rod	68.2	77.1	15.0
7079-T6	Die Forging	68.6	77.8	14.8
X7080-T7	Rolled Rod	52.6	63.9	14.8
X7080-T7	Die Forging	64.2	72.0	14.8
2014-T6	Rolled Rod	64.2	71.4	12.0
2014-T6	Die Forging	63.8	71.3	11.5
CH70-T7	Premium Casting	63.0	68.2	6.2

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 113

Materials: Ti-6Al-4V (A, B), Ti-6Al-6V-2Sn

VanOrden, J. M.: The Effects of Macrograin Size Control on Fatigue Properties of Titanium Alloy Forged Billet. LR-24375, Lockheed-California Co., 1971.

Test Information

(1) Fatigue and Fracture Tests: Tests were conducted to evaluate the effect of refinement of the prior beta (macro) grain size on the tensile strength, heat treatment response, fracture toughness, and notched fatigue properties of two titanium alloys.

(2) Type of Test Machine: Lockheed designed resonant fatigue machine.

(3) Number of Specimens: 25 fatigue/annealed Ti-6Al-4V, 18 fatigue/STA Ti-6Al-4V.

(4) Stress Ratio: R = 0.1.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 1700 to 2600 cpm (assumed 35 Hz).

Specimen Data

(1) Melting Practice/Heat Treatment: The Ti-6Al-4V material was in the annealed (1300 F/2 hours, air cooled) or STA (1750 F/4-1/2 hours, water quench, age 1000 F/7 hours, air cool) condition, and was alpha-beta processed to produce a fine grained material. The Ti-6Al-6V-2Sn material was in the annealed (1300 F/2 hours, air cooled) or STA (1600 F/2-1/2 hours, water quench, age at 1025 F/9-1/2 hours, air cool) condition with aging temperatures varied for the heat treatment study.

(2) Ductility: Not specified.

(3) Fabrication Methods: Full size billets were heat treated and then machined into various specimen types in the long transverse grain direction.

(4) Surface Finish: As-machined.

(5) Specimen Dimensions: Fatigue -- length = 5.25 inches, gross diameter = 0.62 inch, net diameter = 0.3 inch, root radius = 0.01 inch (from drawing X-6527-X in Reference 73).

(6) Chemical Composition: Not specified for Ti-6Al-4V.

Ti-6Al-6V-2Sn, wt. %

C	N	Fe	Al	V	Sn	Cu	O	H (ppm)
0.02	0.014	0.69	5.6	5.5	2.3	0.69	0.110-0.131	33-36

REFERENCE NUMBER 113 (continued)

(7) Tensile Properties:

Material	Condition	Grain Direction	TYS, ksi	TUS, ksi	Elong., %	R.A., %
Ti-6Al-6V-2Sn	annealed	LT	139	146	12.0	21.5
Ti-6Al-6V-2Sn	STA	LT	170	177	6.9	17.9
Ti-6Al-4V	annealed	LT	134	141	12.0	26.0
Ti-6Al-4V	STA	LT	133	144	11.0	25.0

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 114

Materials: Ti-6Al-4V

Wells, C. H.; and Sullivan, C. P.: Low-Cycle Fatigue Crack Initiation in Ti-6Al-4V. Transactions of the ASM, vol. 62, 1969, pp. 263-270.

Test Information

(1) Fatigue Tests: The mechanism of low-cycle fatigue crack initiation in one titanium alloy was investigated at several temperatures and under two environmental conditions.

(2) Type of Test Machine: Wiedemann-Baldwin machine (25,000 lb. capacity) under strain control.

(3) Number of Specimens: 6 specimens were tested in ambient air.

(4) Stress Radio: R = -1.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air and 3 percent NaCl, and in air at 300 F and 600 F.

(6) Test Frequency: 1 to 2 cpm (0.025 Hz).

Specimen Data

(1) Melting Practice/Heat Treatment: The material was forged at 1725 F in the $\alpha + \beta$ field and heat treated at 1775 F/1 hr., water quenched, aged at 1300 F/2 hrs., air cooled.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were machined from the heat treated pancake forging.

(4) Surface Finish: The test section surfaces were abrasive polished followed by electropolishing.

(5) Specimen Dimensions: Gross length = 2.5 inches, net length = 1 inch, diameter = 0.375 inch.

(6) Chemical Composition: Ti-6Al-4V, Wt. %

C	N_2	O_2	H_2	Al	V	Fe
0.06	0.015	0.185	0.004	6.2	3.8	<0.3

(7) Tensile Properties: TYS = 133-136 ksi, E = $17.0 \pm 0.4 \times 10^3$ ksi, for Ti-6Al-4V.

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 115

Materials: Ti-6Al-4V

Bucci, R. J.; Paris, P. C.; Hertzberg, R. W.; Schmidt, R. A.; and Anderson, A. F.: Fatigue Threshold Crack Propagation in Air and Dry Argon for a Ti-6Al-4V Alloy. Stress Analysis and Growth of Cracks, Proceedings of the 1971 National Symposium on Fracture Mech., Part I, ASTM STP 513, 1972, pp. 125-140. Original data received from the G. E. Co., April, 1973.

Test Information

(1) Fatigue Crack Propagation Tests: A titanium material was tested in two conditions and in a wide range of crack growth rates and stress intensities.

(2) Type of Test Machine: MTS, closed loop, hydraulically actuated, servo-controlled mechanical test system.

(3) Number of Specimens: 7/Ti-6Al-4V.

(4) Stress Ratio: R = 0.125 to 0.333.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air or dehumified Matheson research grade argon.

(6) Test Frequency: 68 to 170 cps according to test.

(7) FCP Data: Original data was received in basic form.

Specimen Data

(1) Melting Practice/Heat Treatment: The forged Ti-6Al-4V compressor disk was originally solution treated at 1750 F/1 hr., water quenched, annealed to 1300 F/2 hr. and air cooled. Specimens from the disk were solution treated at 1750 F/2 hr., water quenched, and aged at 1000 F/7 hr., air cooled. Part of the specimens were given an additional anneal cycle at 1300 F/2 hr. in argon.

(2) Ductility: Not specified.

(3) Fabrication Methods: Compact tension specimens were prepared with the direction of applied load in the radial direction and direction of crack growth in the tangential or circumferential direction.

(4) Surface Condition: Not specified.

(5) Specimen Dimensions: Length = 3.0 inches, width = 2.5 inches, thickness = 0.125 inch, and notch width = 0.125 inch.

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	Condition	TYS, ksi	TUS, ksi	Elong., %	R.A., %
Ti-6Al-4V	Annealed	139	150	12.0	36.0
Ti-6Al-4V	STA	150	159	11.4	35.1

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 117

Materials: DTD 5070 A, 2024-T 81 (A), BS L73

Binning, M. S.: Direct Stress Fatigue Tests on DTD 5070A, BS L73 and Alclad 2024-T81 Sheets. TR 70221, Royal Aircraft Establishment, 1970.

Test Information

(1) Fatigue Tests: Direct stress fatigue tests were made on three aluminum alloy sheet materials with a range of stress concentrations.

(2) Type of Test Machine: Amsler Vibrophore machine.

(3) Number of Specimens: 77 at room temperature/2024-T81.

(4) Stress Ratio: R = 0.032 to 0.5.

(5) Test Temperature and Environment: Tests were conducted at room temperature and 150 C in air.

(6) Test Frequency: 8000 cpm (133 Hz).

Specimen Data

(1) Melting Practice/Heat Treatment: The 2024 material was solution treated (492-499 C) and aged (180-190 C/12 hours) to the T81 condition. See report for heat treatments of the other materials.

(2) Ductility: Not specified.

(3) Fabrication Methods: Longitudinal and transverse specimens were taken from 0.064 inch sheet.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Unnotched - length = 6.7 inches, width = 0.75 inch. Notched - length = 6.7 inches, width = 1.0 inch (K_t=2.7) or 1.05 inches (K_t= 2.3 and K_t= 3.4), root radius = 0.187 inch (K_t=2.3), 0.0625 inch (K_t= 2.7), or 0.141 inch (K_t= 3.4).

(6) Chemical Composition: 2024-T81, Wt. %

Cu	Fe	Si	Mn	Mg	Zn	Al
4.26	0.33	0.15	0.60	1.43	0.09	Remainder

(7) Tensile Data:

Material	TYS,ksi	TUS, ksi	Elong., %
DTD 5070A	56.4	61.6	6.5
2024-T81	63.8	69.0	6.0
BS L73	56.7	63.6	9.5

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 118

Materials: 2024-T3 (A), 7075-T6 (B)

Broek, D.; and Schijve, J.: The Influence of the Mean Stress on the Propagation of Fatigue Cracks in Aluminum Alloy Sheet. NLR-TR M.2111, Reports and Transactions, National Aero- and Astronautical Research Institute, 1965, pp. 41-61.

Test Information

(1) Fatigue Crack Propagation Tests: Sheet specimens of two aluminum alloys were loaded at three load amplitudes and mean loads to determine the influence of mean stress on crack growth rate.

(2) Type of Test Machine: Vertical Schenck pulsator type PVQ-002S (6 ton capacity).

(3) Number of Specimens: 27/2024-T3 and 7075-T6.

(4) Stress Ratio: R = 0.06 to 0.65.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 2000 cpm (33 Hz).

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were cut from 0.08 inch clad sheet. A severe central notch was made by drilling a hole and slotting with a jeweller's fret saw.

(4) Surface Finish: The notch area was polished and provided with fine scribe line markings.

(5) Specimen Dimensions: Length = 16 inches, width = 6.4 inches, thickness = 0.08 inch, central hole diameter = 0.04 inch.

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	TYS,ksi	TUS, ksi	Elong., %
2024-T3	52.8	68.7	18.9
7075-T6	67.3	75.4	9.4

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 119

Materials: 2024-T3 (A-E)

Broek, D.; and Schijve, J.: The Effect of Sheet Thickness on the Fatigue-Crack Propagation in 2024-T3 Alclad Sheet Material. NLR-TR M.2129, Reports and Transactions, National Aero- and Astronautical Research Institute, 1965, pp. 63-73.

Test Information

(1) Fatigue Crack Propagation Tests: Specimens of one aluminum alloy in several thicknesses were studied to determine the influence of sheet thickness on fatigue crack propagation.

(2) Type of Test Machine: Horizontal Schenck Pulsator type PP6D (six ton capacity).

(3) Number of Specimens: 45/2024-T3.

(4) Stress Ratio: R = 0.1, 0.33, or 0.52.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 1700 - 2300 cpm (28 - 38 Hz).

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were cut from clad sheet ranging in thickness from 0.024 inch to 0.16 inch. A central notch was made by drilling a hole and slotting it with a jeweller's fret saw.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Length = 11 inches, width = 4 inches, central hole diameter = 0.04 inch, total notch length = 0.12 inch, thickness = 0.024, 0.04, 0.08, 0.12, or 0.16 inch.

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	Thickness, in.	TYS, ksi	TUS, ksi	Elong., %
2024-T3	0.024	51.1	65.5	16.0
"	0.04	52.3	67.1	16.5
"	0.08	52.6	68.3	18.0
"	0.12	53.6	68.4	18.5
"	0.16	57.4	70.1	17.0

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 120

Materials: 2024-T3

Schijve, J.; and DeRijk, P.: The Effect of Temperature and Frequency on the Fatigue Crack Propagation in 2024-T3 Alclad Sheet Material. NLR-TR M.2138, Reports and Transactions, National Aero- and Astronautical Research Institute, 1965, pp. 87-98.

Test Information

(1) Fatigue Crack Propagation Tests: Tests were conducted on one aluminum sheet material at three temperatures and frequencies to determine the effect upon fatigue crack propagation.

(2) Type of Test Machine: Horizontal Schenck pulsator type PPD6 (six ton capacity).

(3) Number of Specimens: 26/2024-T3.

(4) Stress Ratio: R = 0.04, 0.27, or 0.47.

(5) Test Temperature and Environment: Tests were conducted at room temperature and 300 F in air.

(6) Test Frequency: 20 or 2000 cpm (0.33 or 33 Hz).

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were cut from 0.08 inch clad sheet. Central notches were made by drilling a hole and slotting.

(4) Surface Finish: Specimens were polished in the notch area.

(5) Specimen Dimensions: Length = 16 inches, width = 6.4 inches, thickness = 0.08 inch, total notch length = 0.12 inch.

(6) Chemical Composition: Not specified.

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi	Elong., %
2024-T3	52.8	68.7	18.9

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 121

Materials: 2024-T3.

Schijve, J.; Nederveen, A.; and Jacobs, F. A.: The Effect of the Sheet Width on the Fatigue Crack Propagation in 2024-T3 Alclad Material. NLR-TR M.2142, Reports and Transactions, National Aero- and Astronautical Research Institute, 1965, pp. 99-112.

Test Information

(1) Fatigue Crack Propagation Tests: Aluminum alloy sheet specimens in several widths were studied to determine the effect of size on crack propagation.

(2) Type of Test Machine: Amsler hydraulic pulsator (50 ton capacity).

(3) Number of Specimens: 40/2024-T3.

(4) Stress Ratio: R = 0.1, 0.33, or 0.52.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 250 cpm (4.2 Hz).

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were cut from 0.125 inch alclad sheet: Sharp central notches were made by drilling a hole and slotting.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions:

Width, inches	Length, inches
23.6	63.2
11.8	30.32
6.3	16.48
6.3	14.68
6.3	13.44
3.15	9.44

(6) Chemical Composition:

2024-T3, wt. %

Cu	Mg	Mn	Al
4.5	1.5	0.6	Remainder

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi	Elong., %
2024-T3	50.9	68.0	16.5

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 122

Materials: Ti-4Al-3Mo-1V, Ti-6Al-4V (A), Ti-8Al-1Mo-1V, AM 350, PH 14-8Mo, PH 15-7Mo, AISI 301, Rene 41

Hudson, C. M.: Fatigue-Crack Propagation in Several Titanium and Stainless-Steel Alloys and One Superalloy. NASA TN D-2331, 1964.

Test Information

(1) Fatigue-Crack Propagation Tests: Tests were conducted on several materials at three temperatures to determine the crack propagation characteristics of each material.

(2) Type of Test Machine: Subresonant, hydraulic, or combination hydraulic and subresonant.

(3) Number of Specimens: 5/Ti-6Al-4V at room temperature and 550 F. See report for others.

(4) Stress Ratio: R = 0 to 0.85.

(5) Test Temperature and Environment: Tests were conducted at room temperature, 550 F or -109 F in air.

(6) Test Frequency: 1800 cpm, 1200 cpm, 50 cpm, or 820 cpm depending upon machine used (not specified what machine was used for each test).

Specimen Data

(1) Melting Practice/Heat Treatment: The Ti-6Al-4V material was mill annealed (1475 F/1 hour; furnace cooled to 1300 F; air cooled). See report for heat treatment of other alloys.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were fabricated with the longitudinal axis parallel to the grain of the sheet. Protective tape was used prior to shearing to insure unmarred surfaces. A central notch was cut by electrical discharge technique.

(4) Surface Finish: Surfaces were chemically cleaned.

(5) Specimen Dimensions: Length = 24 inches; width = 8 inches; thickness = 0.024, 0.040, or 0.050 inch; notch length = 0.1 inch.

(6) Chemical Composition: Nominal compositions only were given.

(7) Tensile Properties:

Material	Temperature, F	TYS, ksi	TUS, ksi	Elong., %	E, 10^3 ksi
Ti-6Al-4V	-109	163.0	170.8	13.2	17.4
Ti-6Al-4V	70	137.3	144.4	12.5	16.4
Ti-6Al-4V	550	96.7	109.1	7.5	14.4

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 124

Materials: 4330 M, 4340, D6AC, H-11, 4130, 300M, 18 Ni, 301, 304L, 410, 10, 17-4PH, Ph 14-8Mo, AM350, AM355, Inco 718, Inco X750, A286, 2014, 2024(A-F), 2618, X7002, 7075(G-H), 7079, 7178, 5086, Ti-6Al-4V, Ti-6Al-6V-2Sn, Ti-7Al-4Mo, Ti-8Al-1Mo-1V, 18-7-5, 18-9-5, HP150, 9Ni-4Co-.30C, 9Ni-4Co-.43C

Smith, S. H.; and Liu, A. F.: Fracture Mechanics Application to Materials Evaluation and Selection for Aircraft Structure and Fracture Analysis. D6-17756.

Test Information

(1) Fracture Tests: The report contains a discussion of the stress intensity factor and its relation to fracture toughness properties, basic mechanics of crack growth, test specimen configurations, and the use of fracture toughness data in estimating crack instability of fatigue cracked structure. Tabulated data was extracted from structural test laboratory reports and additional Boeing reports.

(2) Type of Test Machine: Not specified.

(3) Number of Specimens: Approximately 400/2024 and 200/7075. See report for others.

(4) Stress Ratio: Not specified.

(5) Test Temperature and Environment: Tests were conducted from -320 F to 550 F in air.

(6) Test Frequency: Not specified.

Specimen Data

(1) Melting Practice/Heat Treatment: Final condition only is specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Not specified unless special procedures are noted for specimen.

(4) Surface Finish: See individual specimens.

(5) Specimen Dimensions: Specimens used were surface flaw, center-notched panels, or double edge notched panels. See individual specimens for dimensions.

(6) Chemical Composition: Not specified.

(7) Tensile Properties: See individual specimens.

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 125

Material: Ti-6Al-4V

Feddersen, C. E.; and Hyler, W. S.: Fracture and Fatigue-Crack-Propagation Characteristics of 1/4-in. Mill-Annealed Ti-6Al-4V Titanium Alloy Plate. Report No. G-9706, Battelle's Columbus Laboratories, 1971.

Test Information

(1) Fracture and Fatigue-Crack Propagation Tests: Tests were conducted to determine the influence of crack aspect ratio on the fracture strength of three panel widths and to evaluate the fatigue-crack propagation rates for various maximum stresses, stress ratios and panel widths.

(2) Type of Test Machine: Servocontrolled electrohydraulic testing system (50, 130, or 500-kip capacity).

(3) Number of Specimens: 15 fracture and 24 fatigue-crack propagation/Ti-6Al-4V.

(4) Stress Ratio: R = 0.1, 0.4, or 0.7.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 1 to 25 Hz.

(7) FCP Data: Data is presented in basic form.

Specimen Data

(1) Melting Practice/Heat Treatment: The Ti-6Al-4V material was purchased in the mill-annealed condition.

(2) Ductility: Not specified.

(3) Fabrication Methods: Material was received as sheared rectangular blanks. A central, diamond-shaped notch was made by the EDM process.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Length = 32, 48, 60, or 72 inches, width = 9.6, 16, 18, or 32 inches, notch length = 0.5 inch, notch width = 0.25 inch, thickness = 0.25 inch.

(6) Chemical Composition:

Ti-6Al-4V, wt. %

C	N	Fe	Al	V	O	H (ppm)
0.02	0.01	0.18	6.4	4.2	0.127	81

(7) Tensile Properties:

Material	Lot No.	TYS, ksi	TUS, ksi	Elong., %	R.A., %
Ti-6Al-4V	1	128.7	137.0	15.3	33.7
Ti-6Al-4V	2	130.2	136.6	14.2	32.7
Ti-6Al-4V	3	130.8	136.5	15.7	37.8

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 126

Material: Ti-6Al-4V

Feddersen, C. E.; Porfilio, T. L.; Rice, R. C.; and Hyler, W. S.: Part-Through-Crack Behavior in Three Thicknesses of Mill-Annealed Ti-6Al-4V. Report No. G-1384, Battelle's Columbus Laboratories, 1972.

Test Information

(1) Fracture and Fatigue-Crack-Propagation Tests: Tests were conducted to determine the influence of crack aspect ratio on the fracture strength of three plate thicknesses and to evaluate the influence of periodic overloads on the observed fatigue-crack-propagation rates for three different stress ratios.

(2) Type of Test Machine: Servocontrolled, electrohydraulic testing system (130 and 500 kip capacity).

(3) Number of Specimens: 19 fatigue-crack propagation, 6 fatigue-crack propagation with overloads and 42 fracture/Ti-6Al-4V.

(4) Stress Ratios: -0.3, 0.1, 0.5.

(5) Test Temperature and Environment: Tests were conducted at room temperature in air.

(6) Test Frequency: 3 - 25 Hz.

(7) FCP Data: Data are presented in basic form.

Specimen Data

(1) Melting Practice/Heat Treatment: The Ti-6Al-4V material was purchased in the mill-annealed condition.

(2) Ductility: Not specified.

(3) Fabrication Methods: Material was received as rectangular blanks. The specimens were prepared by milling the reduced section and drilling the appropriate hole patterns for gripping. A semicircular shaped starter notch (0.050-inch deep by 0.010-inch thick) was put in most specimens using an electrical-discharge machine.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Length = 32 inches; width = 6 inches; thickness = 0.25, 0.50, or 1.00 inch.

REFERENCE NUMBER 127

Material: 7075-T6, 7178-T6

Hudson, C. M.; and Newman, J. C., Jr.: Effect of Specimen Thickness on Fatigue-Crack Growth Behavior and Fracture Toughness of 7075-T6 and 7178-T6 Aluminum Alloys. NASA TN D-7173, 1973.

Test Information

(1) Fatigue-Crack-Propagation Tests: A study was made to determine the effects of specimen thickness on fatigue-crack growth and fracture behavior of 7075-T6 and 7178-T6 aluminum-alloy sheet and plate. Specimen thicknesses ranged from 0.20 to 0.50 inch for 7075-T6 and from 0.05 to 0.25 for 7178-T6.

(2) Type of Test Machine: Three machines were used. The first was a 20,000-pound-capacity subresonant machine; the second was a 300,000-pound-capacity hydraulic system; and the third was a 105,000-pound-capacity combination subresonance-hydraulic unit.

(3) Number of Specimens: Fatigue-crack-propagation - 26/7075-T6, 22/7178-T6; Fracture toughness - 29/7075-T6, 17/7178-T6.

(4) Stress Ratio: R = 0.02 and 0.50.

(5) Test Temperature and Environment: Tests were conducted at room temperature in laboratory air.

(6) Test Frequency: For fatigue-crack-propagation tests, different frequencies were used for different tests, ragning from 60 to 840 cpm. The specific frequency of each test is indicated.

(7) FCP data are presented in basic form.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Center-crack specimens were cut with the longitudinal axis parallel to the rolling direction of the various material plates. An EDM processed notch, 0.10 inch long by 0.01 inch wide, was cut in the center of each specimen.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Length = 35.0 inches; width = 11.5 inches; Thickness = 0.05 to 0.50.

REFERENCE NUMBER 127 (Continued)

(6) Chemical Composition:

Alloy	Thickness, inch	Si	Fe	Cu	Mn	Mg	Cr	Zn	Al
		Weight, %							
7075-T6	0.20	0.11	0.28	1.72	0.13	2.74	2.74	5.63	Bal.
	0.38	0.11	0.25	1.69	0.07	2.51	2.51	5.70	Bal.
	0.50	0.11	0.28	1.72	0.13	2.74	2.74	5.63	Bal.
7178-T6	0.05	0.11	0.28	1.76	0.05	2.64	2.64	6.97	Bal.
	0.16	0.08	0.28	2.06	0.07	2.99	2.99	6.86	Bal.
	0.25	0.08	0.28	2.06	0.07	2.99	2.99	6.86	Bal.

(7) Tensile Properties:

Alloy	Thickness, inch	TYS, ksi	TUS, ksi	Elongation, percent	E, psi x 10^6	No. of Tests
7075-T6	0.20	78.6	86.3	13.0	10.0	6
	0.38	76.6	83.3	12.6	10.1	6
	0.50	79.9	86.7	15.5	10.1	6
7178-T6	0.05	81.8	88.2	12.7	9.7	3
	0.16	85.0	90.5	12.8	10.0	6
	0.25	86.0	90.2	13.0	10.1	6

(8) Stress-Strain Curves: Not given.

REFERENCE NUMBER 128

Material: 2024-T3

Carter, T. J.: Crack Propagation Tests on 2024-T3 Unstiffened Aluminum Alloy Panels of Various Length-Width Ratios. C. P. No. 952, Aeronautical Research Council, British Ministry of Technology, 1967.

Test Information

(1) Fatigue-Crack-Propagation Tests: Panels of 2024-T3 clad material of one width and four lengths were tested under constant amplitude tensile fatigue loads. A range of tensile loads were employed.

(2) Type of Test Machine: An Avery Schenk Long-Base 20,000-pound-capacity machine.

(3) Number of Specimens: 35/2024-T3.

(4) Stress Ratio: R = 0.11.

(5) Test Temperature and Environment: Tests were conducted at room temperature in laboratory air.

(6) Test Frequency: Not specified.

(7) Basic FCP data given in tabular form.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Specimens were cut from 4 x 8 foot sheets of 0.08-inch-thick sheet material. All specimens were center notched with a 0.5-inch saw cut.

(4) Surface Finish: Not specified.

(5) Specimen Dimensions: Width = 10 inches; Length = 10, 20, 30, and 40 inches; Thickness = 0.08 inch.

(6) Chemical Composition:

Material Element	Cu	Mg	Mn	Fe	Si	Cr	Zn	Al
Core	4.9	1.8	0.9	0.50	0.50	0.10	0.25	Remainder
Cladding	0.1	--	0.50	--	0.70	--	0.10	Remainder

(7) Tensile Properties:

Material	TYS, ksi	TUS, ksi	Elongation, %
2024-T3	40	62	15

REFERENCE NUMBER 129

Material: 2024-T4, 7075-T6, 4340, Ti-8Al-1Mo-1V

Ende, T.; and Morrow, JoDean: Monotonic and Completely Reversed Cyclic Stress-Strain and Fatigue Behavior of Representative Aircraft Metals. Report No. NAEC-ASL-1105, Dept. of Theoretical and Applied Mechanics, University of Illinois, Urbana, June, 1966.

Test Information

(1) Fatigue Tests: Cyclic stress-strain and low-cycle fatigue data were experimentally developed for four metals used in aircraft structures.

(2) Type of Test Machine: An open-loop limit controlled, 10,000-pound-capacity system.

(3) Number of Specimens: 38/2024-T4, 36/7075-T6, 38/4340, and 24/Ti-8Al-1Mo-1V.

(4) Stress Ratios: R = - 1.0 .

(5) Test Temperature and Environment: Tests were conducted at room temperature in laboratory air.

(6) Test Frequency: From approximately .25 cpm for very low cycle tests to about 15 cpm for high cycle tests. Strain rate was controlled at either 0.05 or 0.20 $min.^{-1}$.

Specimen Data

(1) Melting Practice/Heat Treatment: The 4340 material was obtained in quenched and tempered rod form, and the titanium material was obtained in duplex annealed rod form.

(2) Ductility:

Material	True Fracture Ductility, ϵ_f
2024-T4	0.43
7075-T6	0.41
4340	0.84
Ti-8Al-1Mo-1V	0.66

(3) Fabrication Methods: Round, 3/4-inch gauge length, and hour glass specimens were machined from round bar material. The test section on all specimens was made 1/4-inch in diameter and the 5/8-inch ends were machined with 18 threads per inch.

(4) Surface Finish: Specimens were mechanically polished with 3 successively finer grades of emery paper. Final surface roughness values not specified.

REFERENCE NUMBER 129 (Continued)

(5) Specimen Dimensions: Standard specimens - 5.2 inches long, 5/8-inch diameter, threaded ends, 3/4-inch long, 1/4-inch diameter test section; hourglass specimens - 4.35 inches long, 5/8-inch diameter threaded ends, 1-inch radius of curvature, 1/4-inch diameter test section.

(6) Chemical Composition:

Alloy	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
				Weight, %					
2024-T4	0.50	0.50	4.3	0.60	1.5	0.1	0.25	--	Bal.
7075-T6	0.50	0.70	1.6	0.30	2.5	0.3	5.5	0.2	Bal.

	C	Mn	P	S	Si	Cr	Ni	Mo	Cu	Fe
4340	.43	.71	.01	.01	.24	.86	1.79	.27	.09	Bal.

	Al	Mo	V	C	N	Fe	O	H	Ti
Ti-8Al-1Mo-1V	7.9	1.0	1.1	.02	.01	.06	.09	.01	Bal.

(7) Tensile Properties:

Alloy	TYS, ksi	TUS, ksi	R.A., %	E, ksi
2024-T4	44	69	35	10,200
7075-T6	68	84	33	10,300
4340	171	180	57	28,000
Ti-8Al-1Mo-1V	146	148	48	17,000

(8) Stress-Strain Curves: Not given, but stress change versus cycles for different strain ranges is plotted.

REFERENCE NUMBER 130

Material: 2024-T3, 7075-T6

Anon: Unpublished Low-Cycle Fatigue and Cyclic Stress-Strain Data on 2024-T3 and 7075-T6 Sheet Material. Battelle's Columbus Laboratories, 1973.

Test Information

(1) Fatigue Tests: Tests were conducted to develop additional low-cycle fatigue information on two aluminum sheet materials.

(2) Type of Test Machine: Servocontrolled, electrohydraulic testing system (20 kip capacity).

(3) Number of Specimens: cyclic stress-strain - 3/2024-T3 and 3/7075-T6; low-cycle fatigue - 7/2024-T3 and 7/7075-T6.

(4) Stress Ratio: Strain ratio was controlled at values of - 1.0, 0.0, and 0.5.

(5) Test Temperature and Environment: Tests were conducted at room temperature in laboratory air.

(6) Test Frequency: Strain rate was held constant at 4×10^{-3} sec^{-1}.

Specimen Data

(1) Melting Practice/Heat Treatment: Not specified.

(2) Ductility: Not specified.

(3) Fabrication Methods: Reduced-section, 0.08-inch-thick flat plate specimens were machined with a 0.500-inch-gauge length.

(4) Surface Finish: Specimen edges and corners polished to remove any grinding marks.

(5) Specimen Dimensions: Length = 7.25 inches; End Section Width = 2.00 inches; Radius of Curvature into Test Section = 1.00 inch; Reduced Section (½-inch wide) length = 0.600 inch.

(6) Chemical Composition: Not given.

(7) Tensile Properties: Not given.

(8) Stress-Strain Curves: Given for both cyclic and monotonic material response.

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