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STRUCTURAL TAILORING OF ADVANCED TURBOPROPS (STAT)

User's Manual

K. W. Brown

United Technologies Corporation
Pratt & Whitney
400 Main Street
East Hartford, Connecticut 06108

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Preface

The result of the Structural Tailoring of Advanced Turboprops (STAT) program is a computer code that aids the design and development of single rotation and counter rotation propfans through the application of automated design optimization procedures to the propfan design process. This User's Manual contains instructions and a demonstration case to allow the user to prepare input data, execute the program, and review the results of the STAT computer code. The STAT computer code ties together all of the disciplines required for a propfan design, including aerodynamic, acoustic, forced response, vibrations, stress, and flutter analysis capabilities. An optimizer guides the code to make intelligent design selections.

The STAT program was managed by D. Hopkins of NASA Lewis Research Center, and was a joint project of Pratt & Whitney and Hamilton Standard, divisions of United Technologies. Documentation of the STAT effort includes a Final Report, this User's Manual, a Theoretical Manual, and a Programmer's Manual.

Table of Contents

STAT Input Overview

The STAT computer program is used to optimize the design of a single rotation propfan (SRP) or a counter rotation propfan (CRP). An initial propfan design is defined to the STAT program through an input file. The ADS (Automated Design Synthesis) program is then used by STAT to tailor the prop internal and/or external geometry to obtain an optimal design. The user supplies geometric attributes (called variables) such as blade tilt and twist which are modified in the analysis until the optimal values of these variables are found.

The purpose of this user's manual is to describe the format of the STAT input file. All input is supplied to STAT in a "named card" format where cards are broken down into 10 fields of 8 characters each. (Exceptions to this are noted in the manual.) A given card is identified by a mnemonic name in the first field and data specific to that card is supplied in fields 2 through 9. The 10th field is used to specify a continuation character string. This character string is repeated in the first field of the next card and the card is continued in fields 2 through 9. At any location in the input file (except before a continuation card) a comment card can be inserted into the file by placing a $ in column 1. (The $$PARM card in section 5 is another exception.)

The input file is made up of 5 sections which must appear in consecutive order. An end card is specifed for each of these sections as follows:

Section	End card
1	*END_OPT
2	*END_EFF
3	*END_OBJ
4	*END_GEN

The 5th section contains the finite element directives and must have a block of cards between BEGIN BULK and ENDDATA for each propfan in the design. (One block for SRP and 2 blocks for CRP). Each section has a set of named cards which are used to describe the optimization problem. The order in which cards appear within a given section is not important. Each input section is covered in a chapter in this manual with complete descriptions of the cards appropriate to that section. The input is supplied in english units.

A summary of the 5 input sections follows:

Section 1 - Optimization Input
Defines the initial propfan geometry and specifies the optimization problem.

Section 2 - Blade Geometry and Analysis Control
Defines the airfoil shape and operating conditions.

Section 3 - Objective Function
Defines the optimization objective.

Section 4 - Geometry Generation Data
Defines the finite element breakup used.

Section 5 - Finite Element Program Control
Finite element control cards and additional bulk data.

STAT Design Curves

To fully define both stages of a counter rotation propfan, and then update the rotor design definitions, requires a prodigious amount of data. To organize and simplify the data definition and alteration process, the STAT system arranges the data into "design curves." Within a design curve, one aspect of the geometry definition, airfoil thickness, for example, is defined as a function of an abscissa, in this case non-dimensional radius, via tabular inputs. These tabular inputs are transformed into smooth, continuous functions via splines, so that the blade design is available at any arbitrary abscissa value via interpolation.

These data curves are used for data definition wherever possible throughout the STAT optimization system. The airfoil external geometry is defined through thickness/chord, chord/diameter, section cone angles, twist angle, etc. versus radius/tip radius curves. Composite constructions, when employed, are also designated via design curves. These design definition curves are defined in Section 1 - Optimization Input of this manual. Table 3 details those curves required to define a propfan external geometry. Additionally, for composite blades, the lay-up definitions listed in Table 4 are required.

To provide for design updates during a blade optimization, the blade definitions must be allowed to change. This is accomplished in STAT by temporarily perturbing the original, or base, design curves. To provide for power and generality, yet economy, STAT allows the user to select those curves, and those locations on the curves, that he wants parameters to vary during an optimization.

The user designates the curves which are to vary, and the number of design variables to be ascribed to those curves, through VARIABLE definitions, in Section 1 of this manual. Thus, a design VARIABLE allows a selected curve to vary at a specific abscissa location. In the STAT scheme, all design variables are increments from the original design. Thus, a design change of 0.0 mirrors the original design. If a value or values on a curve changes, the increments are splined, and added to the base curve. Thus, if a design variable changes, the entire updated curve reflects the design change. Further control over the updates that are included in a design are obtained through CONSTANT and DEPEND definitions. A CONSTANT card designates a value on a curve that will not change as the design is updated. A DEPEND card defines a proportional relation between a value on a curve and another value on that curve.

Further details on the STAT usage of design curves are included in the STAT Theoretical Manual (Reference 1).

Section 1 - Optimization Input

This section describes the input cards required to setup the optimization problem and define the initial propfan geometry. All cards are easily recognized by the assigned mnemonic name.

Rear blade descriptors (R suffix) are required only if a counter rotation propfan (CRP) analysis is desired. If a rear blade is to be defined, a full set of descriptors is required. If analyzing a single rotation propfan (SRP), omit all rear blade descriptors.

The following cards are explained in this section:

Card Title	Description
ABSCISSA	defines the independent axis terms, such as percent of span.
CONSTANT	locations and values of dependent axis values which are to be held constant.
CONSTRNT	defines constraints for the optimizer.
CURVE	defines the dependent axis values on a referenced ABSCISSA.
CUTOFF	provides an upper and lower ABSCISSA limit for each CURVE.
DEBUG	optional diagnostics from analysis modules
DEPEND	links a dependent variable to a design variable.
LAY-UP LAY-UPR	defines the layer order for front and rear composite blades.
MATERIAL	material properties for composite layers.
OPTIMIZE	sets up the optimization strategy and procedure.

continued...

Card Title	Description
PLOT	optional plotted output
PRIORITY PRIORITR	sets the layer thickness allocation hierarchy for front and rear composite blades.
VARIABLE	defines a design variable.
*END_OPT	signals end of Section 1 input.

Each card definition will be preceded by a short explanation of the card's purpose and utilization.

The following Tables are included in Section 1:

Table	Title
1	Library of Constraint Equations
2	Calculated Terms Storage Locations and Descriptions
3	REQUIRED Names, Initial Geometry
4	REQUIRED Names, Composite Layup Control

Data Card Format:

1. All continuation cards must follow the parent card. Continuation is designated via any alphanumeric input in field -10- of the previous card. All continuation cards must follow the parent card in proper order.
2. All input is currently input in free field format within the specified 8 column field, except where specifically stated otherwise.
3. A $ in column 1 indicates a comment card for any data input section. The card will be ignored. The only exception to this is the $$PARAM card used for analysis control in the bulk data section.

OPTIMIZATION CONTROL CARD CROSS REFERENCES:

Within the optimization control, only the OPTIMIZE, ABSCISSA, and CONSTRNT cards are completely independent of other card sets. A CURVE card, for instance, must reference an ABSCISSA to provide an x-axis definition to properly describe a curve. Other card cross reference requirements are listed below.

```
MOST INDEPENDENT                                  MOST DEPENDENT

OPTIMIZE
                 CURVE          VARIABLE   --->   DEPEND
ABSCISSA   --->          --->
                 CUTOFF         CONSTANT
CONSTRNT
```

Thus, a curve card must reference an abscissa. To alter a curve, a variable may be defined, with reference to that curve. On that curve, other abscissa locations may be held CONSTANT, or vary in proportion to a defined variable according to a DEPEND relationship.

In composite materials, the dependency chain is:

```
MOST INDEPENDENT                                  MOST DEPENDENT

LAY-UP       --->        MATERIAL       --->       PRIORITY
```

Thus, the usage of a composite is prescribed on the LAY-UP card. Any composite that is used must be defined as a MATERIAL. The extent of use of the composite ply is determined by its PRIORITY.

GENERAL RULES FOR SECTION 1:

1. Sections 1 thru 5 input must be in sequential order.

2. The end of Section 1 input is signaled by the *END_OPT card.

3. Pay particular attention when REQUIRED names (found in Tables 3 and 4) are requested.

4. A comment card must not precede a continuation card.

ABSCISSA

The ABSCISSA card defines points on an independent axis such as percent span. The user may specify up to 20 points using continuation cards. The ABSCISSA identification number is referenced by the CURVE card.

```
field locations..
   -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
ABSCISSA  NAME     ID#      AB1      AB2      AB3      AB4      AB5      AB6
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
ABSCISSA     ROR        1     .239    .2905    .3611    .4547    .5630    .6762

continuation card(s)...
   -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
+ABS1     AB7      AB8      AB9      AB10     AB11     AB12     AB13     AB14
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
+           .7845    .8780    .9486    1.000
```

field	Format	Name	Description
-1-	alpha	ABSCISSA	mnemonic card name = ABSCISSA
-2-	alpha	NAME	required name for external geometry, and a mnemonic name for all others. (reference TABLE 3)
-3-	integer	ID#	independent axis identification number
-4- thru -9-	real	AB(1) thru AB(6)	values on axis
-10-	alpha	CONT	continuation designation - any alpha-numeric input is acceptable - a blank field signals end of abscissa input

notes:

1) The continuation card(s), if needed, may have input in -2- thru -9-. Field 10, if filled, designates another continuation card follows.

2) Abscissa ID numbers must start at 1 and be consecutive.

CONSTANT

The CONSTANT card defines points on the CURVE card which are held fixed during the optimization. The CONSTANT card references a CURVE card, to specify which value to hold constant. By having VARIABLE cards and CONSTANT cards referencing the same curve, it is possible to alter the design changes made on that particular curve.

```
field locations..
  -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
CONSTANT  NAME    ICURV     LOC     VALUE
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
CONSTANT      T/B       1      .25     .125
```

field	Format	Name	Description
-1-	alpha	CONSTANT	card name = CONSTANT
-2-	alpha	NAME	mnemonic name for CONSTANT type
-3-	integer	ICURV	CURVE card identification number
-4-	real	LOC	location on ABSCISSA referenced by CURVE (ICURV) (fraction of span)
-5-	real * 16	VALUE	delta value added to the input curve at the specified ABSCISSA location... default is zero (length 16)

notes:

1) If a design curve is to be modified, a minimum of 3 VARIABLE, CONSTANT, and/or DEPEND locations must reference that curve.

CONSTRNT

The CONSTRNT cards define the constraints for the optimization program. A constraint compares a value calculated during a function call, such as stress, with an allowable value. This comparison is accomplished by using these values in a specified equation form. Each CONSTRNT card defines the form of the constraint equation, and the terms to be used in the equation. The function call generated terms are stored in an array and referenced by array location (see TABLE 2).The constraint equation forms are listed in TABLE 1. The CONSTRNT card must have a continuation card.

```
field locations.. card 1 ..
  -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
CONSTRNT  NAME    FACTOR   IFORM    ITYPE   ITERM1   ITERM2   ITERM3   ITERM4
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
CONSTRNT    POWER   .95691        2        0       33
```

card 1

field	Format	Name	Description
-1-	alpha	CONSTRNT	card type = CONSTRNT
-2-	alpha	NAME	mnemonic name of constraint
-3-	real	FACTOR	multiplication factor applied to TERMS for analysis calibration (default = 1.0)
-4-	integer	IFORM	equation form of constraint (reference TABLE 1)
-5-	integer	ITYPE	0 = nonlinear inequality constraint 2 = linear inequality constraint -1 = nonlinear equality constraint
-6- thru -9-	integer	ITERM1 thru ITERM4	location of function call generated terms in storage array - reference Table 2
-10-	alpha	CONT	continuation specification - leave blank to end card

CONSTRNT (continuation card)

```
field locations..
  -1-       -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
 -cont-    VAL1     VAL2     VAL3     VAL4     VAL5     VAL6     VAL7     VAL8
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
+          2589.4
```

card 2

field	Format	Name	Description
-1-	alpha	CONT	continuation designation
-2- thru -9-	real	VAL1 -thru- VAL8	values needed to formulate constraint equations listed in TABLE 1

notes:

1. The continuation card is required.
2. Refer to TABLES 1 and 2 to properly set up constraint equations.
3. IFORM is not used when ITYPE = -1 (equality constraint).
4. Current constraint forms use at most two ITERMS and three VALS inputs. The CONSTRNT card definition allows for future, more complicated constraint forms, with up to four ITERMS and eight VALS.

CURVE

The CURVE card inputs a dependent axis term for each independent axis term found on the referenced ABSCISSA card. Each CURVE usually has a unique identification number and a unique name for cross referencing. The name field will contain a REQUIRED name found in Table 3 if defining intial blade external geometry. If the internal layup geometry of a composite blade is being defined then the name contains two parts, a prefix to logically group cards and a REQUIRED suffix (Table 4) to differentiate cards within any layer group. Rule exceptions are explained in note 3.

```
field locations..
  -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
CURVE    NAME     IAB#    ICURV    CUR1     CUR2     CUR3     CUR4     CUR5
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
CURVE         HOB       1       1   .2135   .1180   .0775   .0512   .0370

continuation card(s)..
  -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
+CURV1   CUR6     CUR7     CUR8     CUR9    CUR10    CUR11  ------->
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
+          .0280   .0233   .0212   .0203  .01955
```

field	Format	Name	Description
-1-	alpha	CURVE	card type name = CURVE
-2-	alpha	NAME	mnemonic name(prefix and suffix) or REQUIRED name depending on use - refer to notes 1 and 2
-3-	integer	IAB#	ABSCISSA identification number
-4-	integer	ICURV	CURVE identification number
-5- thru -9-	real	CUR1 -thru- CUR5	CURVE values
-10-	alpha	CONT	continuation designation - leave blank to end card input (see note #4)

Notes for the CURVE card:

1. The NAME field serves two purposes depending on use:
   a. If defining the initial blade external geometry the REQUIRED name must be found in Table 3.

   b. If defining a composite layer geometry the name has two parts; a prefix and a suffix.
      1. The prefix must be unique and may contain 5 characters. The prefix logically groups CURVE cards defining parts of the same layer.
      2. The suffix REQUIRED part logically differentiates common layer CURVE cards (see note #2). The REQUIRED suffixes are found in Table 4.

2. The suffix REQUIRED name for composite definition may be one of t he following;
   - ML -- meanline location vs. span,
   - C/S -- %chord vs. span, (layer chord is divided by the meanline),
   - T/S -- thickness vs. span.

   The suffix is right justified to column 16. The prefix must match a material name. For a given prefix name, ML and C/S curves must reference the same abscissa curve (field 3).

3. The CURVE ID (field 4) will usually be unique from all other CURVE or CUTOFF cards. Using the same ID# for two different CURVES would produce coincident curve values. This can be useful for composite layers which begin and end together. See SECTION 6, Special Applications, for examples of such input. (see note 6)

4. The continuation card(s), if needed, may have input in fields -2- thru -9-. Field 10, if filled, designates another continuation card is to follow.

5. The maximum number of points allowed on a CURVE definition is 20.

6. CURVE ID numbers must be sequential and begin with the number 1. (The exception is for CURVES with the same ID, see note 3)

CUTOFF

The CUTOFF card provides an upper and lower ABSCISSA limit for a CURVE. Ordinate values beyond these upper and lower ABSCISSA limits are zero. The CUTOFF card references a C/S CURVE, but has its own ID for VARIABLE cross reference. If a CURVE does not have a companion CUTOFF card, the CURVE will be applied over the entire abscissa.

```
field locations..
  -1-     -2-      -3-     -4-     -5-      -6-      -7-      -8-      -9-
CUTOFF    NAME    CID#    ICURV   VAL1
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
CUTOFF  SHEA    L      19      15      .50
```

field	Format	Name	Description
-1-	alpha	CUTOFF	card type name = CUTOFF
-2-	alpha	NAME	prefix - mnemonic name (up to 5 cols) suffix - last column (REQUIRED name) - U-upper , L-lower
-3-	integer	CID#	CUTOFF identification number (refer to note 2)
-4-	integer	ICURV	CURVE identification number (must be a C/S curve)
-5- thru -9-	real	VAL1	value of ABSCISSA limit for CURVE

Notes:

1. The NAME input (field 2) must contain two parts, a prefix and a suffix. The prefix is any mnemonic name, but it is recommended this match the companion CURVE card prefix NAME. The suffix is a REQUIRED name which specifies whether the CUTOFF is an upper, U, or lower, L, ABSCISSA limit (refer to Table 4 for REQUIRED names).

2. The CUTOFF identification number, field 3, will usually be unique from all other CURVE and CUTOFF cards. Using the same ID# would produce coincident CUTOFF values. See SECTION 6, Special Applications, for examples of such input. (see note 3)

3. CUTOFF ID numbers must be greater than the total number of defined CURVEs.

DEBUG

The DEBUG card allows the user to request extra output from any of the STAT analysis modules. Data format for this card is: (A8,10I4). This data format allows input of all 10 DEBUG data items on a single card. A value of 0 (default) for a term of the IDEBUG array requests no added module output. A value of 1 requests extra output (this can create a very large output file if an optimization is in progress).

```
field locations..        (Note: After DEBUG field, use I4 format)
  -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
DEBUG    IDEBUG
           (1) (2) (3) (4) (5) (6) (7) (8) (9)(10)
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
DEBUG        0   0   0   0   1   0   0   0   0   0
```

field	Format	Name	Description
-1-	alpha	DEBUG	card mnemonic name = DEBUG
-2a-	I4	IDEBUG(1)	Extra output request, aerodynamic efficiency module
-2b-	I4	IDEBUG(2)	Extra output request, acoustic analysis module
-3a-	I4	IDEBUG(3)	Extra output request, one-p forced response analysis
-3b-	I4	IDEBUG(4)	Extra output request, airfoil geometry generator
-4a-	I4	IDEBUG(5)	Extra output request, finite element analysis module
-4b-	I4	IDEBUG(6)	This field not currently used.
-5a-	I4	IDEBUG(7)	This field not currently used.
-5b-	I4	IDEBUG(8)	Extra output request, flutter module
-6a-	I4	IDEBUG(9)	Extra output request, objective function module
-6b-	I4	IDEBUG(10)	Extra output request, cold to hot geometry update module

Notes:

1. For this card, data items are entered in fields of 4 rather than the usual fields of 8.

DEPEND

The DEPEND card defines points on the CURVE card which are dependent upon a specified VARIABLE. The DEPEND card allows the user to alter CURVE values without defining another independent design variable. A constant multiplier is permitted.

```
field locations..
  -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
DEPEND   NAME    VID#     LOC     CONST
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
DEPEND   TIPTOB          1      1.0      .10
```

field	Format	Name	Description
-1-	alpha	DEPEND	card name = DEPEND
-2-	alpha	NAME	mnemonic name for DEPEND type
-3-	integer	VID#	VARIABLE card identification number
-4-	real	LOC	location on the ABSCISSA referenced by VARIABLE thru the CURVE cards
-5-	real	CONST	value assigned to VARIABLE value multiplier. (default = 1.0).

Notes:

1. A total of 50 dependent variables is currently allowed.
2. If a design curve is to be modified,.a minimum of 3 DEPEND, CONSTANT and/or VARIABLE cards must reference that curve.

LAY-UP, LAY-UPR

The LAY-UP and LAY-UPR cards defines the composite material construction order. This card is required for any blade that has a laminated construction. The mnemonic names (prefix part) specified on the CURVE cards are used as the layer identifiers. Since all laminated blades must be midplane symmetric it is necessary to input layers on one side starting at the surface and progressing inward to the geometric midplane.

The LAY-UPR card is identical in format to the LAY-UP card, and is required if a CRP analysis is desired.

```
field locations..
  -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
LAY-UP   NAME1    NAME2    NAME3    . . . . . . . . . . . . . . . . . . . NAME8
1.......1.......1.......1.......1.......1.......1.......1.......1.......1.......1
LAY-UP      SHEA     SHEL     FOAM     SPAR
```

field	Format	Name	Description
-1-	alpha	LAY-UP	Card mnemonic name = LAY-UP
-2- thru -9-	alpha	NAME1 -thru- NAME8	MATERIAL names listed from surface to the geometric midplane
-10-	alpha	CONT	continuation specification - leave blank to end card

Notes:

1. Continuation cards have NAME(i) data in fields 2 thru 9, field 10 remains the continuation flag.
2. The NAME(i) values are the mnemonic indicators from the MATERIAL cards.
3. Using the above example card, the layer order would be as follows ;

```
surface ---------------- midplane----------------surface
Sheath ...... Shell ..... Spar ...... Shell ..... Sheath
```

4. The maximum number of layers allowed is 19.

MATERIAL

The MATERIAL card defines the material properties for a composite material. In addition the material orientation and material strengths are included. The lamina material properties are defined parallel and perpendicular to the fiber direction. The material strength values are used in the Tsai-Wu strength evaluation. The MATERIAL input occupies three cards and is required for each composite lamina.

```
field locations... card#1
  -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
MATERIAL  NAME     E11      E22      V12      G12      RHO      ANG
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
MATERIAL     SHEA 30.E+06 30.E+06    .2712 11.8E+6     .32      0.0
```

field	Format	Name	Description
-1-	alpha	MATERIAL	card mnemonic name = MATERIAL
-2-	alpha	NAME	CURVE "prefix" name for this lamina (5 character maximum length)
-3-	real	E11	modulus in fiber direction (psi)
-4-	real	E22	modulus in perpendicular to fiber direction (psi)
-5-	real	V12	inplane Poisson's ratio
-6-	real	G12	inplane shear modulus (psi)
-7-	real	RHO	density (lb / in**3)
-8-	real	ANG	orientation angle (degrees) relative to the element X-axis

MATERIAL (1st continuation card)

```
field locations..
 -1-     -2-     -3-     -4-     -5-     -6-     -7-     -8-     -9-
         XT1     XC1     XT2     XC2     S6
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
+       94000.  94000.  94000.  94000.  54238.
```

field	Format	Name	Description
-1-	alpha	CONT	continuation designation
-2-	real	XT1	tensile strength in fiber direction (psi)
-3-	real	XC1	absolute value of compressive strength in fiber direction (psi)
-4-	real	XT2	tensile strength perpendicular to the fiber direction (psi)
-5-	real	XC2	absolute value of compressive strength perpendicular to the fiber direction (psi)
-6-	real	S6	in-plane shear strength (psi)

MATERIAL (2nd continuation card)

```
field locations..
  -1-     -2-     -3-     -4-     -5-     -6-     -7-     -8-     -9-
         FXT1    FXC1    FXT2    FXC2    FS6
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
+        30000.  30000.  30000.  30000.  17310.
```

field	Format	Name	Description
-1-	alpha	CONT	continuation designation
-2-	real	FXT1	fatigue tensile strength in fiber direction (psi)
-3-	real	FXC1	absolute value of fatigue compressive strength in fiber direction (psi)
-4-	real	FXT2	fatigue tensile strength perpendicular to the fiber direction (psi)
-5-	real	FXC2	absolute value of fatigue compressive strength perpendicular to the fiber direction (psi)
-6-	real	FS6	fatigue in-plane shear strength (psi)

Notes:

1. For its composite failure criterion, STAT uses the Tsai-Wu failure criterion.
2. Up to 20 MATERIAL definitions are allowed.
3. Vibratory and static strengths are used in conjunction with a Tsai-Wu Goodman diagram for a one-p forced response analysis.
4. The composite ply orientation angle, measured relative to the finite element X-axis, is shown on Figure 1. The STAT finite elements are created such that the element X-axis is directed along a spanwise tangent to the blade surface. Thus, a given angle for a ply corresponds to a ply being laminated to the airfoil contour, at a given angle relative to true spanwise.

OPTIMIZE

The OPTIMIZE card defines the optimization solution procedure, the optimization strategy, the search procedure and the ADS output requests. Refer to the STAT theoretical manual for explanation of the input terms.

```
field locations..
  -1-       -2-       -3-       -4-       -5-       -6-       -7-       -8-       -9-
OPTIMIZE  ISTRAT      IOPT    ISERCH      IOUT     ISCAL       IDM     ITERS
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
OPTIMIZE         0         5         8      3552         0         5
```

field	Format	Name	Description
-1-	alpha	OPTIMIZE	card mnemonic name = OPTIMIZE
-2-	integer	ISTRAT	ADS strategy
-3-	integer	IOPT	ADS optimization procedure
-4-	integer	ISERCH	ADS search procedure
-5-	integer	IOUT	ADS output request
-6-	integer	ISCAL	ADS scaling indicator = 0 - scaling off (default) = 1 - scaling on
-7-	integer	IDM	Desired number of completed ADS design moves (default=1000)
-8-	integer	ITERS	Maximum number of function calls allowed for this run (default = 10,000)

Notes:

1. Typical options used for ADS input include:
   ISTRAT = 0 (no specific optimization strategy)
   IOPT = 5 (Modified method of feasible directions)
   ISERCH = 8 (one-dimensional search using polynomial inter/extrapolation without bounds)
   IOUT = 3552 (print all available output)
   ISCAL = 0 (scaling off)

PLOT

The PLOT card gives the user the option to get printer plots of the initial and current design curves from a STAT run. Upon normal completion of a run curve plots are always generated. A NO on this card (default) will result in only these final curves being generated. A YES will cause the initial and intermediate curves to also be generated.

```
field locations..
  -1-      -2-
PLOT     IPLOT
1.......1........1
PLOT     YES
```

field	Format	Name	Description
-1-	alpha	PLOT	card mnemonic name = PLOT
-2-	char.	IPLOT	Design variable plots at: NO: optimum design. YES: start, every function call.

PRIORITY, PRIORITR

The PRIORITY and PRIORITR cards defines the hierarchy used to assign layer thicknesses for all blade components. This card only has meaning for composite blade models. The mnemonic names (prefix part) specified on the CURVE cards are used as the layer identifiers. If the PRIORITY card is omitted, the order of LAY-UP card input will define the layer hierarchy. The layup is assumed to be midplane symmetric, therefore list layers between the midplane and a surface, not from surface to surface.

The format of the PRIORITR card is identical to that of the PRIORITY card. The PRIORITR card is required if a CRP analysis is desired.

```
field locations..
  -1-       -2-       -3-       -4-       -5-       -6-       -7-       -8-       -9-
PRIORITY NAME1     NAME2     NAME3     . . . . . . . . . . . . . . . . . . . . . NAME8
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
PRIORITY   SHEA      SHEL      SPAR      FOAM
```

field	Format	Name	Description
-1-	alpha	PRIORITY	card mnemonic name = PRIORITY
-2- thru -9-	alpha	NAME1 -thru- NAME8	MATERIAL names listed in descending order of importance
-10-	alpha	CONT	continuation specification - leave blank to end card

Notes:

1. Continuation cards have NAME(i) data in fields 2 thru 9, field 10 remains the continuation flag.

2. The NAME(i) values are the mnemonic indicators from the MATERIAL cards.

3. Using the above example card, the layer hierarchy would specify that the SHEA layer be given highest priority, followed by each successive layer in the list. The SHEA layer would be allocated its entire thickness, if the total thickness was not filled the SHEL layer would be added. This process would continue until the total thickness was filled.

VARIABLE

Each VARIABLE card defines one optimization design variable. A design variable may reference a CURVE card such as thickness vs. span, or may be a stand-alone variable such as a composite ply orientation. In practice, each design variable represents the change of a given quantity, not the absolute value. See STAT theoretical manual for details.

```
field locations..
 -1-        -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
VARIABLE  NAME     VID#    ICURV#   LOC      VMIN     VMAX      VSTART
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
VARIABLE SPAR CS        5      10    .250   -.250     .250   -0.123456E-1
```

field	Format	Name	Description
-1-	alpha	VARIABLE	card type name = VARIABLE
-2-	alpha	NAME	mnemonic name for variable (see note #1)
-3-	integer	VID#	VARIABLE identification number - (refer to note 2)
-4-	integer	ICURV#	CURVE or CUTOFF identification number if curve related - if a stand-alone variable set = 0. (see note 3)
-5-	real	LOC	location of variable on independent axis of ABSCISSA card, expressed as a fraction of span. Leave blank if field -4- is zero.
-6-	real	VMIN	minimum value side constraint -lower limit for design value increment
-7-	real	VMAX	maximum value side constraint -upper limit for design value increment
-8,9-	real *16	VSTART	intial value for design variable default = 0 (length 16) (change from initial curve definition)
-10-	alpha	CONT	continuation card required only for scale factor input

VARIABLE (continuation card)

```
field locations..
  -1-     -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
         SCALE
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
+CONT        .021
```

field	Format	Name	Description
-1-	real	SCALE	variable scale factor default=1.0

Notes:

1. When updating a curve: The name must be a unique name. Avoid using REQUIRED names. Refer to Tables 3 and 4 for listings of the restricted names.

   ALTERNATIVELY:

   a. The blade neck geometry may be varied by specifying ATTD (for diameter) and/or ATTL (for length) in field 2 (right justified). Field 4 should be blank or zero. VMIN, VMAX, VSTART are still applicable.

   b. The material orientation angle may be varied by specifying MAT in the first three columns of field 2, followed by the 5 character material name in the remaining columns of field 2. Field 4 must be blank or zero.

2. The VARIABLE ID# will usually be unique. The ID# need not follow in any order. An example which uses non-unique ID#'s is found in SECTION 7, Special Applications.

3. The CURVE or CUTOFF identification number is omitted if the VARIABLE is not CURVE dependent, such as a composite layer orientation angle.

4. The SCALE factor is used to reduce or increase the sensitivity of a particular variable during optimization. Default is no sensitivity change.

5. If a design curve is to be modified, a minimum of 3 VARIABLE, CONSTANT and/or DEPEND locations must reference that curve.

Table 1 - Library of Constraint Equations

Table 1 lists the available library of constraint equations in STAT. The catalog number is input on the CONSTRNT card field -4-, IFORM. Each equation compares one or more of the VAL1 thru VAL8 input values to function(s) call generated TERM, located by ITERM1 thru 4 on the CONSTRNT card (see TABLE 2). Equations are interpreted as follows;

```
G .LT. 0 -- inactive constraint
G .EQ. 0 -- active   constraint
G .GT. 0 -- violated constraint
```

The ADS optimizer allows a tolerance band about zero for defining a constraint as active.

IFORM	Form of Equation	Description
-1-	G = (TERM - VAL1) / VAL1	upper bound contraint (TERM < = VAL)
-2-	G = (VAL1 - TERM) / VAL1	lower bound constraint (TERM > = VAL)
-3-	G = VAL2 - (TERM - VAL1) / VAL1	lower limit constraint w/margin (TERM> =V1+V1*V2)
-4-	G = (TERM - VAL1) / VAL1 + VAL2	upper limit constraint w/margin (TERM< =V1-V1*V2)
-5-	G = VAL2 - ABS(TERM - VAL1) / VAL1	"avoid nominal" constraint (TERM< =V1-V1*V2) and (TERM> =V1+V1*V2)
-6-	EQ1 = VAL3 - (1. - TERM1/VAL1) EQ2 = VAL3 - (TERM2/VAL2 - 1.) G = smallest value between EQ1 , EQ2	excitation crossing constraint between two speeds

Notes:

1. For IFORM = 1, to 5:
   VAL1 = nominal value
   VAL2 = desired margin (e.g. 0.10 translates to a 10% margin)

2. For IFORM = 6
   VAL1 = speed 1
   VAL2 = speed 2
   VAL3 = desired margin

Table 2 - Calculated Terms Storage Locations and Descriptions

Table 2 defines the storage locations of important values calculated during each function call. The appropriate number is input on the CONSTRNT card in field -5-, ITERMS.

ITERM	DESCRIPTION OF TERM
-1- thru -5-	Natural frequencies, first analysis speed, first five modes of vibration, front blade. (Hz)
-6- thru -10-	Not used
-11- thru -60-	Tsai-Wu layer failure criterion, for each layer present, as defined on the LAY-UP card, front blade. (dimensionless)
-61-	free-stream flutter Mach number, front blade (MN)
-62-	stall flutter parameter, front blade. (dimensionless)
-63-	power, front blade. (HP)
-64-	activity factor, front blade. (dimensionless)
-65-	maximum element Von Mises stress, front blade. (psi)
-66-	tip uncamber front blade. (radians)
-67-	tip untwist front blade. (radians)
-68-	tip leading edge axial displacement, front blade. (inches)
-69-	tip trailing edge axial displacement, front blade. (inches)
-70-	One-P forced response minimum life fraction from Tsai-Wu Goodman Diagram, front blade. (dimensionless)
-71-	efficiency, front blade. (fraction)
-72-	thrust, front blade. (pounds)
-73-	weight, front blade. (pounds)
-74-	noise, front blade. (db)
-75- thru -80-	Not used

Table 2 (continued) Calculated Terms Storage Locations and Descriptions

The TERMS array continues with the calculated parameters for the rear blade.

ITERM	DESCRIPTION OF TERM
-81- thru -85-	Natural frequencies, first analysis speed, first five modes of vibration, rear blade. (Hz)
-86- thru -90-	Not used
-91- thru -140-	Tsai-Wu maximum layer stresses in the order of defined on the LAY-UP card, rear blade. (dimensionless)
-141-	flutter mach number, rear blade. (MN)
-142-	stall flutter parameter, rear blade. (dimensionless)
-143-	power, rear blade. (HP)
-144-	activity factor, rear blade. (dimensionless)
-145-	maximum element Von Mises stress, rear blade. (psi)
-146-	tip uncamber rear blade. (radians)
-147-	tip untwist rear blade. (radians)
-148-	tip leading edge axial displacement, rear blade. (inches)
-149-	tip trailing edge axial displacement, rear blade. (inches)
-150-	One-P forced response minimum life fraction from Tsai-Wu Goodman Diagram, rear blade. (dimensionless)
-151-	efficiency, rear blade. (fraction)
-152-	thrust, rear blade. (pounds)
-153-	weight, rear blade. (pounds)
-154-	noise, rear blade. (db)

Notes:

1. ITERM 11 is the Tsai-Wu combined stress failure criterion for ply 1, front blade. ITERM 12 is the Tsai-Wu value for ply 2, etc.

Table 3 - Required Names Initial Geometry

REQUIRED names are currently used in the STAT program as identifiers for ABSCISSA and CURVE cards. Be careful not to use any of these REQUIRED names as user-selected mnemonic names. The names listed here are needed to set up the initial propfan geometries.

REQUIRED NAME	DESCRIPTION OF NAME
ROR,RORR	station radius / tip radius (i.e. percent span)
HOB,HOBR	thickness / chord
BOD,BODR	chord / blade tip diameter
CLD,CLDR	camber
BETA,BETAR	blade angle of twist
CONE,CONER	streamline cone angle wrt. engine center-line
XOR,XORR	radial stacking location / blade radius
YOR,YORR	tangential stacking location / blade radius
ZOR,ZORR	axial stacking location / blade radius

Nomenclature:

The definitions used herein are consistent with NASA airfoil definitions, and are detailed in Reference 2. The definitions of thickness, chord, and Beta are shown in Figure 2.

CLD - Design lift coefficient, as determined from the airfoil series and shape.

BETA - Section Twist angle, in degrees, measured from the rotor plane, positive clockwise looking radially towards the rotation axis. Within STAT, since variable pitch blades are allowed, BETA is defined to be 0.0 at 75% span.

CONE - Streamline cone angle, in degrees, measured as illustrated in Figure 3.

XOR
YOR
ZOR - Airfoil section center of gravity stacking coordinates, in inches, in the radial (positive outward), tangential, and axial (positive rearward) directions.

Table 4 - Required Names Composite Lay-up Control

REQUIRED names in this table define "suffix" sections of names on the CURVE and CUTOFF cards. These names differentiate the CURVE cards for a given composite layer. The CUTOFF card REQUIRED name defines an upper or lower ABSCISSA limit for a CURVE.

REQUIRED NAME	DESCRIPTION OF NAME
ML	CURVE card suffix for meanline data. Meanline data is defined as a % of chord, 0% at LE, 100% at TE. Default meanline value is .5 (50%).
C/S	CURVE card suffix for % chord vs. span data. Default value is 1.01 (101%).
T/S	CURVE card suffix for wall thickness vs. span data Ply thickness is defined in inches.
U	CUTOFF suffix specifying upper limit, based on abscissa.
L	CUTOFF suffix specifying lower limit, based on abscissa.

Section 2 - Blade Geometry and Analysis Control

This section describes the input cards required to setup the blade geometry and aero information. The geometry data is input via five cards, each having a unique mnemonic name. Input format is fields of eight. Continuation cards, if required, are signaled by a non-blank field 10 in the parent card. The following cards will be descibed:

End of Section 2 aerodynamic analysis data is signaled by *END_EFF card.

Card Title	Description
AIRFOIL, AIRFOILR	defines the airfoil series for each input station
AXIALV, AXIALVR	array of local axial inflow velocities / free- stream velocity array.
BLADE, BLADER	blade geometry.
ENVIRON, ENVIRONR	blade operating environment.
FILR/R, FILR/RR	array of local radius / blade radius lifting line segment boundaries.
RFILR/R RFILR/RR	array of local radius / blade radius lifting line segment boundaries for refined aerodynamics
*END-EFF	signals end of Section 2 input.

AIRFOIL, AIRFOILR

The AIRFOIL card defines the propeller airfoil series for each input station, where the number of stations is defined on the BLADE card. The currently available airfoil series are:

23. = UTRC NACA - 16 series compressible
24. = NACA - 16 series compressible

```
field locations..
  -1-      -2-     -3-      -4-      -5-      -6-      -7-      -8-      -9-
AIRFOIL   ST(1)  ST(2)    ST(3)    ST(4)    ST(5)   ................ ST(8)
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
AIRFOIL   24.     24.      24.      24.      24.      24.      24.      24.
```

field	Format	Name	Description
-1-	alpha	AIRFOIL	card type name = AIRFOIL
-2- thru -9-	real	ST(1) -thru- ST(8)	section series type indicator
-10-	alpha	CONT	continuation indicator - any alpha-numeric input indicates continuation

Notes:

1. The continuation format is identical to above card with the exception of the first field input.
2. Input ends with first blank field.
3. Radial sections corresponding to this data are defined via the ABSCISSA-ROR and ABSCISSA-RORR cards.

AXIALV, AXIALVR

The AXIALV card defines the array of axial inflow velocity / freestream velocity. One value for each airfoil station defined on the AIRFOIL card. Continuation cards, if necessary, are signaled with any alpha- numeric input in field -10- of preceding card.

```
field locations..
  -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
AXIALV    VOV(1)  VOV(2)   VOV(3)   VOV(4)   VOV(5)  ...............  VOV(8)
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
AIRFOIL  1.018    1.005    0.992    0.978    0.964    0.951    0.939    0.915
```

field	Format	Name	Description
-1-	alpha	AXIALV	card type name = AXIALV
-2- thru -9-	real	VOV(1) -thru- VOV(8)	ratio values
-10-	alpha	CONT	continuation indicator - any alpha- numeric input indicates continuation

Notes:

1. The continuation format is identical to above card with the exception of the first field input.
2. Input ends with first blank field.

BLADE, BLADER

The BLADE card defines the swept blade geometry. The BLADE data is input via a two card set, both cards are required.

```
field locations..
  -1-       -2-      -3-       -4-      -5-       -6-      -7-       -8-      -9-
BLADE       NB     NSTAT      SCO    DESANG    BODT    THETD   AIRFTYP   SWPN
1......1.......1.......1.......1.......1.......1.......1.......1.......1
BLADE        8        9      .239    57.26     0.05    55.83      5.      .75
```

field	Format	Name	Description
-1-	alpha	BLADE	card type name = BLADE
-2-	integer	NB	number of blades in the rotor
-3-	integer	NSTAT	number of blade stations
-4-	real	SCO	root radius / propeller radius
-5-	real	DESANG	propeller blade angle at 75% radius (degrees)
-6-	real	BODT	tip chord / propeller diameter
-7-	real	THETD	design blade angle corresponding to XOR,YOR,ZOR values
-8-	real	AIRFTYP	airfoil correction indicator 0. = none , 1. = cascade 4. = sweep, 5. = sweep + cascade
-9-	real	SWPN	sweep correction - cos(sweep)**SWPN - 0.75 suggested, 1.0 for off
-10-	alpha	CONT	continuation signal- any alpha-numer. input will signal a continuation

BLADE, BLADER (continuation card)

```
field locations..
  -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
  CONT     DIAM    TIPCL    PROPT     YAW
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
$BLADE    10.0     0.8      1.0     8.247
```

field	Format	Name	Description
-1-	alpha	CONT	same as field 10 on parent card
-2-	real	DIAM	propeller diameter , feet
-3-	real	TIPCL	propeller tip clearence to fuselage / propeller diameter
-4-	real	PROPT	wake geometry print option
-5-	real	YAW	aircraft yaw angle for 1-P analysis (degrees)
-6-	real	ZORROW	rotor spacing / avg of front and rear tip diameter (Z/D). This field applies to cont card for BLADE and not BLADER.

Notes:

1. DESANG defines the blade angle at full thrust, for the cruise condition. DESANG follows the same orientation as BETA (Table 3).
2. THETD defines the blade design angle corresponding to the blade stacking coordinates, at the 75% span location. DESANG follows the same orientation as BETA.
3. PROPT, if nonzero, activates the printing of wake radial and axial coordinates for each blade angle analyzed. This option will create a lot of extra output if activated during a large optimization analysis, and as such is not recommended.

ENVIRON, ENVIRONR

The ENVIRON card defines the propeller operating environment. The two card set is required.

```
field locations..
  -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
ENVIRON   ALT      RPM     VKTS     TDEGF    COMPRS   REV      DPSI    EVAARD
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
ENVIRON  35000.   1697.7  461.14   -65.8     1.0      2.0      45.       1.0
```

field	Format	Name	Description
-1-	alpha	ENVIRON	card type name = ENVIRON
-2-	real	ALT	altitude, feet
-3-	real	RPM	propeller revolutions / minute
-4-	real	VKTS	freestream velocity, knots
-5-	real	TDEGF	temperature, degrees F
-6-	real	COMPRS	compressible induction correction =1. for on , =2. for off
-7-	real	REV	number of revolutions of wake geometry
-8-	real	DPSI	azimuth increment of wake geometry
-9-	real	EVAARD	tip relief correction = 1. for on , = 0. for off
-10-	alpha	CONT	continuation signal- any alpha-numer. input will signal a continuation

ENVIRON, ENVIRONR (continuation card)

```
field locations..
   -1-     -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
   CONT    CNSECT   VIMON
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
$ENVIRON    1.0      -22.
```

field	Format	Name	Description
-1-	alpha	CONT	same as field 10 on parent card
-2-	real	CNSECT	Evaard correction chord intersection - use 1.0
-3-	real	VIMON	momentum velocity , feet/sec - use 0.0

Notes:

1. The REV value controls the number of revolutions of wake vortex to be analyzed. Program execution time will increase as more revs are considered. Generally, for most conditions, 2 to 6 revs are quite adequate. For the cruise condition, 1 to 2 revs is sufficient.

2. The DPSI value is the increment in degrees of each wake analysis segment. The DPSI value must be an integer multiple of 360 divided by the number of blades. Thus, for 10 blades, DPSI can be 36 (360 / 10), 72 (2 * 360 / 10), etc.

FILR/R, FILR/RR

The FILR/R card defines the array of local radius / propeller radius lifting line segment boundaries.

```
field locations..
  -1-       -2-     -3-      -4-      -5-      -6-      -7-      -8-      -9-
FILR/R    RSB(1) RSB(2)    RSB(3)   RSB(4)   RSB(5)   ...............  RSB(8)
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
FILR/R    0.239   0.30     0.40     0.50     0.60     0.70     0.80     0.90
```

field	Format	Name	Description
-1-	alpha	FILR/R	card type name = FILR/R
-2- thru -9-	real	RSB(1) -thru- RSB(8)	ratio values
-10-	alpha	CONT	continuation indicator - any alpha-numeric input indicates continuation

Notes:

1. The continuation format is identical to above card with the exception of the first field input.
2. Input ends with first blank field.
3. The FILR/R cards define the locations of the PANPER aerodynamic analysis output stations, and must meet the following:
   a. Include the airfoil root (SCO of BLADE card) and tip (r/R = 1.0) stations.
   b. NSTAT+1 stations are required. (NSTAT defined on BLADE card)
   c. It is recommended to use more stations at the airfoil tip than at the root.
   d. Analysis stations must be input in order of increasing radius.

RFILR/R, RFILR/RR

The RFILR/R card defines the array of local radius / propeller radius lifting line segment boundaries for refined aerodynamics.

```
field locations..
   -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
RFILR/R  RSB(1)  RSB(2)   RSB(3)   RSB(4)   RSB(5)   ................   RSB(8)
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
RFILR/R  0.239    0.30     0.40     0.50     0.60     0.70     0.80     0.90
```

field	Format	Name	Description
-1-	alpha	RFILR/R	card type name = RFILR/R
-2- thru -9-	real	RSB(1) -thru- RSB(8)	ratio values
-10-	alpha	CONT	continuation indicator - any alpha-numeric input indicates continuation

Notes:

1. The continuation format is identical to above card with the exception of the first field input.
2. Input ends with first blank field.

Section 3 - Objective Function

This section describes the input cards required to setup the objective function solution. Two objective function types are supported for tailoring of a full size propfan stage, or for aerodynamically and structurally tuning a scale model propfan. For full scale propfan systems, include the BASELINE card to describe the blade conditions. For scale model optimizations of propfan systems the BLDDATA, BLDDEFL, BLDFREQ, and BLDMASS cards will be required. The cards with the R suffix are required for counter-rotating propfan systems (CRP) to define the objective function for the rear blade. Single rotation propfan systems (SRP) will not require these cards since no rear blade exists.

The end of Section 3 input is signaled with the *END_OBJ card.

The following cards are explained in this section:

Card Title	Description
BASELINE, BASELNR	baseline blade input to compare with current design
BLDDATA, BLDDATAR	OBJTYPE 2 input data
BLDDEFL BLDDEFLR	OBJTYPE 2 full model deflection data
BLDFREQ BLDFREQR	OBJTYPE 2 full model frequency data
BLDMASS BLDMASSR	OBJTYPE 2 full model sectional mass data
OBJTYPE	objective function equation type
SENSE	sensitivity values for the objective function
*END_OBJ	signals end of objective function data

BASELINE

The BASELINE card defines the baseline blade parameters for comparison with each new design. The BASELNR card description will follow this description.

```
field locations..
  -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
BASELINE SHPDBS  PINDBS    BBS      AFBS    SWEPBS   EFFBS    DBBS    SHPTO
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
BASELINE   32.     800.     8.0    226.18  36.776  0.81651  143.32  12850.
```

field	Format	Name	Description
-1-	alpha	BASELINE	card type name = BASELINE
-2-	real	SHPDBS	cruise shaft horsepower / (prop diameter)**2, HP/ft**2
-3-	real	PINDBS	propeller tip speed, feet/sec
-4-	real	BBS	number of blades in the rotor stage
-5-	real	AFBS	blade activity factor
-6-	real	SWEPBS	blade tip sweep, degrees
-7-	real	EFFBS	propeller efficiency
-8-	real	DBBS	noise level, db
-9-	real	SHPTO	take-off shaft horsepower, hp.
-10-	alpha	CONT	continuation signal- any alpha-numer. input will signal a continuation

BASELINE, (continuation card)

```
field locations..
  -1-      -2-     -3-      -4-      -5-      -6-      -7-      -8-      -9-
  CONT     SHP    DFUSE    XNPROP    DDB      XMF     CFACT    ZORBS   TIPCBS
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
$BASELIN 5782.    13.      2.       5.       1.0      1.0      .520    .800
```

field	Format	Name	Description
-1-	alpha	CONT	same as field 10 on parent card
-2-	real	SHP	cruise shaft horsepower, hp.
-3-	real	DFUSE	fuselage diameter, feet.
-4-	real	XNPROP	total number of rotors on aircraft
-5-	real	DDB	delta db reduction for syncrophasing and dynamic damping
-6-	real	XMF	mission factor to correct delta efficiency for climb
-7-	real	CFACT	factor for customer vs. airline cost
-8-	real	ZORBS	Baseline Z/R distance between the two rows (front & rear blades) measured at stacking points.
-9-	real	TIPCBS	Baseline tip clearance used for noise calculation. This is the distance between tip and fuselage.

Notes:

1. XNPROP is the total number of propeller rotors on the aircraft. Thus, a two engine CRP craft would have XNPROP = 4.
2. The XMF parameter allows shifting of the STAT flight cycle. The parameter equals 1.0 if the cruise and climb mission durations are equal (usually true for prop fan aircraft). This parameter is generally supplied by the aircraft manufacturer.
3. The CFACT parameter allows for adjusting the STAT cost calculation from an airline basis to a customer basis. Generally, this parameter will not alter the final design, effecting instead only the final cost value.

BASELNR

The BASELNR card defines the baseline rear blade parameters for comparison with each new design.

```
field locations..
  -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
BASELNR  SHPDBS   PINDBS    BBS      AFBS    SWEPBS    DBBS    SHPTO      SHP
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
BASELNR   32.      800.     8.0     226.18   36.776   143.32   12850.    5782.
```

field	Format	Name	Description
-1-	alpha	BASELNR	card type name = BASELNR
-2-	real	SHPDBS	cruise shaft horsepower / (prop diameter)**2, HP/ft**2
-3-	real	PINDBS	propeller tip speed, feet/sec
-4-	real	BBS	number of blades in the rotor stage
-5-	real	AFBS	blade activity factor
-6-	real	SWEPBS	blade tip sweep, degrees
-7-	real	DBBS	noise level, db
-8-	real	SHPTO	take-off shaft horsepower, hp.
-9-	real	SHP	cruise shaft horsepower, hp.
-10-	alpha	CONT	continuation signal- any alpha-numer. input will signal a continuation

BASELNR, (continuation card)

```
field locations..
  -1-     -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
  CONT   TIPCBS
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
$BASELNR  .800
```

field	Format	Name	Description
-1-	alpha	CONT	same as field 10 on parent card
-9-	real	TIPCBS	Baseline tip clearance used for noise calculation. This is the distance between tip and fuselage.

BLDDATA, BLDDATAR

The BLDDATA card defines the model scale factor, number of modes to be used in the objective function calculation, full blade tip chord and tip untwist.

```
field locations..
   -1-     -2-     -3-     -4-     -5-     -6-     -7-     -8-     -9-
BLDDATA  SCALE   NMODES  TIPCHD  TIPUNT
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
BLDDATA  4.40816        3     5.4      .09
```

field	Format	Name	Description
-1-	alpha	BLDDATA	card type name = BLDDATA
-2-	real	SCALE	Full blade / scale model diameter
-3-	integer	NMODES	number of modes, 1 thru NMODES, to be used in the objective function
-4-	real	TIPCHD	Full blade tip chord (inches)
-5-	real	TIPUNT	Full blade tip untwist (radians)

Notes:

1. The TIPCHD parameter is required when aero-elastic similarity is required between the full size and the scale model blades.
2. The TIPUNT parameter is required when static untwist similarity is required between the full size and the scale model blades.

BLDDEFL, BLDDEFLR

The BLDDEFL card defines the full blade modal deflections at the tip. Both torsion and easy-wise bending deflections are input for modes one through NMODES (NMODES is specified on the BLDDATA card).

The BLDDEFL cards are used when tip vibratory mode shape similarity is desired between full size and scale model propfans. Two card sets are required to ensure vibratory similarity - modal twist, and modal easy-wise bending amplitude comparisons are made by STAT. The mode shape type on a BLDDEFL card is defined via the ITYPE parameter, field 2.

```
field locations..
 -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
BLDDEFL  ITYPE    DEF(1)   DEF(2)   --------->                          DEF(7)
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
BLDDEFL        2  -1.335   -0.885  .04351
```

field	Format	Name	Description
-1-	alpha	BLDDEFL	card type name = BLDDEFL
-2-	integer	ITYPE	1 = torsion, 2 = easy-wise bending
-3- thru -9-	real	DEF(1) thru DEF(7)	modal deflections for modes 1 thru 7

Notes:

1. Continuation cards are allowed.
2. Maximum of ten entries for each deflection type.
3. A single BLDDEFL card set can define tip vibratory mode shapes for either bending or torsional deflections for up to 10 vibratory modes.
4. Two card sets are required - one for bending, the other for torsion (radians).

BLDFREQ, BLDFREQR

The BLDFREQ card defines the natural frequencies (hz) of the full size propfan, for vibratory frequency similarity determination. These frequencies correspond to the at-speed condition, and include centrifugal effects. Similarity over the first ten natural frequencies may be enforced.

```
field locations..
 -1-       -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
BLDFREQ   F(1)     F(2)     F(3)     --------->                          F(8)
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
BLDFREQ      45.      80.     110.
```

field	Format	Name	Description
-1-	alpha	BLDFREQ	card type name = BLDFREQ
-2- thru -9-	real	F(1) thru F(8)	blade frequencies (hz), modes 1 thru 8.

Notes:

1. Continuation cards are allowed.
2. Maximum of ten entries are allowed.

BLDMASS, BLDMASSR

The BLDMASS card defines the full size blade sectional mass distribution, for aero-elastic scale model blade optimizations. The mass sections defined must correspond to the fractional span locations specified on the SPANTAB card.

```
field locations..
  -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
BLDMASS  M(1)     M(2)     M(3)     --------->                          M(8)
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
BLDMASS    5.095    4.566    4.032    3.659    3.022    2.885    2.650    2.346
```

field	Format	Name	Description
-1-	alpha	BLDMASS	card type name = BLDMASS
-2- thru -9-	real	M(1) thru M(8)	blade sectional masses, lbs, sections 1 thru 8

Notes:

1. Continuation cards are allowed.
2. Maximum of twenty entries are allowed.
3. The M(i) parameters correspond to the total weight in pounds of the finite element nodal points at the corresponding radial coordinate. Thus to obtain a meaningful scale model mass similarity optimization, the radial finite element mesh distribution must correspond (in tip radius fraction) between the full size and scaled airfoils. Thus, the SPANTAB cards must match for the two geometries.

OBJTYPE

The OBJTYPE card defines the objective function equation type.

```
field locations..
  -1-     -2-     -3-     -4-     -5-     -6-     -7-     -8-     -9-
OBJTYPE  ITYPE
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
OBJTYPE         1
```

field	Format	Name	Description
-1-	alpha	OBJTYPE	card type name = OBJTYPE
-2-	integer	ITYPE	1 = minimize operating costs 2 = minimize aero-elastic differences between full and scale models

Notes:

1. OBJTYPE 1 requires cards SENSE and BASELINE.
2. OBJTYPE 2 requires cards BLDDATA, BLDFREQ, BLDMASS, and BLDDEFL.
3. The OBJTYPE card is always required.

SENSE

The SENSE card defines the cost sensitivity factors for the objective function. The SENSE card is required for a cost optimization.

```
field locations..
 -1-     -2-     -3-     -4-     -5-     -6-     -7-     -8-     -9-
SENSE   SENS(1) SENS(2) SENS(3) SENS(4) SENS(5) SENS(6)
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
SENSE   0.      0.      0.      0.      .0013   74.
```

field	Format	Name	Description
-1-	alpha	SENSE	card type name = SENSE
-2-	real	SENS(1)	DOC factor for near field noise, $/db
-3-	real	SENS(2)	DOC factor for prop power, $/hp
-4-	real	SENS(3)	DOC factor for activity factor, $
-5-	real	SENS(4)	DOC factor for tip sweep, $/in
-6-	real	SENS(5)	DOC factor for airfoil weight, $/lb
-7-	real	SENS(6)	DOC factor for propfan system efficiency, $

Notes:

1. STAT seeks to minimize the following objective function:

$$OBJ = SENS(1) * DB + SENS(2) * SHP + SENS(3) * AF + SENS(4) * TIPSWP + SENS(5) * BLDWT + SENS(6) * EFF$$

where DB is the total propfan system near-field noise (db),
SHP is the system power (hp),
AF is the total of activity factors,
TIPSWP is the total of blade tip sweeps (in),
BLDWT is the total propfan blade weight (lb), and
EFF is the propfan system efficiency (1.00 is perfect).

Section 4 - Geometry Generation Data

This section describes the input cards required to setup the blade geometry for finite element preprocessing. Input format is in fields of eight. Continuation cards, if required, are signaled by a non-blank field 10 in the parent card.
End of Section 4 geometry generation data is signaled by *END_GEN card.

The following cards are described in this section:

Card Title	Description
ATTACHMT, ATTCHMTR	defines the airfoil attachment geometry
CHORDTAB, CHRDTABR	chordwise breakup for finite element model
GEOMGEN, GEOMGENR	additional blade geometry
RCHORD	chordwise breakup for refine finite element model
RSPAN	spanwise breakup for refine finite element model
SPANTAB, SPANTABR	spanwise breakup for finite element model
*END-GEN	signals end of Section 4 input

ATTACHMT, ATTCHMTR

ATTACHMT defines the neck geometry data for the finite element model. This card is required only when neck diameter and/or length will be used as variables. An ATTCHMTR card is required if rear blade neck diameter and/or length are design variables in a CRP optimization.

```
field locations..
  -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
ATTACHMT  EID      PID      MID      GRID1    GRID2    DIAM     LENGTH
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
ATTACHMT     109      109      109       71       72  1.3390     0.68
```

field	Format	Name	Description
-1-	alpha	ATTACHMT	card type name = ATTACHMT
-2-	integer	EID	CBAR element identification number
-3-	integer	PID	CBAR property identification number
-4-	integer	MID	CBAR material identification number
-5-	integer	GRID1	End-A gridpoint number
-6-	integer	GRID2	End-B gridpoint number
-7-	real	DIAM	Neck diameter (inches)
-8-	real	LENGTH	Neck length (inches)

Notes:

1. The property (PBAR card), material (MAT1 card) and grid (GRID card) definitions must be supplied by the user in the bulk data section of the STAT input file (see section 5).

2. Any neck boundary conditions and/or tying equations must also be user supplied in the bulk data section.

CHORDTAB, CHRDTABR

CHORDTAB defines the chordwise location for the finite element nodes. Values must range from 0.0 to 100.0 and a 50.0 value is required. Continuation cards are allowed. A CHRDTABR card defines the chordal breakup for the rear blade in a CRP optimization.

```
field locations..
  -1-       -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
CHORDTAB  CT(1)   CT(2)    CT(3)    CT(4)    CT(5)    CT(6)    CT(7)    CT(8)
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
CHORDTAB      0.0      20.      40.      50.      60.      70.      90.     100.
```

field	Format	Name	Description
-1-	alpha	CHORDTAB	card type name = CHORDTAB
-2- thru -9-	real	CT(1) thru CT(8)	chordal percentages for node locations
-10-	alpha	CONT	continuation indicator - any alpha-numeric input signals continuation

Notes:

1. The continuation format is identical to above card with the exception of the first field input.
2. Input ends with first blank field.

GEOMGEN, GEOMGENR

The GEOMGEN card defines additional blade geometry.The GEOMGEN card is a two card set, both cards are required. For counter-rotation propfan analysis, a GEOMGENR card set is also required.

```
field locations..
  -1-      -2-      -3-      -4-      -5-
GEOMGEN  DIREC    IOPT1    IOPT2    NSEC
1.......1.......1.......1.......1.......1
GEOMGEN   LEFT      1        0        1
```

field	Format	Name	Description
-1-	alpha	GEOMGEN	card type name = GEOMGEN
-2-	alpha	DIREC	rotation direction, LEFT or RIGHT see note 1
-3-	integer	IOPT1	interpolation option
-4-	integer	IOPT2	calculation option
-5-	integer	NSEC	number of section types

Notes:

1. LEFT = clockwise when viewed from the rear.
   RIGHT = counter-clockwise when viewed from the rear.

2. Supported IOPT1 options are:
   0 - Bi-quadratic interpolation
   1 - 3-D cubic parametric spline

3. Supported IOPT2 options are:
   0 - Full 3-D airfoil (recommended)
   1 - Non-dimensional airfoil (NOT recommended for STAT)

4. NSEC allows a blade to be generated using more than one airfoil generation option, identified via the ISERS parameter(s) of continuation card(s). Up to 2 section types are allowed for airfoil definition in STAT.

GEOMGEN, GEOMGENR card set 2

(repeated NSEC times)

```
field locations..
  -1-      -2-      -3-      -4-      -5-      -6-      -7-
          ISERS   MEANLN     SROR     EROR   EXCAM1   EXCAM2
1......1.......1.......1.......1.......1.......1.......1
+              7      10      .35       .5       0.       0.
+              7      10     .625      1.1       0.       0.
```

field	Format	Name	Description
-1-			-blank-
-2-	integer	ISERS	airfoil series number
-3-	integer	MEANLN	meanline series type
-4-	real	SROR	starting blade radius / tip radius
-5-	real	EROR	ending blade radius / tip radius
-6-	real	EXCAM1	camber at SROR
-7-	alpha	EXCAM2	camber at EROR

Notes:

1. Available ISERS airfoil types in STAT are:
   1 - NACA Series 16
   2 - NACA Series 64
   4 - NACA Series 65
   5 - NACA Series 66
   6 - NACA Series 63
   7 - Circular Arc
   9 - NACA Series 65M

Notes are continued on the next page.

Notes continued for the GEOMGEN, GEOMGENR cards:

2. Available MEANLN meanline types in STAT are:
   1 - NACA Series 16
   2 - NACA Series 64
   4 - Circular Arc
   5 - NACA Series 230
   6 - NACA Series 62
   7 - NACA Series 63
   8 - NACA Series 64
   9 - NACA Series 65
   10 - Circular Arc, with camber converted to theta*.

3. Each standard airfoil section runs from its start radius ratio (SROR) to its end radius ratio (EROR). SROR for the first airfoil series must be less than or equal to the SCO value on the BLADE card. EROR of the last airfoil series should be greater than or equal to 1.0. A small radial gap is required between airfoil series. Between series, sections are interpolated.

RCHORD

RCHORD defines the chordwise locations for the refined finite element model nodal points. Values must range from 0.0 to 100.0 and a 50.0 value is required. Continuation cards are allowed.

```
field locations..
  -1-     -2-     -3-     -4-     -5-     -6-     -7-     -8-     -9-
RCHORD   CT(1)   CT(2)   CT(3)   CT(4)   CT(5)   CT(6)   CT(7)   CT(8)
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
RCHORD  0.0     20.     40.     50.     60.     70.     90.     100.
```

field	Format	Name	Description
-1-	alpha	RCHORD	card type name = RCHORD
-2- thru -9-	real	CT(1) thru CT(8)	chordal percentage for nodal locations
-10-	alpha	CONT	continuation indicator - any alpha-numeric input signals continuation

Notes:

1. The continuation format is identical to above card with the exception of the first field input.
2. Input ends with first blank field.

RSPAN

RSPAN defines the spanwise locations for the refined finite element model nodal points. Values must range from 0.0 to 1.0. Continuation cards are allowable.

```
field locations..
  -1-      -2-     -3-     -4-     -5-     -6-     -7-     -8-     -9-
RSPAN     ST(1)   ST(2)   ST(3)   ST(4)   ST(5)   ST(6)   ST(7)   ST(8)
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
RSPAN      0.0     .2      .4      .6      .7      .8      .9     1.0
```

field	Format	Name	Description
-1-	alpha	RSPAN	card type name = RSPAN
-2- thru -9-	real	ST(1) thru ST(8)	span fractions for node locations
-10-	alpha	CONT	continuation indicator - any alpha-numeric input signals continuation

Notes:

1. The continuation format is identical to above card with the exception of the first field input.

2. Input ends with first blank field.

SPANTAB, SPANTABR

SPANTAB defines the spanwise location for the finite element nodes. Values must range from 0.0 to 1.0. The SPANTABR card defines the finite element nodal locations for the rear blade in a CRP optimization. Continuation cards are allowable.

```
field locations..
  -1-      -2-     -3-      -4-      -5-      -6-      -7-      -8-      -9-
SPANTAB   ST(1)   ST(2)    ST(3)    ST(4)    ST(5)    ST(6)    ST(7)    ST(8)
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
SPANTAB    0.0     .2       .4       .6       .7       .8       .9      1.0
```

field	Format	Name	Description
-1-	alpha	SPANTAB	card type name = SPANTAB
-2- thru -9-	real	ST(1) thru ST(8)	span fractions for node locations
-10-	alpha	CONT	continuation indicator - any alpha-numeric input signals continuation

Notes:

1. The continuation format is identical to above card with the exception of the first field input.
2. Input ends with first blank field.

Section 5 - Finite Element Program Control

This section describes the control cards needed by the finite element program, and also lists those NASTRAN bulk data cards which may be used to supplement the automatically created airfoil and neck models. This data section must begin with a BEGIN BULK card, and must end with an ENDDATA card.

Analysis Control Cards

These analysis control cards ($$PARAM cards) define analysis type, procedure and output. The STAT finite element analysis module does not have case control capability; therefore, the control cards appear in the finite element program bulk data, rather than in a case control structure as in NASTRAN. Those familiar with the NASTRAN case control will recognize that these $$PARAM cards perform the same function. Each $$PARAM card has an assigned mnemonic name.

The following $$PARAM cards are described in this section:

Card Title	Description
CONVERGE	convergence criterion control
CMGUPD	centrifugal mass matrix update control.
EIGEN	eigenvalue calculation control
K6ROT	inplane rotation degree of freedom constraint control
LOADID	load cases control
MAXITER	maximum number of iterations/load case for convergence
NONLIN	analysis type - geometric linear or nonlinear
PRINT	output control
SKPLOAD	load regeneration control
SKPMAT	stiffness matrix regeneration control

Notes:

1. All $$PARAM cards have been assigned default values, as explained within the respective card definitions.

Bulk Data Cards

Supplementary bulk data cards are required to define the loadings, boundary conditions, Guyan reduction parameters, and, in the case of conventional, extended neck airfoils, the platform model and airfoil to neck connectivities.

Those bulk data cards that are recognized by the STAT finite element code are classified according to function, and described in this section.

Data Control

Nodal Point Definition

Element Definition

Element Properties Definition

Material Properties Definition

Coordinate System Definition

Constraint Definition

Guyan Reduction Control

Eigenvalue Extraction Control

Load Definition

Notes:

1. Only single field (8 column) data input is available. Input is free field within the specified 8 column field.
2. A separate finite element model is constructed for each rotor. In each case, the node numbers start at one (1).
3. The finite element node numbers start at the tip leading edge. Nodes are numbered across the chord, moving successively inward, to the root trailing edge, according to the breakup defined on the CHORDTAB and SPANTAB cards.
4. Except for RFORCE loads, load set ID's (NASTRAN field 2) are not used. Any load (other than RFORCE) that is present is always applied.
5. The following Bulk Data cards are required:
   - SPC - As a minimum, sufficient constrainst must be present to suppress rigid body motions (3 displacements and 3 rotations). SPC set identifiers are not used - if an SPC card is present, the constraint is always applied.
   - ASET - The eigensolver in STAT is an in-core Householder method. Thus, reduction is required. The user must ASET enough points to ensure frequency accuracy over any constrained frequencies.
   - RFORCE - Propfan rotation analysis speed is required.

CONVERGE

The CONVERGE parameter card defines the convergence criterion value and type. The current choices for type are:

1. STRAIN -- change in strain energy between iterations,
2. DEFLEC -- maximum change in any deflection component between iteration (not currently functional).

If this card is omitted the program will use STRAIN at a value of .001.

```
field locations..
  -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
$$PARAM CONVERGE  CTYPE   VALUE
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
$$PARAM CONVERGE  STRAIN     .002
```

field	Format	Name	Description
-1-	alpha	$$PARAM	Defines this card as a $$PARAM type
-2-	alpha	CONVERGE	Defines $$PARAM card type
-3-	alpha	CTYPE	Convergence test type; STRAIN - strain energy DEFLEC - deflection (not functional) (default -- STRAIN)
-4-	real	VALUE	Convergence criterion value (default for STRAIN = .001)

CMGUPD

The CMGUPD parameter card controls when the "centrifugal mass matrix" effect is applied to the stiffness. For correct frequencies of a rotating blade, this matrix must always be applied to the modal analysis. Often, however, including this effect in the large deflection static analysis will enhance convergence. If a run has convergence problems, it is advised to try switching this parameter.

```
field locations..
 -1-     -2-     -3-     -4-     -5-     -6-     -7-     -8-     -9- $$PARAM
CMGUPD                                                                CMGGFLG
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
$$PARAM  CMGUPD          NO
```

field	Format	Name	Description
-1-	alpha	$$PARAM	Defines this card as a $$PARAM type
-2-	alpha	CMGUPD	Defines $$PARAM card type
-3-	alpha	CMGGFLG	YES - update stiffness for both static and modal analyses (default) NO - update stiffness for modal analysis only

EIGEN

The EIGEN parameter card controls eigenvalue calculation for each load case to be analyzed. This card works in conjunction with the LOADID card and follows the same load case input order. If this card is omitted eignvalues will only be calculated for the last load case. The number of load cases is currently limited to 8 or less.

```
field locations..
  -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
$$PARAM  EIGEN    EI(1)    EI(2)    EI(3)    EI(4)    EI(5)    EI(6)    EI(7)
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
$$PARAM  EIGEN      +1       +1       -1       -1       -1       -1       -1
```

field	Format	Name	Description
-1-	alpha	$$PARAM	Defines this card as a $$PARAM type
-2-	alpha	EIGEN	Defines $$PARAM card type
-3- thru -10-	integer	EI(1) -thru- EI(8)	= +1 -- eigenvalues calculated = -1 -- no calculation default = -1 for all load cases except the last , +1.

K6ROT

The K6ROT parameter card is used to eliminate the plate element in- plane rotation singularity. The input value is a multiplication factor used to couple all three in-plane rotation degrees of freedom for the triangular element using the method of Chapter 13.4 of the reference below. If this card is omitted no coupling occurs.

```
field locations..
  -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
$$PARAM  K6ROT    ROTK6
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
$$PARAM  K6ROT     1.E-6
```

field	Format	Name	Description
-1-	alpha	$$PARAM	Defines this card as a $$PARAM type
-2-	alpha	K6ROT	Defines $$PARAM card type
-3	real	ROTK6	Value of multiplication factor. 1.E-6 is recommended

Reference:

O. C. Zienkiewicz. The Finite Element Method. McGraw-Hill, 1977, Third Edition.

LOADID

The LOADID parameter card controls the order of load application. The program currently allows up to 8 load cases to be sequentially analyzed. The LOADID card references RFORCE identification numbers only. This is a required card and has no defaults. End of input is signaled by a blank field.

```
field locations..
  -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
$$PARAM  LOADID   LD(1)    LD(2)    LD(3)    LD(4)    LD(5)    LD(6)    LD(7)
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
$$PARAM  LOADID      1        5       33        2        4       10        6
```

field	Format	Name	Description
-1-	alpha	$$PARAM	Defines this card as a $$PARAM type
-2-	alpha	LOADID	Defines $$PARAM card type
-3- thru -10-	integer	LD(1) -thru- LD(8)	RFORCE load identification number

Notes:

1. An RFORCE card is required for each indicated LD load identification.

2. A full finite element analysis is performed for each load case included. The large displacement solution (if nonlinear analysis is being performed) for a load case commences with the converged displaced shape of the previous load case. For STAT, only the results of the first load case are stored for application as constraints to the optimization (see Table 2).

MAXITER

The MAXITER parameter card defines the maximum number of iterations per load case allowed in order to achieve a converged solution. If this card is omitted, then MAXITER is defaulted to 20.

```
field locations..
  -1-     -2-     -3-     -4-     -5-     -6-     -7-     -8-     -9-
$$PARAM  MAXITER  MAX
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
$$PARAM  MAXITER   10
```

field	Format	Name	Description
-1-	alpha	$$PARAM	Defines this card as a $$PARAM type
-2-	alpha	MAXITER	Defines $$PARAM card type
-3-	integer	MAX	Maximum number of iterations/load to achieve a converged solution. (default = 20)

NONLIN

The NONLIN parameter card selects either a linear, prestressed stress and frequency analysis or a full nonlinear static analysis followed by a frequency analysis.

```
field locations..
  -1-     -2-     -3-     -4-     -5-     -6-     -7-     -8-     -9-
$$PARAM  NONLIN  TYPE
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
$$PARAM  NONLIN  YES
```

field	Format	Name	Description
-1-	alpha	$$PARAM	Defines this card as a $$PARAM type
-2-	alpha	NONLIN	Defines $$PARAM card type
-3-	alpha	TYPE	NO - linear, prestressed analysis, or, YES - full nonlinear analysis (default is YES)

Notes:

1. The NONLIN card controls the analysis for all load cases input on the LOADID card.
2. STAT bases its geometry definition on a "cold," or as manufactured airfoil. To properly evaluate the airfoil stresses and frequencies in the true running position, it is recommended that a nonlinear, large displacement analysis be performed.

PRINT

The PRINT parameter card controls the printed output for both the static and eigenvalue anaylses. This card works in conjunction with the LOADID card and follows the same load case input order. If this card is omitted printed output will only be generated for the last load case. The number of load cases is currently limited to 8 or less.

```
field locations..
 -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
$$PARAM   PRINT   IP(1)    IP(2)    IP(3)    IP(4)    IP(5)    IP(6)    IP(7)
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
$$PARAM   PRINT     +1       -1       -1       +1       +1       -1       +1
```

field	Format	Name	Description
-1-	alpha	$$PARAM	Defines this card as a $$PARAM type
-2-	alpha	PRINT	Defines $$PARAM card type
-3- thru -10-	integer	IP(1) -thru- IP(8)	+1 -- turns print on -1 -- turns print off (default = -1, except last load = +1)

SKPLOAD

The SKPLOAD parameter card controls load vector regeneration per itera- tion per load case. A SKPLOAD card set may be input for each load case to be analyzed. A value of +1 for an iteration causes the load vector to be regenerated, while a value of -1 means this iteration will use the previous load vector. The number of values input must be less than or equal to MAXITER. Continuation cards use fields -2- through -9- for input values and must be in order. End of input is signaled by a blank field.

```
field locations..
  -1-     -2-      -3-      -4-      -5-      -6-      -7-     -8-      -9-
$$PARAM  SKPLOAD  LOADID  SK(1)    SK(2)    SK(3)     ........SK(MAXITER)
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
$$PARAM  SKPLOAD   +1      -1       -1       +1       ........
```

field	Format	Name	Description
-1-	alpha	$$PARAM	Defines this card as a $$PARAM type
-2-	alpha	SKPLOAD	Defines $$PARAM card type
-3-	integer	LOADID	Defines load set for load regeneration control
-4- thru -9-	integer	SK(1) -thru- SK(6)	+1 -- load regenerated -1 -- use previous load (default = +1)
-10-	alpha	CONT	Indicates that another load control card follows

Continuation cards use fields -2- to -9- and must follow the parent card in the correct order. A blank field or no continuation flag in field -10- signals the end of input.

SKPMAT

The SKPMAT parameter card controls stiffness matrix regeneration per iteration per load case. A SKPMAT card set may be input for each load case to be analyzed. A value of +1 for an iteration causes the stiffness to be regenerated, while a value of -1 means this iteration will use the previous stiffness. The number of values input must be less than or equal to MAXITER. Continuation cards use fields -2- to -9- for input values and must be in order. End of input is signaled by a blank field.

```
field locations..
  -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
$$PARAM  SKPMAT   LOADID MK(1)    MK(2)    MK(3)    ........MK(MAXITER)
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
$$PARAM  SKPMAT    +1      -1       -1       +1      ........
```

field	Format	Name	Description
-1-	alpha	$$PARAM	Defines this card as a $$PARAM type
-2-	alpha	SKPMAT	Defines $$PARAM card type
-3-	integer	LOADID	Defines load set for matrix generation control
-4- thru -9-	integer	MK(1) -thru- MK(6)	+1 -- stiffness regenerated -1 -- use previous stiffness (default = +1)
-10-	alpha	CONT	Indicates that another load control card follows

Continuation cards use fields -2- to -9- and must follow the parent card in the correct order. A blank field or no continuation flag in field -10- signals the end of input.

Data Control

The Bulk Data Deck must begin with a BEGIN BULK card, and must end with an ENDDATA card. The bulk data deck contains the necessary $$PARAM control cards, as well as that supplementary data required to define the loadings, boundary conditions, Guyan reduction parameters, and, if required, blade neck geometry. The cards utilize NASTRAN bulk data input format. All bulk data cards are optional, unless otherwise indicated.

Bulk Data Initiation

```
field locations..
  -1-     -2-     -3-     -4-     -5-     -6-     -7-     -8-     -9-
BEGIN BULK
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
BEGIN BULK
```

Notes:

1. This card is required to indicate the start of the supplementary finite element inputs.

Bulk Data Termination

```
field locations..
  -1-     -2-     -3-     -4-     -5-     -6-     -7-     -8-     -9-
ENDDATA
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
ENDDATA
```

Notes:

1. This card is required to indicate the conclusion of the supplementary finite element inputs, and is the last card in the STAT data deck.

Nodal Point Definition

Nodal points for STAT are defined via GRID cards, as they are in the NASTRAN program. In STAT, however, all coordinate definitions are assumed to be in the global rectangular coordinate system.

```
field locations..
   -1-     -2-     -3-     -4-     -5-     -6-     -7-     -8-     -9-
GRID     ID              X1      X2      X3      CD      PS
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
GRID     1              16.     0.      0.              123456
```

field	Format	Name	Description
-1-	alpha	GRID	Defines this card as a GRID card
-2-	integer	ID	Grid point identification number
-3-			Leave blank
-4-	real	X1	Location of grid point in global coordinate system
-5-	real	X2	Location of grid point in global coordinate system
-6-	real	X3	Location of grid point in global coordinate system
-7-			Leave blank
-8-	integer	PS	Grid point permanent single point constraints

Element Definition

Elements available within STAT include springs (CELAS), a two noded beam (CBAR), and a three noded plate bending triangle (CTRIA3). While blade and neck elements are generated internally by the STAT blade generator, supplementary elements are occasionally necessary, as in representing the platform with a series of beams.

Beam Element

```
field locations..
  -1-       -2-       -3-       -4-       -5-       -6-       -7-       -8-       -9-
CBAR      EID       PID       GA        GB        X1        X2        X3
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
CBAR      81        81        6         11        1.        0.        0.
```

field	Format	Name	Description
-1-	alpha	CBAR	Defines a two noded beam element
-2-	integer	EID	Unique element identification number
-3-	integer	PID	Identification number of PBAR property card
-4-	integer	GA	First element grid connection point
-5-	integer	GB	Second element grid connection point
-6-	real	X1	Vector first component
-7-	real	X2	Vector second component
-8-	real	X3	Vector third component

Notes:

1. The vector v is defined by directing the vector components of fields 6 - 8 from grid point GA. This vector is used to define the directions associated with the bending stiffness properties on the PBAR card.

Spring Element

```
field locations..
  -1-     -2-     -3-     -4-     -5-     -6-     -7-     -8-     -9-
CELAS2  EID      K       G1      C1      G2      C2
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
CELAS2  100     1000.   1       4       2       4
```

field	Format	Name	Description
-1-	alpha	CELAS2	Defines a spring element
-2-	integer	EID	Unique element identification number
-3-	real	K	Stiffness value for spring
-4-	integer	G1	First grid connection point
-5-	integer	C1	Spring connection displacement component
-6-	integer	G2	Second grid connection point
-7-	integer	C2	Spring connection displacement component

Notes:

1. A zero or a blank for G2 implies a grounded spring terminal.

Triangular Plate Bending Element

```
field locations..
  -1-     -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
CTRIA3   EID      PID      G1       G2       G3      THETA
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
CTRIA3   1        1        6        1        2
```

field	Format	Name	Description
-1-	alpha	CTRIA3	Defines a three noded triangular plate bending element
-2-	integer	EID	Element identification number
-3-	integer	PID	Identification number of associated PSHELL property card
-4-	real	G1	First grid connection point
-5-	real	G2	Second grid connection point
-6-	real	G3	Third grid connection point
-7-	real	THETA	Material property orientation angle
-10-	alpha	CONT	Continuation card indicator when grid point thicknesses desired

Notes:

1. By including the optional continuation card, nodal thickness values may be input, thus allowing use of tapered element representations.

Triangular Plate Element (continuation card)

```
field locations..
  -1-     -2-     -3-     -4-     -5-     -6-     -7-     -8-     -9-
CONT                      T1      T2      T3
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
+CT1                     .050    .060    .075
```

field	Format	Name	Description
-1-	alpha	CONT	Continuation card indicator
-2-			Leave blank
-3-			Leave blank
-4-	real	T1	Thickness at first grid point (inches)
-5-	real	T2	Thickness at second grid point (inches)
-6-	real	T3	Thickness at third grid point (inches)

Element Properties Definition

Element properties for STAT are defined via PBAR and PSHELL cards for the beam and shell elements, respectively.

Beam Properties Definition

```
field locations..
  -1-     -2-     -3-     -4-     -5-     -6-     -7-     -8-     -9-
PBAR      PID     MID      A       I1      I2      J
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
PBAR      1       1      .12     .001    .0023   .006
```

field	Format	Name	Description
-1-	alpha	PBAR	Defines beam stiffness properties
-2-	integer	PID	Property identification number
-3-	integer	MID	Material identification number
-4-	real	A	Area of element cross-section (in**2)
-5-	real	I1	Area moment of inertia for bending in plane of element, v vector (in**4)
-6-	real	I2	Area moment of inertia for bending in plane defined by element, and normal to plane of I1 (in**4)
-7-	real	J	Torsional stiffness constant (in**4)
-10-	alpha	CONT	Continuation card indicator

Notes:

1. By including a continuation card, stress recovery coefficients ma y be input.

Beam Properties Definition (continuation card)

```
field locations..
  -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
CONT      C1       C2       D1       D2
1.......1........1........1........1........1........1........1........1........1
+PB1     .2       .3       .3       .4
```

field	Format	Name	Description
-1-	alpha	CONT	Continuation card indicator
-2-	real	C1	First recovery point local y axis stress recovery coordinate (inches)
-3-	real	C2	First recovery point local z axis stress recovery coordinate (inches)
-4-	real	D1	Second recovery point local y axis stress recovery coordinate (inches)
-5-	real	D2	Second recovery point local z axis stress recovery coordinate (inches)
-10-	alpha	CONT2	Second continuation card indicator

Notes:

1. If no stress recovery coefficients are included, only membrane stresses will be calculated.

2. By including a second continuation card, transverse shear flexibilities may be included.

Beam Properties Definition (second continuation card)

```
field locations..
  -1-     -2-     -3-     -4-     -5-     -6-     -7-     -8-     -9-
CONT2    K1      K2
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
+PB2     .8333   .8333
```

field	Format	Name	Description
-1-	alpha	CONT2	Continuation card indicator
-2-	real	K1	Transverse shear stiffness, plane 1 (dimensionless)
-3-	real	K2	Transverse shear stiffness, plane 2 (dimensionless)

Notes:

1. If no transverse shear card is included, transverse shear flexibilities are set to zero.

Plate Property Definition

```
field locations..
 -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
PSHELL    PID     MID1       T      MID2    12I/T**3  MID3     TS/T
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
PSHELL    1        1        .15      1        1.       1        1.
```

field	Format	Name	Description
-1-	alpha	PSHELL	Defines membrane, bending, and shear properties of thin shell elements
-2-	integer	PID	Property identification number
-3-	integer	MID1	Material identification for membrane
-4-	real	T	Default value for membrane thickness (inches)
-5-	integer	MID2	Material identification for bending
-6-	real	12I/T**3	Bending stiffness parameter (default = 1.0)
-7-	integer	MID3	Material identification for transverse shear
-8-	real	TS/T	Transverse shear thickness ratio (default = .8333)
-10-	alpha	CONT	Continuation card indicator when fiber stress recovery desired

Notes:

1. By including the optional continuation card, fiber distances for stress computation may be input.

Plate Property Definition (continuation card)

```
field locations..
  -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
CONT      Z1       Z2
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
+PS1     -.075    .075
```

field	Format	Name	Description
-1-	alpha	CONT	Continuation card indicator
-2-	real	Z1	First fiber distance (default is -T/2)
-3-	real	Z2	Second fiber distance (default is T/2)

Material Properties Definition

Both isotropic and anisotropic materials are available in STAT. In each case, only elastic, temperature independent properties are currently available.

Linear Isotropic Materials

```
field locations..
  -1-     -2-     -3-     -4-     -5-     -6-     -7-     -8-     -9-
MAT1     MID      E       G       NU      RHO      A
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
MAT1      1     16.1E6           .33     .41E-3
```

field	Format	Name	Description
-1-	alpha	MAT1	Defines linear, isotropic material properties
-2-	integer	MID	Material identification number
-3-	real	E	Young's modulus (psi)
-4-	real	G	Shear modulus (psi)
-5-	real	NU	Poisson's ratio
-6-	real	RHO	Mass density (lb * s**2 / in**4)

Notes:

1. If any one of the E, G, of NU fields is blank, the missing item will be calculated based upon the relation E = 2*(1+NU)*G

Linear Anisotropic Materials

```
field locations..
 -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
MAT2     MID      G11      G12      G13      G22      G23      G33      RHO
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
MAT2     101     19.E6    4.E6     0.       10.E6    0.       11.E6    .31E-3
```

field	Format	Name	Description
-1-	alpha	MAT2	Defines linear, anisotropic material properties
-2-	integer	MID	Material identification number
-3-	real	G11	G11 term of material property array property card (see note below)
-4-	real	G12	(see note below)
-5-	real	G13	(see note below)
-6-	real	G22	(see note below)
-7-	real	G23	(see note below)
-8-	real	G33	(see note below)
-9-	real	RHO	Mass density

Notes:

1. The convention for the Gij on fields 3 through 8 are represented by the matrix relationship:

```
| S1  |   =   | G11  G12  G13 |   | E1  |
| S2  |       | G12  G22  G23 |   | E2  |
| S12 |       | G13  G23  G33 |   | E12 |
```

2. 2x2 matrices (transverse shear properties) use elements G11, G12, and G22. In this case, G33 must be blank.

Coordinate System Definition

Local displacement coordinate systems may be defined using either rectangular or cylindrical definitions.

Cylindrical Coordinate System Definition

```
field locations..
  -1-     -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
CORD2C    CID               A1       A2       A3       B1       B2       B3
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
CORD2C   100                0.       0.       0.       0.       0.       1.
```

field	Format	Name	Description
-1-	alpha	CORD2C	defines a cylindrical coordinate system
-2-	integer	CID	Coordinate system identification number
-3-			Leave blank
-4-	real	A1	First coordinate of first definition point. See note below
-5-	real	A2	Second coordinate, first point
-6-	real	A3	Third coordinate, first point
-7-	real	B1	First coordinate, second point
-8-	real	B2	Second coordinate, second point
-9-	real	B3	Third coordinate, second point
-10-	alpha	CONT	Continuation card indicator - required

Cylindrical Coordinate System Definition (continuation card)

```
field locations..
  -1-     -2-     -3-     -4-     -5-     -6-     -7-     -8-     -9-
CONT      C1      C2      C3
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
+COC1     1.      0.      1.
```

field	Format	Name	Description
-1-	alpha	CONT	Continuation card indicator
-2-	real	C1	First coordinate, third point
-3-	real	C2	Second coordinate, third point
-4-	real	C3	Third coordinate, third point

Notes:

1. The three points (noncollinear) define the local system as follows:
   a. Point 1 is the origin of the new system.
   b. Point 2 lies on the positive side of the new local z-axis.
   c. Point 3 lies in the first quadrant of the new x-z plane.

Rectangular Coordinate System Definition

```
field locations..
  -1-       -2-       -3-       -4-       -5-       -6-       -7-       -8-       -9-
CORD2R    CID                 A1        A2        A3        B1        B2        B3
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
CORD2R    100                 0.        0.        0.        0.        0.        1.
```

field	Format	Name	Description
-1-	alpha	CORD2R	defines a rectangular coordinate system
-2-	integer	CID	Coordinate system identification number
-3-			Leave blank
-4-	real	A1	First coordinate of first definition point. See note below
-5-	real	A2	Second coordinate, first point
-6-	real	A3	Third coordinate, first point
-7-	real	B1	First coordinate, second point
-8-	real	B2	Second coordinate, second point
-9-	real	B3	Third coordinate, second point
-10-	alpha	CONT	Continuation card indicator - required

Rectangular Coordinate System Definition (continuation card)

```
field locations..
  -1-     -2-     -3-     -4-     -5-     -6-     -7-     -8-     -9-
CONT      C1      C2      C3
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
+COR1     1.      0.      1.
```

field	Format	Name	Description
-1-	alpha	CONT	Continuation card indicator
-2-	real	C1	First coordinate, third point
-3-	real	C2	Second coordinate, third point
-4-	real	C3	Third coordinate, third point

Notes:

1. The three points (noncollinear) define the local system as follows:
   a. Point 1 is the origin of the new system.
   b. Point 2 lies on the positive side of the new local z-axis.
   c. Point 3 lies in the first quadrant of the new x-z plane.

Constraint Definition

Constraints available within STAT are ties to ground (SPC and GRID) and rigid element (RBE) constraints.

Rigid Body Element Definition

```
field locations..
  -1-     -2-     -3-     -4-     -5-     -6-     -7-     -8-     -9-
RBE2     EID     GN      CM      GM1     GM2     GM3     GM4     GM5
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
RBE2    1000     6      123456   11
```

field	Format	Name	Description
-1-	alpha	RBE2	Defines a rigid body element
-2-	integer	EID	Unique identification number
-3-	integer	GN	Independent grid point
-4-	integer	CM	Dependent degree of freedom displacement components
-5- to -4+i-	integer	GM1 -to- GMi	Grid points at which dependent degrees of freedom are assigned
-10-	alpha	CONT	Continuation card indicator (as required to complete grid list)

Rigid Body Element (continuation card)

```
field locations..
  -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
CONT       GM6      GM7      GM8      etc.
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
+RB1
```

field	Format	Name	Description
-1-	alpha	CONT	Continuation card indicator
-2- to - i-4 -	real	GM6 -to- GMi	Grid points at which dependent degrees of freedom are assigned

Single Point Constraint

```
field locations..
   -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
SPC                   G        C        D
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
SPC                  1       123456
```

field	Format	Name	Description
-1-	alpha	SPC	Defines single point constraints and enforced displacements
-2-			Leave blank
-3-	integer	G	Grid point identification number
-4-	integer	C	Displacement components to be constrained
-5-	real	D	Value of enforced displacement

Single Point Constraint, Alternate Form

```
field locations..
  -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
SPC1               C        G1       G2       G3       G4       G5       G6
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
SPC1             123456  1        2        3
```

or, alternatively,

```
field locations..
  -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
SPC1               C      GID1    "THRU"   GID2
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
SPC1             123456  1        THRU     5
```

field	Format	Name	Description
-1-	alpha	SPC1	Defines single point constraints
-2-			Leave blank
-3-	integer	C	Displacement components to be constrained
-4- to - 3+i -	integer	G1, GID1 -to- Gi, GID2	Grid point numbers

Notes:

1. As many continuation cards as desired may be used when "THRU" is not used.

Guyan Reduction Control

To allow efficient eigenvalue extraction, and keep the solution within core limits, STAT utilizes Guyan reduction, prescribed through ASET and ASET1 data cards. For STAT blades, the recommended set is listed in Section 4, Example Input. By altering this set, however, the user can tune the accuracy of his frequencies, to improve tip mode results, for instance. Because STAT uses lumped mass representations, all rotational degrees of freedom may be omitted (deselected from the ASET) with no accuracy loss.

Aset Coordinate Selection

```
field locations..
  -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
ASET       ID        C       ID        C       ID        C       ID        C
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
ASET       41       123      43       123      45       123
```

field	Format	Name	Description
-1-	alpha	ASET	Defines degrees of freedom to remain in the analysis set
-2-,-4-, -6- and -8-	integer	ID	Grid point identification number
-3-,-5-, -7- and -9-	integer	C	Displacement components to be kept in the analysis set

C-2

Aset Coordinate Selection, Alternate Form

```
field locations..
  -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
ASET1      C        G        G        G        G        G        G        G
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
ASET1     123      41       43       45
```

or, alternatively,

```
field locations..
  -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
ASET1      C       ID1    "THRU"     ID2
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
ASET1      23       21      THRU      25
```

field	Format	Name	Description
-1-	alpha	ASET1	Defines degrees of freedom to be placed in analysis set
-2-	integer	C	Displacement components to be kept in analysis set
-3- to -9-	integer	G, ID1, ID2	Grid point identification number

Eigenvalue Extraction Control

The STAT finite element code uses an upper Hessenberg extraction procedure similar to the Givens' (GIV) method of the NASTRAN program. An eigenvalue extraction control card is required to indicate the number of eigenvectors and the frequency range that the analyst is considering for later analysis.

Real Eigenvalue Extraction Data

```
field locations..
  -1-     -2-     -3-     -4-     -5-     -6-     -7-     -8-     -9-
EIGR                      F1      F2              ND
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
EIGR                      50.    3000.            10
```

field	Format	Name	Description
-1-	alpha	EIGR	Eigenvalue extraction control
-4-	real	F1	Lower frequency of range of interest (Hz)
-5-	real	F2	Upper frequency of range of interest (Hz)
-7-	integer	ND	Desired number of eigenvectors

Load Definition

Load inputs to STAT include point loads (FORCE, FORCE1 AND FORCE2), point moments (MOMENT, MOMENT1 and MOMENT2), and centrifugal loads (RFORCE).

Static Load at a Grid Point

```
field locations..
   -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
FORCE                 G       CID       F       N1       N2       N3
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
FORCE                12        12    100.       0.       1.       0.
```

field	Format	Name	Description
-1-	alpha	FORCE	Defines a static load at a grid point by specifying a vector
-3-	integer	G	Grid point identification number
-4-	integer	CID	Coordinate system identification number
-5-	real	F	Load scale factor
-6- to -8-	real	N1,N2, N3	Components of vector measured in coordinate system defined by CID

Notes:

1. A CID of zero references the basic coordinate system.
2. The load applied is the scale factor F times the vector (N1,N2,N3).

Static Load, Alternate Form 1

```
field locations..
   -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
FORCE1               G        F        G1       G2
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
FORCE1               12       100.     100      101
```

field	Format	Name	Description
-1-	alpha	FORCE1	Defines a static load at a grid point by specifying a value and two grid points to define direction
-3-	integer	G	Loaded grid point identification number
-4-	real	F	Value of load
-5-	integer	G1	Grid point identification number
-6-	integer	G2	Grid point identification number

Notes:

1. The direction of the force is determined by the vector from G1 to G2.

Static Load, Alternate Form 2

```
field locations..
  -1-       -2-       -3-       -4-       -5-       -6-       -7-       -8-       -9-
FORCE2               G         F        G1        G2        G3        G4
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
FORCE2              12       111.      101       102       103       104
```

field	Format	Name	Description
-1-	alpha	FORCE2	Defines a static load at a grid point by specifying a value and four grids to define direction.
-3-	integer	G	Grid point identification number where load is to be applied.
-4-	real	F	Value of load.
-5- to -8-	integer	-G1- to -G4-	Grid points to define load direction (see note below).

Notes:

1. The direction of the force is determined by the vector cross product of the vector from G1 to G2 and the vector from G3 to G4.

Static Moment at a Grid Point

```
field locations..
  -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
MOMENT              G        CID      M        N1       N2       N3
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
MOMENT              12          12    100.     0.       1.       0.
```

field	Format	Name	Description
-1-	alpha	MOMENT	Defines a static moment at a grid point by specifying a vector
-3-	integer	G	Grid point identification number
-4-	integer	CID	Coordinate system identification number
-5-	real	M	Moment scale factor
-6- to -8-	real	N1,N2, N3	Components of vector measured in coordinate system defined by CID

Notes:

1. A CID of zero references the basic coordinate system.
2. The load applied is the scale factor M times the vector (N1,N2,N3).

Static Moment, Alternate Form 1

```
field locations..
   -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-
MOMENT1             G        M        G1       G2
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
MOMENT1             12       100.     100      101
```

field	Format	Name	Description
-1-	alpha	MOMENT1	Defines a static moment at a grid point by specifying a value and two grid points to define direction
-3-	integer	G	Loaded grid point identification number
-4-	real	M	Value of moment
-5-	integer	G1	Grid point identification number
-6-	integer	G2	Grid point identification number

Notes:

1. The direction of the moment is determined by the vector from G1 to G2.

Static Moment, Alternate Form 2

```
field locations..
  -1-     -2-     -3-     -4-     -5-     -6-     -7-     -8-     -9-
MOMENT2           G       M       G1      G2      G3      G4
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
MOMENT2           12      111.    101     102     103     104
```

field	Format	Name	Description
-1-	alpha	MOMENT2	Defines a static moment at a grid point by specifying a value and four grids to define direction
-3-	integer	G	Grid point identification number where load is to be applied
-4-	real	M	Value of moment
-5- to -8-	integer	-G1- to -G4-	Grid points to define load direction (see note below)

Notes:

1. The direction of the force is determined by the vector cross product of the vector from G1 to G2 and the vector from G3 to G4.

Static Load Due to Centrifugal Force Field

```
field locations..
  -1-     -2-     -3-     -4-     -5-     -6-     -7-     -8-     -9-
RFORCE    SID                             A       N1      N2      N3
1.......1.......1.......1.......1.......1.......1.......1.......1.......1
RFORCE    SID                           100.      0.      0.      1.
```

field	Format	Name	Description
-1-	alpha	RFORCE	Defines a static load due to a centrifugal force field
-2-	integer	SID	Load set identification number
-5-	real	A	Scale factor for rotational velocity, revolutions per unit time
-6- to -8-	real	N1,N2, N3	Components of rotation direction vector, global coordinate system, rotation about system origin

Notes:

1. RFORCE card load sets must be selected by the $$PARAM LOADID card.
2. STAT's airfoil coordinate system (right-handed, cartesian) is as follows:
   X - Radial, positive away from engine centerline
   Y - Tangential
   Z - Engine axial, positive aft

Example Input

Section 6 contains an example of a typical input file required to execute the STAT program. This input file describes the geometry for a spar and shell constructed counter rotation Prop-Fan stage. In addition, all the input needed to define the optimization problem and the finite element control cards are included.

The spar and shell blade is constructed of four materials; an external shell, labeled SHELL, covering the entire surface; a leading edge sheath, labeled SHEA; a centrally located spar, labeled SPAR; and finally a filler layer of foam, labeled FOAM.

The example should be reviewed while following the input definition found in SECTIONs 1 through 5.

```
field locations..
  -1-     -2-     -3-     -4-     -5-     -6-     -7-     -8-     -9-     -10-
1.......1.......1.......1.......1.......1.......1.......1.......1.......1.......1

$
$  CRPX1 Counter-Rotating Propfan Scaled to Full Size
$
$=======================================================================
$  INDEPENDENT AXIS DEFINITIONS.. SPANWISE LOCATIONS
$=======================================================================
ABSCISSA     ROR       1   .2450   .2965   .3665   .4594   .5668   .6792+
+          .7866   .8795   .9495  1.0000
ABSCISSA    RORR       2   .2820   .2965   .3665   .4594   .5668   .6792+
+          .7866   .8795   .9495  1.0000
ABSCISSA   SPAN2       3  0.2389  0.2870  0.3426  0.3981  0.4537  0.5000+
+         0.5370  0.5926  0.6481  0.7037  0.7593  0.8056  0.8519  0.8796+
+         0.9074  0.9352  0.9630  0.9815  1.0000
ABSCISSA   SPAN3       4  0.2389  0.3426  0.3981  0.4537  0.5000  0.5370+
+         0.5926  0.6481  0.7037  0.7593  0.8056  0.8519  0.8796  0.9074+
+         0.9352  0.9630  0.9815  1.0000
```

field locations..

```
  -1-     -2-     -3-     -4-     -5-     -6-     -7-     -8-     -9-     -10-
1.......1.......1.......1.......1.......1.......1.......1.......1.......1.......1

$=========================================================================
$  DEPENDENT AXIS VALUES.. CHORD, THICKNESS, TWIST .... ETC.
$=========================================================================
CURVE        HOB       1       1   .1911   .1030   .0664   .0490   .0380+
+          .0301   .0248   .0218   .0204  .02004
CURVE        BOD       1       2   .1636  .17170   .1840   .1980   .2040+
+          .1952   .1740   .1420   .1060  .07094
CURVE        CLD       1       3   .0450  .07000   .0950   .1300   .1710+
+          .2070   .2300    .231   .2200    .204
CURVE       BETA       1       4   24.07   21.40   17.79   13.00    7.60+
+           2.60   -1.50   -4.30   -6.15   -7.36
CURVE       CONE       1       5    5.33    4.22    3.42    2.69    1.98+
+           1.35     .85     .47     .21     .05
CURVE        XOR       1       6  .24499  .29627  .36598  .45868  .56651+
+         .67910  .78403  .87114  .93523  .98104
CURVE        YOR       1       7 -.00173  -.0097  -.0195  -.0257  -.0180+
+         .01150  .06350  .12100  .16400  .19368
CURVE        ZOR       1       8 -.00371  -.0165  -.0370  -.0419  -.0251+
+          .0137  .06978  .12200  .15875  .18324
CURVE       HOBR       2       9   .1739   .1422   .0717   .0508   .0369+
+          .0282   .0240   .0219   .0206  .02000
CURVE       BODR       2      10   .1690   .1714   .1842   .1975   .2027+
+          .1939   .1733   .1428   .1048   .0715
CURVE       CLDR       2      11   .0010   .0070   .0400   .1050   .1590+
+          .1971   .2250   .2298   .2191   .2035
CURVE      BETAR       2      12   16.87   16.53   14.82   11.81    7.50+
+           2.64   -1.60   -3.57   -4.77   -5.50
CURVE      CONER       2      13    4.90    4.69    3.90    3.10    2.33+
+           1.63    1.04     .60     .33     .17
CURVE       XORR       2      14  .28201  .29648  .36600  .45853  .56647+
+         .67908  .78373  .87045  .93348  .97897
CURVE       YORR       2      15 -.00114 -.00352  -.0193  -.0283  -.0193+
+         .01268  .06708  .12578  .17368  .20400
CURVE       ZORR       2      16 -.01450 -.01837 -.03396 -.03982 -.02427+
+          .0155  .06546  .11432  .14877  .17150
$=========================================================================
$  blade component geometry.. spar, shell, sheath and foam
$=========================================================================
CURVE   SPAR  ML       4      17  0.5449  0.5768  0.5940  0.5988  0.5962+
+         0.5896  0.5797  0.5625  0.5421  0.5188  0.4829  0.4452  0.4152+
+         0.3919  0.3796  0.3644  0.3600  0.3556
CURVE   SPAR C/S       4      18  0.3097  0.4232  0.4840  0.5078  0.5143+
+         0.5151  0.5178  0.5227  0.5323  0.5481  0.5776  0.6188  0.6433+
+         0.6351  0.5959  0.5053  0.3867  0.2681
CURVE   SHEL T/S       3      19  0.0360  0.0360  0.0400  0.0440  0.0480+
+         0.0510  0.0530  0.0540  0.0540  0.0540  0.0540  0.0540  0.0510+
+         0.0480  0.0430  0.0380  0.0330  0.0310  0.0300
CURVE   SHEA  ML       3      20   .0000   .0000   .0000   .0000   .0000+
+          .0000   .0000   .0000   .0000   .0000      0.      0.      0.+
+          .0000   .0000   .0000   .0000   .0000      0.
CURVE   SHEA C/S       3      21  0.0910  0.0910  0.0910  0.0910  0.0910+
+         0.0910  0.1170  0.1650  0.2080  0.2540  0.2970  0.3420  0.3920+
+         0.4390  0.4860  0.5390  0.5850  0.5070  0.5000
CURVE   SHEA T/S       3      22  0.0200  0.0200  0.0200  0.0200  0.0200+
+         0.0200  0.0200  0.0200  0.0200  0.0200  0.0200  0.0200  0.0200+
+         0.0200  0.0200  0.0200  0.0200  0.0200  0.0200
$
$ component cutoffs...
$
CUTOFF  SHEA    L       23      21     .50
```

field locations..

```
  -1-      -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-     -10-
1.......1.......1.......1.......1.......1.......1.......1.......1.......1.......1

$========================================================================
$ BLADE EXTERNAL SHAPE VARIABLES.. FRONT
$========================================================================
$
$  TWIST...(BETA)
$
CONSTANT TW.250        4   .2500
VARIABLE TW.455        1       4   .4547   -90.0     90.0
VARIABLE TW.785        2       4   .7845   -90.0     90.0
VARIABLE TW1.00        3       4     1.0   -90.0     90.0
$
$ TANGENTIAL TILT...(YOR)
$
CONSTANT YOR.250       7   .2500
VARIABLE YOR.676       4       7   .6762 -1.E-01  1.E-01
VARIABLE YOR1.00       5       7     1.0 -1.E-01  1.E-01
$
$ AXIAL TILT...(ZOR)
$
CONSTANT ZOR.250       8   .2500
VARIABLE ZOR.676       6       8   .6762 -1.E-01  1.E-01
VARIABLE ZOR1.00       7       8     1.0 -1.E-01  1.E-01
$========================================================================
$ BLADE EXTERNAL SHAPE VARIABLES.. REAR
$========================================================================
$
$  TWIST...(BETA)
$
CONSTANT TW.25R       12   .2500
VARIABLE TW.67R        8      12   .6762   -90.0     90.0
VARIABLE TW1.0R        9      12     1.0   -90.0     90.0
$
$ TANGENTIAL TILT...(YOR)
$
CONSTANT YOR.25R      15   .2500
VARIABLE YOR.67R      10      15   .6762 -1.E-01  1.E-01
VARIABLE YOR1.0R      11      15     1.0 -1.E-01  1.E-01
$
$ AXIAL TILT...(ZOR)
$
CONSTANT ZOR.25R      16   .2500
VARIABLE ZOR.67R      12      16   .6762 -1.E-01  1.E-01
VARIABLE ZOR1.0R      13      16     1.0 -1.E-01  1.E-01
$========================================================================
$ BLADE COMPOSITE CONSTRUCTION VARIABLES - BOTH FRONT AND REAR
$========================================================================
$
$  SPAR CHORDWISE POSITION
$
VARIABLE SPAR ML      14      17   .2389   -.40      .40
VARIABLE SPAR ML      15      17   .6481   -.40      .40
VARIABLE SPAR ML      16      17     1.0   -.40      .40
$
$  SPAR CHORDWISE EXTENT
$
VARIABLE SPAR CS      17      18   .2389   -.25      .25
VARIABLE SPAR CS      18      18   .6481   -.25      .25
VARIABLE SPAR CS      19      18     1.0   -.25      .25
$
$  SHELL THICKNESS
$
VARIABLE SHEL  T      20      19   .2389   -.02      1.0
VARIABLE SHEL  T      21      19   .6481   -.02      1.0
VARIABLE SHEL  T      22      19     1.0   -.02      1.0
```

```
field locations..
  -1-     -2-     -3-     -4-     -5-     -6-     -7-     -8-     -9-    -10-
1.......1.......1.......1.......1.......1.......1.......1.......1.......1.......1

$=========================================================================
$  CONSTRAINTS....FRONT ROTOR
$=========================================================================
CONSTRNT F1 / 2P   1.000        5       0       1
&CNST      246.3     0.1
$
CONSTRNT F2 / 5P   1.000        5       0       2
&CNST      615.7    .025
$
CONSTRNT F3 / 5P   1.000        5       0       3
&CNST      615.7    .025
$
$ layer Tsai-Wu stress constraints...
$
CONSTRNT  SHEATH       1.       1       0       11
&CNST          1.0
$
CONSTRNT  SHELL        1.       1       0       12
&CNST          1.0
$
CONSTRNT  SPAR         1.       1       0       14
&CNST          1.0
$
CONSTRNT  FOAM         1.       1       0       13
&CNST          1.0
$
$ FLUTTER CONSTRAINTS..
$
CONSTRNT FLUT MN    1.00        2       0       61
&CNST          1.0
CONSTRNT STALL P    1.00        2       0       62
&CNST          1.0
$
$ POWER CONSTRAINED 5349.6 HP...
$
CONSTRNT POWER      1.00        1      -1       63
&CNST      5349.6
$
CONSTRNT ONEPFR        1.       1       0       70
&CNST          1.0
$
$=========================================================================
$  CONSTRAINTS....REAR  ROTOR
$=========================================================================
CONSTRNT F1/2P R   1.000        5       0       81
&CNST      246.3     0.1
$
CONSTRNT F2/5P R   1.000        5       0       82
&CNST      615.7    .025
$
CONSTRNT F3/5P R   1.000        5       0       83
&CNST      615.7    .025
$
$ layer Tsai-Wu stress constraints...
$
CONSTRNT  SHEATH       1.       1       0       91
&CNST          1.0
$
CONSTRNT  SHELL        1.       1       0       92
&CNST          1.0
$
CONSTRNT  SPAR         1.       1       0       94
&CNST          1.0
$
CONSTRNT  FOAM         1.       1       0       93
&CNST          1.0
```

field locations..

```
  -1-     -2-     -3-     -4-     -5-     -6-     -7-     -8-     -9-     -10-
1.......1.......1.......1.......1.......1.......1.......1.......1.......1.......1

$
$ FLUTTER CONSTRAINTS..
$
CONSTRNT FL MN R    1.00       2       0       141
&CNST        1.0
CONSTRNT STL P R    1.00       2       0       142
&CNST        1.0
$
$ POWER CONSTRAINED 5349.6 HP...
$
CONSTRNT POWER R    1.00       1      -1       143
&CNST     5349.6
$
CONSTRNT 1P FR R      1.       1       0       150
&CNST        1.0
$
$
OPTIMIZE       0       5       8    3552       0       8      50
PLOT          NO
$
$    1 - EFFICR    4 - BDS      7 -            10 - GAEROH
$    2 - CNOISE    5 - FEARUN   8 - FLUTER
$    3 - ONEP      6 - ONEPFR   9 - OBJF
$
DEBUG       0   0   0   0   0   0   0   0   0   0
$
$=========================================================================
$  composite layer material and layup hierarchy..
$=========================================================================
PRIORITY     SHEA    SHEL    SPAR    FOAM
LAY-UP       SHEA    SHEL    FOAM    SPAR
PRIORITR     SHEA    SHEL    SPAR    FOAM
LAY-UPR      SHEA    SHEL    FOAM    SPAR
MATERIAL     SHEA 30.E+06 30.E+06    .271211.8E+06      .32
+         94000.  94000.  94000.  94000.  54238.
+         30000.  30000.  30000.  30000.  17310.
MATERIAL     SHEL2.225E+62.225E+6     .4501.55E+06     .065
+         21000.  21000.  21000.  21000.  12120.
+          7000.   7000.   7000.   7000.   4040.
MATERIAL     SPAR10.4E+0610.4E+06      .33 3.9E+06     .101
+        100000. 100000. 100000. 100000.  57700.
+         15000.  15000.  15000.  15000.   8655.
MATERIAL     FOAM  9800.0  9800.0      .35 3630.00   .0046
+         245.00  245.00  245.00  245.00  141.37
+          48.00   48.00   48.00   48.00   27.70
*END_OPT
$=========================================================================
$ AERODYNAMIC ANALYSIS DATA..
$=========================================================================
BLADE          5      10    .245  58.230   .0710   55.40      5.    .75+
+           12.0      .8      1.   9.000   .5224
ENVIRON   35000. 1193.66  414.90  -65.82      1.      2.     36.     1.+
+             1.    -22.
AIRFOIL      23.     23.     23.     23.     23.     23.     23.    23.+
+            23.     23.
AXIALV     1.000   1.000   1.000   1.000   1.000   1.000   1.000  1.000+
+          1.000   1.000
FILR/R      .245      .3      .4      .5      .6      .7      .8     .9+
+            .94     .98      1.
BLADER         5      10    .282  58.430   .0720   52.15      5.    .75+
+           12.0      .8      1.   9.000   .5224
ENVIRONR  35000. 1193.66  414.90  -65.82      1.      2.     36.     1.+
+             1.    -22.
AIRFOILR     23.     23.     23.     23.     23.     23.     23.    23.+
+            23.     23.
AXIALVR    1.000   1.000   1.000   1.000   1.000   1.000   1.000  1.000+
+          1.000   1.000
FILR/RR     .282      .3      .4      .5      .6      .7      .8     .9+
+            .94     .98      1.
*END_EFF
```

field locations..

```
  -1-     -2-      -3-      -4-      -5-      -6-      -7-      -8-      -9-     -10-
1.......1.......1.......1.......1.......1.......1.......1.......1.......1.......1
$=========================================================================
$ OBJECTIVE FUNCTION DATA...
$=========================================================================
OBJTYPE        1
BASELINE  37.15     750.       5. 235.000 35.0000    .880 143.435  12850.+
+         5782.     12.0       2.     5.0     1.0     1.0    .520    .800
BASELNR   37.15     750.       5. 235.000 35.0000 143.435  12850.   5782.+
+          .800
SENSE      1.57     2.10     2.38    0.74    1.30    1.76     .27    0.10
*END_OBJ
$=========================================================================
$ GEOMETRY GENERATION DATA... AERO MODEL --> FEA MODEL
$=========================================================================
GEOMGEN    LEFT        1        0       2
+             4       10      .15     .45      .0    0.00
+             1       10     .610     1.1    .000      .0
CHORDTAB    0.1    16.07    32.15   50.00   62.41   81.20    99.9
SPANTAB    .242      .40      .50     .60     .70     .80     .85     .90+
+           .95     1.00
GEOMGENR  RIGHT        1        0       2
+             4       10      .15     .45      .0    0.00
+             1       10     .610     1.1      .0      .0
CHRDTABR    0.1    16.07    32.15   50.00   62.41   81.20    99.9
SPANTABR   .282      .40      .50     .60     .70     .80     .85     .90+
+           .95     1.00
*END_GEN
$=========================================================================
$ FINITE ELEMENT ANALYSIS DATA...FRONT BLADE
$=========================================================================
BEGIN BULK
EIGR           1      GIV       1.  30000.          5       5       0
$
$  ROOT MODEL -- BAR ELEMENTS
$
GRID          71          17.279
GRID          72           10.93
CBAR         109      109       72      71      0.      1.      0.
CBAR         110      110       71      67      0.      1.      0.
CBAR         111      110       67      66      0.      1.      0.
CBAR         112      110       67      68      0.      1.      0.
PBAR         109      217    21.98   38.22   38.22   76.45
PBAR         110      218    10.00   10.00   10.00   20.00
$
$ ROOT CONSTRAINT AND INDEPENDENT DOF'S..
$
SPC1           1   123456       72
ASET1   123           55       53      51
ASET1   123           41       39      37
ASET1   123           27       25      23
ASET1   123           13       11       9
MAT1         217.160E+08 6.1E+06.310E+00.414E-03
MAT1         218.160E+08 6.1E+06.310E+00.000E-03
RFORCE         1                 -19.89.0       .0       .100E+01
```

```
field locations..

  -1-     -2-     -3-     -4-     -5-     -6-     -7-     -8-     -9-     -10-
1.......1.......1.......1.......1.......1.......1.......1.......1.......1.......1

$========================================================================
$ FINITE ELEMENT CONTROL CARDS..
$========================================================================
$$PARAM   NONLIN     YES
$$PARAM  MAXITER      25
$$PARAM   LOADID       1
$$PARAM    PRINT      -1
$$PARAM    EIGEN      +1
$$PARAM  SKPLOAD       1      +1      +1      +1      +1      +1
$$PARAM   SKPMAT       1      +1      +1      +1      +1      +1
$$PARAM   STRESS     YES
$$PARAM  CONVERG  STRAIN  .00001
$$PARAM    K6ROT 1.0E-06
ENDDATA
$========================================================================
$ FINITE ELEMENT ANALYSIS DATA...REAR BLADE
$========================================================================
BEGIN BULK
EIGR           1     GIV      1.  30000.       5       5       0
$
$  ROOT MODEL -- BAR ELEMENTS
$
GRID          71         20.2066
GRID          72          13.858
CBAR         109     109      72      71      0.      1.      0.
CBAR         110     110      71      67      0.      1.      0.
CBAR         111     110      67      66      0.      1.      0.
CBAR         112     110      67      68      0.      1.      0.
PBAR         109     217   21.98   38.22   38.22   76.45
PBAR         110     218   10.00   10.00   10.00   20.00
$
$ ROOT CONSTRAINT AND INDEPENDENT DOF'S..
$
SPC1           1  123456      72
ASET1    123          55      53      51
ASET1    123          41      39      37
ASET1    123          27      25      23
ASET1    123          13      11       9
MAT1         217.160E+08 6.1E+06.310E+00.414E-03
MAT1         218.160E+08 6.1E+06.310E+00.000E-03
RFORCE         1                 -19.89.0      .0      .100E+01
$========================================================================
$ FINITE ELEMENT CONTROL CARDS..
$========================================================================
$$PARAM   NONLIN     YES
$$PARAM  MAXITER      25
$$PARAM   LOADID       1
$$PARAM    PRINT      -1
$$PARAM    EIGEN      +1
$$PARAM  SKPLOAD       1      +1      +1      +1      +1      +1
$$PARAM   SKPMAT       1      +1      +1      +1      +1      +1
$$PARAM   STRESS     YES
$$PARAM  CONVERG  STRAIN  .00001
$$PARAM    K6ROT 1.0E-06
ENDDATA
```

Special Applications

Section 7 contains an example which illustrates special or non-standard input. The user should reference this section when questions arise as to the validity of any non-standard input.

Example #1. Non-unique VARIABLE and CUTOFF ID#'s.

A composite propfan blade model consisting of 12 separate layers; (1) a fiberglass shell, (2) a layer of fiberglass, (3) a layer of graphite, (4) a layer of fiberglass, (5) a layer of graphite, (6) a layer of fiberglass, (7) a layer of graphite, (8) a layer of fiberglass, (9) a layer of glue, and (10) the geometric centered titanium spar with all remaining gaps filled with either fiberglass or foam material yields an example of separate materials with coin- cident width (C/S CURVEs) and position (ML CURVEs). All of the five fiberglass layers cover the entire blade, whereas the three separate graphite layers have unique C/S and ML CURVEs defined, but the remaining glue and spar layers have the unique characteristic that where ever spar exist there must be glue to tack on the innermost fiberglass layer.

Since, the glue and spar are to be coincident, it is most efficient to reference the same identification numbers on both the CURVE and CUTOFF cards used to define these layers. The CURVE mnemonic names remain unique and act to differentiate between the coincident layers. Note, that even though the spar and glue layers are coincident, it is still necessary to have CURVEs for each material. The following input shows that CURVE IDs 25 and 26 are used for the glue layer ('GLUE') and for the spar layer ('SPAR'). Additionally, the CUTOFF identification numbers 45 and 46 are shared by the glue and spar layers. The sharing of ID numbers while maintaining unique mnemonic names allows for the two layers to have coincident area coverage, but unique thickness and material definitions. This also reduces the number of geometric variables by a factor of two. Note, the input listed below contains only the data required for this particular example and is not complete.

field locations..

```
  -1-     -2-     -3-     -4-     -5-     -6-     -7-     -8-     -9-     -10-
1.......1.......1.......1.......1.......1.......1.......1.......1.......1.......1
$========================================================================
$  independent axis definitions.. spanwise locations
$========================================================================
ABSCISSA  SPAN1         2  0.2056  0.2500  0.2870  0.3426  0.3981  0.4537+
+         0.5000  0.5371  0.5926  0.6482  0.7037  0.7593  0.8056  0.8518+
+         0.8796  0.9074  0.9352  0.9629  0.9815  1.0000
```

field locations..

```
  -1-     -2-     -3-     -4-     -5-     -6-     -7-     -8-     -9-     -10-
1.......1.......1.......1.......1.......1.......1.......1.......1.......1.......1
$========================================================================
$  blade component geometry.. spar, glue only
$========================================================================
CURVE   GLUE  ML       2      25  0.4150  0.4875  0.5311  0.5690  0.5933+
+         0.5983  0.5923  0.5846  0.5711  0.5561  0.5365  0.5136  0.5036+
+         0.4962  0.4834  0.4605  0.4204  0.3453  0.2538  0.0881
CURVE   SPAR  ML       2      25  0.4150  0.4875  0.5311  0.5690  0.5933+
+         0.5983  0.5923  0.5846  0.5711  0.5561  0.5365  0.5136  0.5036+
+         0.4962  0.4834  0.4605  0.4204  0.3453  0.2538  0.0881
CURVE   GLUE C/S       2      26  0.1431  0.1631  0.2147  0.3324  0.4002+
+         0.4230  0.4242  0.4193  0.4071  0.3912  0.3671  0.3203  0.2235+
+         0.0659  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
CURVE   SPAR C/S       2      26  0.1431  0.1631  0.2147  0.3324  0.4002+
+         0.4230  0.4242  0.4193  0.4071  0.3912  0.3671  0.3203  0.2235+
+         0.0659  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
$
$ component cutoffs...
$
CUTOFF  GLUE    1      45      26  .20316
CUTOFF  SPAR    1      45      26  .20316
CUTOFF  GLUE    U      46      26  .80555
CUTOFF  SPAR    U      46      26  .80555
$========================================================================
$ blade component design variables..
$========================================================================
$
$  cutoff variable...upper cutoff for both spar and glue
$
VARIABLE SPGL CO       1      46              -.5      .5
$
$  spar and glue chordwise position...
$
VARIABLE SPGL ML       2      25   .2500    -.40     .40
VARIABLE SPGL ML       3      25   .6250    -.40     .40
VARIABLE SPGL ML       4      25     1.0    -.40     .40
$
$  spar and glue chordwise extent...
$
VARIABLE SPGL CS       7      26   .2389    -.25     .25
VARIABLE SPGL CS       8      26   .6200    -.25     .25
VARIABLE SPGL CS       9      26     1.0    -.25     .25
$========================================================================
$  composite layer material properties
$========================================================================
MATERIAL     GLUE .500E+6 .500E+6    .300 .200E+6    .065
+          5000.   5000.   5000.   5000.   2885.
+          2000.   2000.   2000.   2000.   1154.
MATERIAL     SPAR16.13E+616.13E+6    .3505.973E+6    .160
+        105000. 105000. 105000. 105000.  60585.
+         45000.  45000.  45000.  45000.  25965.
```

Figures

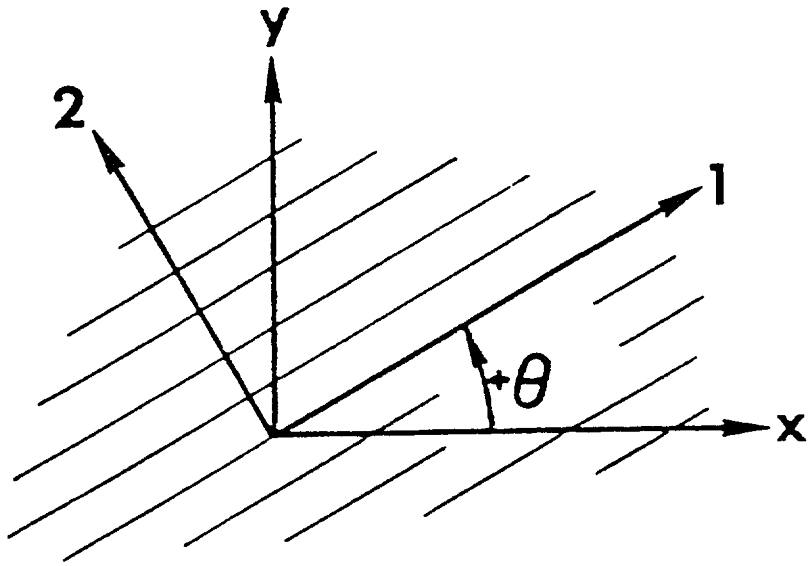

Figure 1. Positive rotation of principal material axes from element xy axes.

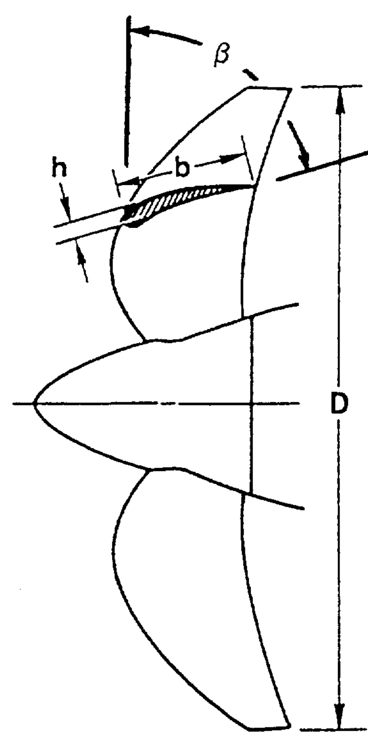

Figure 2. Airfoil section thickness, chord, and twist definitions.

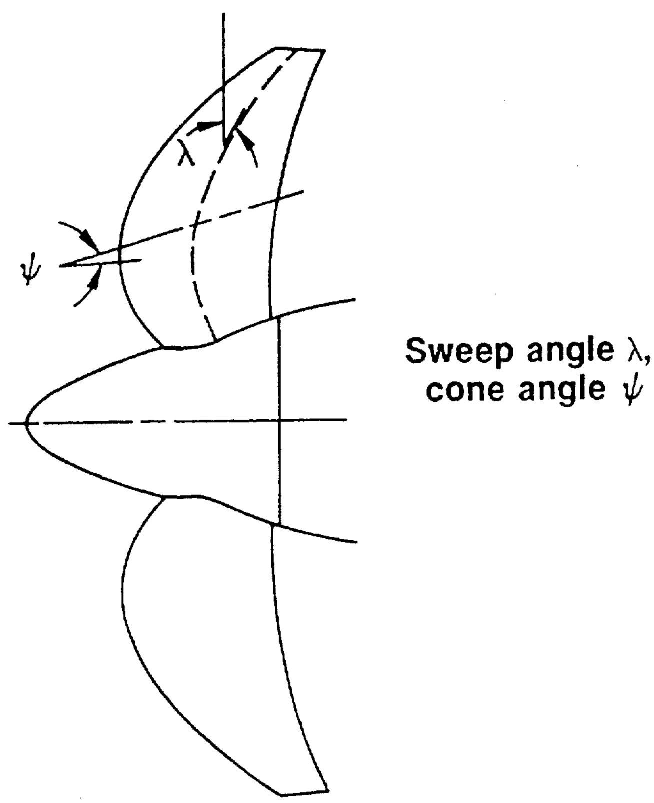

Figure 3. Airfoil Sweep and Cone Angle Definitions.

References

1. STAT Theoretical Manual, to be published.

2. Wainauski, H. S., et al, Prop-Fan Performance Terminology, SAE Paper 871838, Oct. 5, 1987.

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16. Abstract

This User's Manual describes the Structural Tailoring of Advanced Turboprops program. It contains instructions to prepare the input for optimization, blade geometry and analysis, geometry generation, and finite element program control. In addition, a sample input file is provided as well as a section describing special applications (i.e., non-standard input).

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