BUCKLING ANALYSIS OF A MISSILE INTERSTAGE

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SUMMARY

NASTRAN was used to find the buckling location and the degradation factor due to a specified temperature field for an interstage of a typical three stage missile. The model was made up of 6332 independent degrees of freedom. This large size required the use of an IBM 370/195 for evaluation of the eigenvalues. The effect of elevated temperature was to lower the critical buckling load by 3%.

INTRODUCTION

A three dimensional buckling analysis, with and without temperature gradients, was performed on the aft skirt of a typical three stage missile using an IBM 370/195 computer and the NASTRAN computer program.

OBJECTIVE

Static structural tests were performed on the aft skirt, at ambient temperature. The NASTRAN analysis was performed to provide a temperature degradation factor for use with the failure loads from the structural test program and to demonstrate adequacy of the second stage aft skirt when subjected to loading, including effects of temperature gradients. The analysis was to provide the following information for determination of the degradation factor.

The critical buckling failure load factor for the aft skirt at ambient temperature.

The critical buckling failure load factor for the aft skirt having radial, circumferential, and longitudinal thermal gradients computed for specific conditions.

The buckling mode.

The critical buckling location.

MODELING

Basic Grid

The model used for this analysis was designed to account for the load peaking caused by cutouts, and the effects of doublers and other stiffening members, as well as thermal effects. To minimize the size of the problems, the basic model was designed as a 180 degree section (from 210° through 360° to 30°) of an axisymmetric shell, using flat quadrilateral plate elements. The basic model, as shown in Figure 1, included the following structural components:

An aft segment of a second stage chamber (total segment length = 1.02 m (39.7 inches)) including a portion of the chamber and the aft skirt.

The aft closure was included from the aft Y-joint part way back.

To achieve results accurate to 5% or better[1] the basic grid was divided into elements approximately square; 5 degrees wide by approximately 0.063 m (2.5 in.) long. Each circumferential grid line was assigned a reference number (1, 2, 3, etc.), with odd numbers for the interstage, skirt flare, and chamber wall, and even numbers (2 through 10) for the aft closure. Each basic grid nodal point was then identified by a five-digit number, (e.g. 21015), beginning with three digits for the azimuth (e.g. 210°) and ending with a two-digit number for the circumferential line (e.g. 15) on which the point lies.

To better represent the stiffness of the Y-joint, the aft skirt and closure elements were joined at reference line 23, as shown in Figure 2, and a radially oriented element was connected between reference line 10 on the aft closure and an added line 12 on the skirt, at the Y-joint crotch. Representation of the aft chamber girth weld area is shown in Figure 3.

Final Grid

Modifications were made to the basic model to obtain the final model which includes:

All skirt cutouts with doublers and debris deflectors.

Raceway on chamber skirt and barrel.

Disconnect bracket.

1-2 interstage attachment ring.

1-2 interstage raceway cutout.

1-2 interstage ordnance ports and doors.

1-2 interstage longitudinal ordnance (splice) joints.

To model in openings, doublers, brackets, etc., a local network of nodal points was established, forming a pattern of quadrilateral and triangular elements encompassing the shapes of all the layers of material to be included. Wherever two or more layers of material were involved, a separate set of elements was created for each layer and the appropriate material properties were assigned to each set of elements. This practice results in multiple elements occupying the same space, since overlying elements are formed by connecting the same grid points, which are all defined at the mean radius of the skirt or interstage skins. Some structural components were modeled as simple beam elements and nodal points were established at locations where these components were attached to the skirt/interstage structure. This model is shown in Figure 4.

Temperatures

Buckling analysis runs were made for both "room temperature" (80°F) and for an elevated temperature. Since the temperatures were uniform circumferentially except near the raceway and the longitudinal splices, it was assumed that distribution could be extended circumferentially past 360° to the 30° azimuth.

For the motor aft chamber and skirt temperatures, a three-dimensional heat transfer analysis was performed using the TRW SINDA (Systems Improved Numerical Differencing Analyzer) computer program.

PROCEDURE

Bandwidth Reduction

The time required to decompose a matrix in NASTRAN is proportional to the square of the bandwidth and the first power of the size of the matrix. To reduce running time to an acceptable level, the data deck for NASTRAN was processed by BANDIT. BANDIT is a computer program written by the Naval Ship Research and Development Center to minimize bandwidth for NASTRAN. The results of running BANDIT reduced the bandwidth by almost an order of magnitude. This required 10 minutes of computer time on a UNIVAC 1108.

Ambient Temperature Run

The first NASTRAN run, at a uniform temperature of 80°F, was evaluated by level L11.1.4 on an IBM 370/195. It required 800,000 bytes of core and ran for 104 minutes. Table 1 shows the timing information taken from the NASTRAN summary.

Elevated Temperature Condition Run

The second NASTRAN run was similar to the first. The major difference was the use of temperature data.

Subsection Elevated Temperature

Results of the elevated temperature condition run produced a mode of failure in the barrel instead of the skirt. To obtain the mode for the skirt a small section of the model was selected for further analysis.

The subsection was evaluated on the Univac 1108 and CDC 6600 computers using levels 12.1 and CDC NASTRAN. Deflections from Run 2 (elevated temperature run) were input as boundary conditions to the Univac 1108 computer version of NASTRAN. This version was used to calculate the equivalent load vector based on the input deflections. The CDC 6600 version of NASTRAN was then used to find the next mode of failure using the loads calculated from the Univac run. Table 1 also has the timing data for this analysis (Run 3).

RESULTS

The results of the first run (room temperature) gave a minimum eigenvalue of 1.340, for buckling in the barrel at the forward end of the model as shown by Figure 5. Even though the lowest mode was found, it was not the mode of failure which was expected based on test data. Indeed, it was a mode which was due to the modeling technique and the way the load was applied. It is not uncommon in buckling problems of this size to find modes of failure other than those desired. This model has 6500 modes of failure! What is important is the fact that the lowest mode was found, and experience has shown that the modes will be packed together in a band. Therefore it is expected that the desired mode of failure has an eigenvalue very close to 1.340.

The second loading case (criteria condition temperatures) was run in a much shorter time by starting the eigenvalue search at a value of (1.3). The result was 1.302 and gave the same mode of failure as loading case one.

Since the expected mode of failure had not been found and the approximate location of this desired mode was known, it was decided to run a subsection of the model to find the next mode of failure. Table 2 lists the dimensional data to describe the submodel. Loading was accomplished by taking displacements from the results of the second run, evaluated by using both the UNIVAC 1108 and CDC 6600 computer. This submodel gave an eigenvalue of 1.304 and the correct mode shape. Figure 6 indicates this mode of failure. The buckling occurred at 250 degrees in an area near the dumpline port.

Based on this data the effect of temperature is to lower the buckling capacity of the structure by a factor of $\frac{1.302}{1.340} = 0.972$.

CONCLUSIONS

The results of this computer study substantiate the ability of the aft skirt to withstand the elevated temperature condition loads with a positive margin of safety. Elevated temperatures were found to degrade the buckling capacity of the aft skirt by a factor of 0.972.

REFERENCES

1. Brolliar, Richard H., "A NASTRAN Buckling Analysis of a Large Stiffened Cylindrical Shell with a Cutout," NASA TM X-2378, September 13, 1971, pp 65-84.

TABLE 1

NASTRAN TIMING DATA (MAJOR ROUTINES)

	Run 1 (IBM 370/195)		Run 3 (CDC 6600)	
	CPU Time, sec	Elapse Time, sec	CPU Time, sec	Elapse Time, sec
SMA1	276	343	223	263
SCE1	19	69	7	--
RBMG	317	441	64	293
FBS	115	326	14	33
DSMG	101	129	261	322
READ	1395	3932	187	1323
SDCØ	(277)	(373)	(55)	(78)
ITERATION	(459)	(1718)	--	--
TOTALS	2406	6254	851	2289
Bandwidth	309		125	
I.D.F.*	6332		867	
COST	$2640 (Total)		$369 + Printing Cost	

*Independent Degrees of Freedom

TABLE 2

SMALL PANEL DATA

I. MODEL DATA

1. Elements	
Bar	20
Quadrilateral Plates	98
Triangular Plates	233
2. Grid Points	228
3. Bandwidth	140
4. Degrees of Freedom	1,110

II. RUNNING TIME CDC 6600, 165000_8 CORE

1236 Central Processor, sec

2964 Input/Output, sec

2587 Total System, sec

III. SOLUTION EIGENVALUE

$\lambda = 1.303$

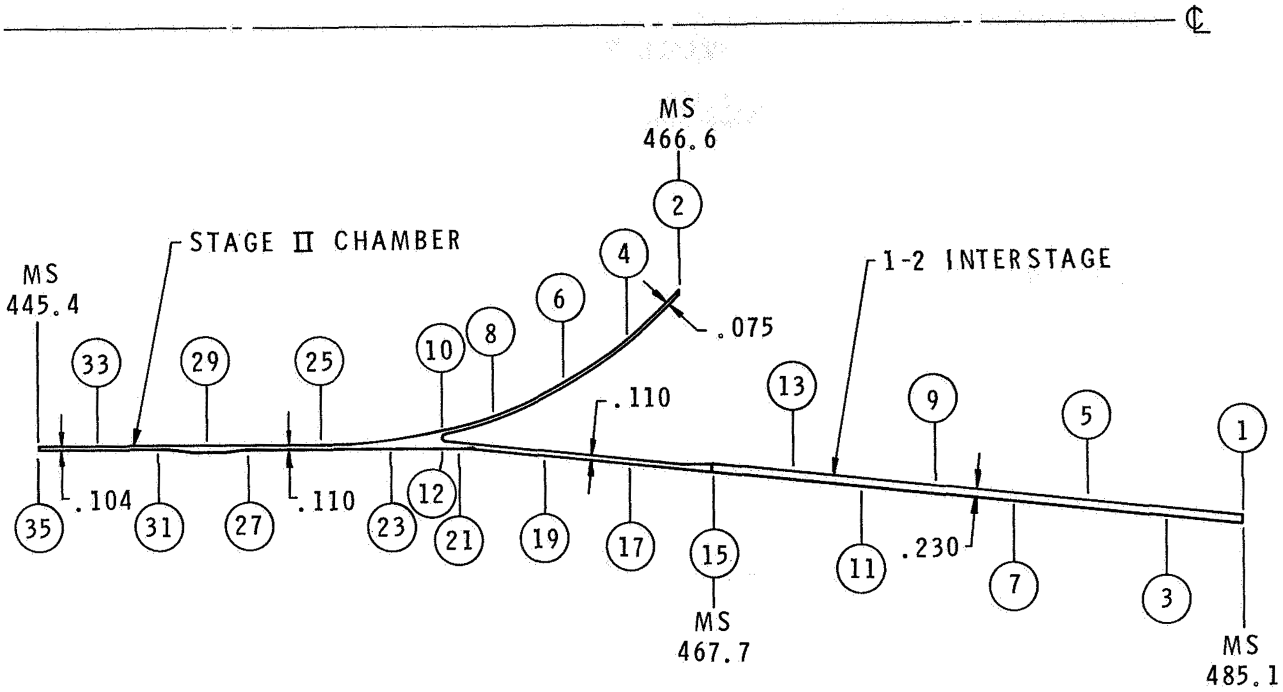

FIGURE 1

MAJOR COMPONENTS OF BASIC MODEL
AND LONGITUDINAL REFERENCE POINTS

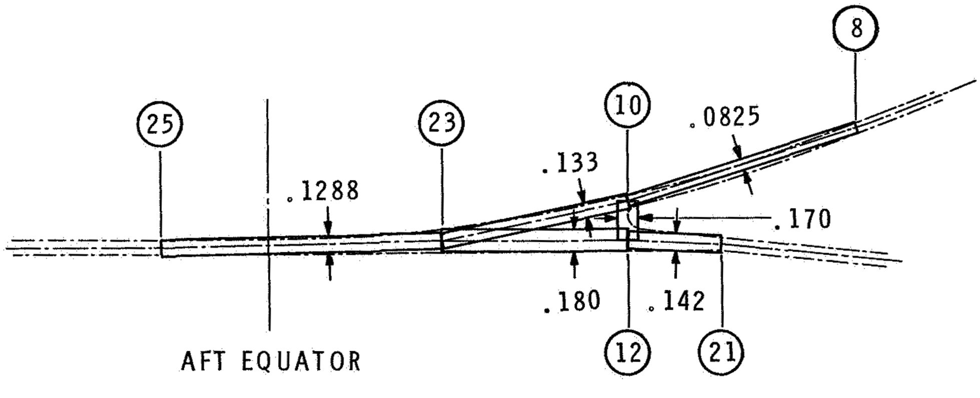

FIGURE 2

MODELING OF AFT Y-JOINT

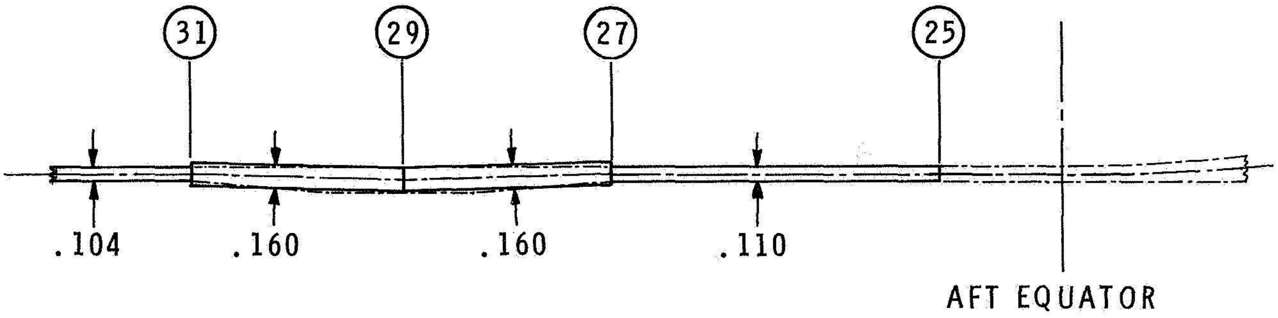

FIGURE 3

MODELING OF AFT CHAMBER WELD AREA

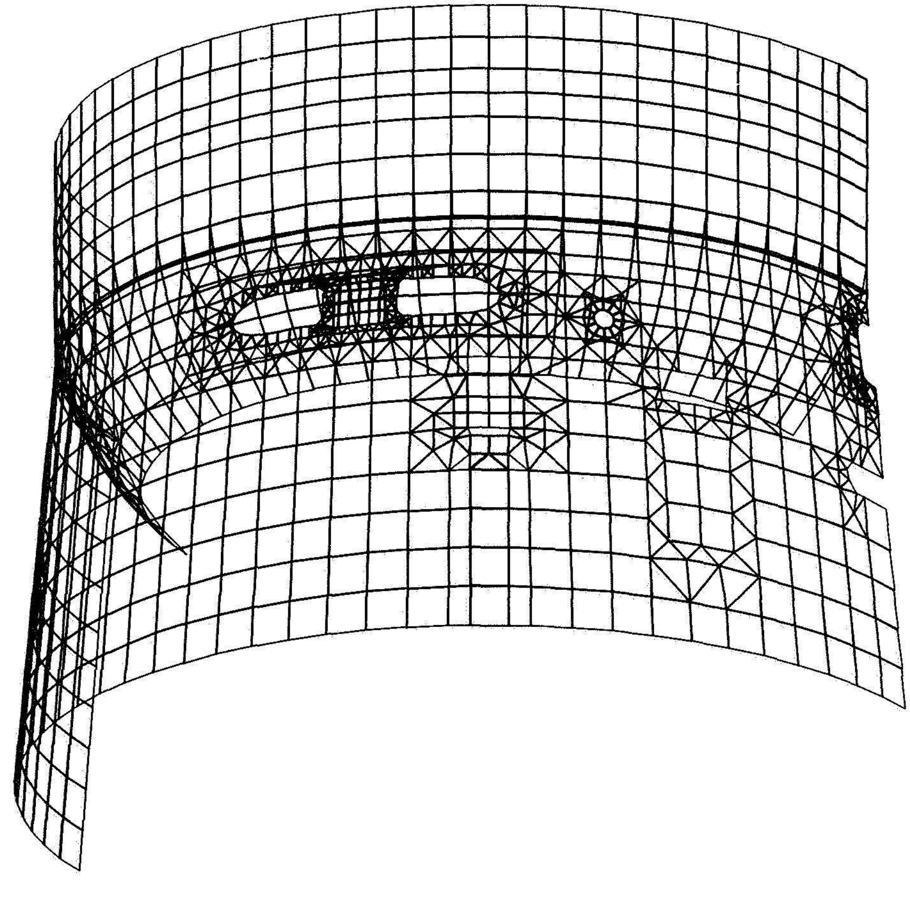

FIGURE 4

NASTRAN MODEL IN UNDEFORMED SHAPE

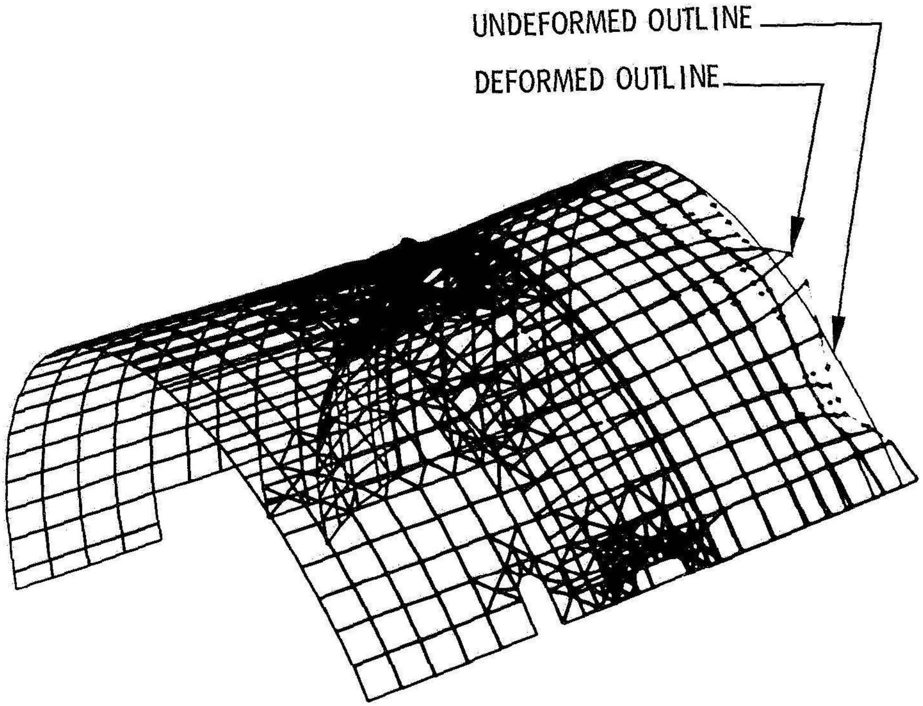

FIGURE 5

FULL NASTRAN MODEL
DEFORMED SHAPE

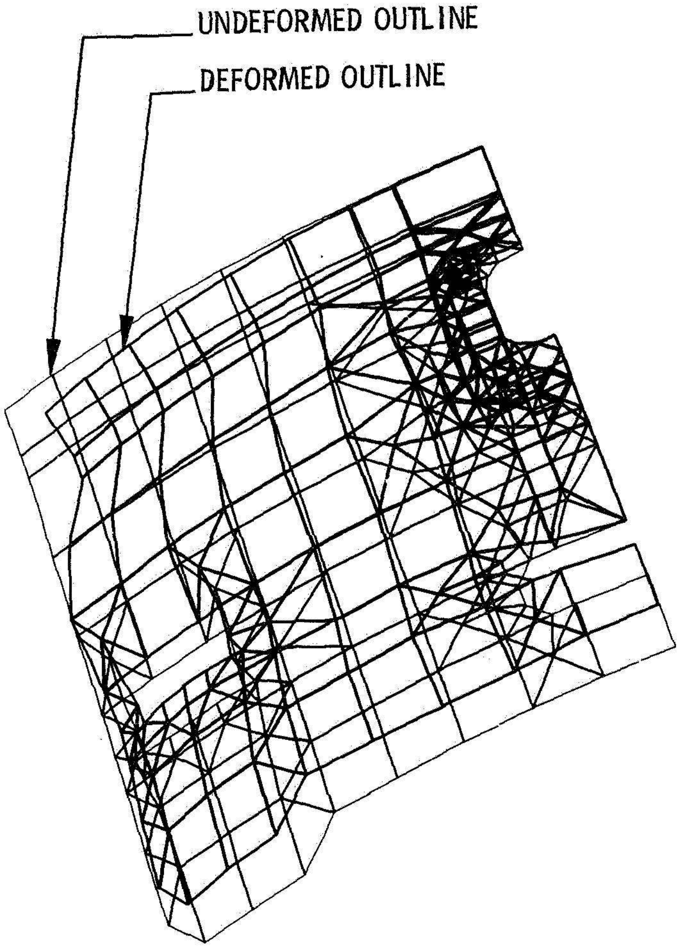

FIGURE 6

DEFORMED SHAPE OF NASTRAN
SUBSECTION MODEL