APOLLO MSC/NASTRAN: A USER's EXPERIENCE

by

VERN D. OVERBYE

A. O. SMITH Data Systems Company
Milwaukee, Wisconsin

Presented at the
MSC/NASTRAN USER's CONFERENCE
Pasadena, CA
March 22-23, 1984

ABSTRACT

MSC/NASTRAN availability on the Apollo microcomputer was discussed at 1983 MSC/NASTRAN User's Conference. A. O. SMITH Data Systems Company acquired an Apollo computer in early 1983. This paper describes some of our experiences with MSC/NASTRAN. Particular emphasis is placed on structural analysis CPU time and elapsed time with comparisons made to a large main-frame computer. A variety of solution sequences have been used and experiences in each are discussed.

INTRODUCTION

Introduction of minicomputers during the late 1970's resulted in vendors of finite element code adapting to the limitations of these small machines. Engineers thus acquired large-problem analysis capability with a small computer located within the engineering department rather than accessing a centralized main frame computer or time-sharing computer service. The early 1980's saw these minicomputers becoming microcomputers with capabilities rivaling minicomputer models of just a few years earlier. One of these microcomputers is the Apollo.

MSC/NASTRAN was introduced on the Apollo in early 1983 (1)*. Table 1 compares CPU time for real double precision operations on the Apollo microcomputer and IBM 3033 main frame computer. The table shows the Apollo/IBM ratio to vary from 21 to 48. The Reference 1 paper also presented typical Apollo CPU times versus model DOF for conventional static, modes, and frequency response analyses along with superelement

---

*See references at end of paper

statics and dynamics analyses.

WHY APOLLO?

A. O. SMITH chose the Apollo microcomputer for the following reasons:

- Cost Effective - The computer has an up-to-date CPU and storage technology at a highly competitive price.
- Large User Potential - Availability of MSC/NASTRAN (and ANSYS) finite element code along with CAD/CAM software appeals to the design engineering community.
- Software Development - A. O. SMITH Engineering Systems has two proprietary software packages suitable for the Apollo:
  - AOS/GRAFAX - A pre- and post-processor for MSC/NASTRAN (2-4) with color stress contours.
  - AOS/MAGNETIC - The world's most widely used finite element analysis program for planar and axisymmetric magnetic field analysis (5) with interactive model generation and color magnetic flux contours.
- Consulting Applications - a cost-effective alternative to main-frame computing in structural and magnetic consulting engagements.

A. O. SMITH APOLLO CONFIGURATION

Table 2 compares the A. O. SMITH Apollo configuration and the MSC recommendation for large problem capability. The table shows that the

300 megabyte storage dis, tape drive, and high speed printer were not purchased. The Fortran 77 software package was purchased to adapt the two A.O. SMITH proprietary software packages to the Apollo.

Figure 1 shows the A.O. SMITH Apollo network arrangement. MSC/NASTRAN and AOS/MAGNETIC finite element data sets are either transferred (at 1200 Baud) to the IBM main frame for long term storage or off-loaded to floppy disks. (This floppy disk off-loading has thus far proved unsatisfactory for superelement data bases.) MSC/NASTRAN and AOS/MAGNETIC print-outs are transferred in a similar fashion and printed on high-speed printers. The time element involved in this data transfer encourages the structural and magnetic field analysis engineer to limit output requests or summarize data with color contour plots. If required, OUT files (from AOS/MAGNETIC DISPLAY and AOS/GRAFAX) may be transferred to the IBM main frame for display on Tektronix 4014 terminals.

MSC/NASTRAN Small Model Experience

Early in 1983, MSC/NASTRAN (Version 62A, November 17, 1982 release) was installed from 16 floppy disks supplied by MSC. A number of small sample problems were solved with indifferent success. Apollo had inadvertently failed to supply the program identifying bad spots on the Winchester disk, and MSC/NASTRAN had problems with the XSORT preface sorting subroutine. Also, SOL 66 ignored the TABLES1 card. These minor irritations were corrected by Apollo and MSC. MSC/NASTRAN Version 62A (January 11, 1983 release) is still being used.

Figure 2 shows a series of small MSC/NASTRAN structural mechanics test problems that were solved using both the Apollo and IBM 3033 main frame computer .

The first example is the cantilever angle shown in Figure 2A. The tip load resolves into two orthogonal transverse loads. The angle is represented by 50 CQUAD4 plate elements and 66 GRIDS, with 5 or 6 degrees-of-freedom, as appropriate, per GRID.

The second example is a symmetric-half arch from a cathedral structure, shown in Figure 2B. Gravity and dead weight define the loading. The structure is represented by 188 CQUAD4 plate elements and 244 GRIDS, with 3 degrees-of-freedom per GRID.

The third example is a symmetric half of a notched plate, shown in Figure 2C. The plate is represented by 192 CQUAD4 elements and 610 GRIDS, with 3 degrees-of-freedom per GRID.

The final example, shown in Figure 2D, is the keyhole fatigue speciman used in an SAE fatigue study. The fatigue speciman was loaded to produce tension and bending at the keyhole notch and is represented by a symmetric half structure assembled with 45 CQUAD4 and 207 CTRIA3 elements. There are 174 GRIDS, with 3 degrees-of-freedom per GRID. The solution procedure is iterative and the analysis was stopped after seven iteration loops.

Table 3 compares CPU times and elapsed times for the two machines. As might be expected from timing parameters (see Table 1) the Apollo CPU run times were reduced by a factor of over forty when run on the IBM main frame. However, the turnaround time (from beginning to end of execution) was only about 3 times faster on the IBM main frame. Each

Apollo job was executing alone, while the IBM CPU has 13 job initiators.

No system storage requirements data were recorded for these small MSC/NASTRAN runs. As shown below, this factor becomes a serious restriction in using the Apollo for large-model consulting engineering engagements.

MSC/NASTRAN Large Model Experience

Several consulting engagements have been successfully completed (or partially completed) using MSC/NASTRAN on the Apollo microcomputer.

Figure 3 shows a steering wheel structure in which linear and nonlinear stress analyses were performed. The linear statics run (SOL 24) consisted of a vertical load on the rim GRID with hub constraints. Geometric nonlinear analysis (SOL 64) used four subcases with complete stiffness matrix and load (vertical on rim) updates. The material nonlinear analysis (SOL 66) applied the vertical rim load in two increments. SEMIQN stiffness matrix updates were used requiring two new stiffness matrices on the first load increment and one on the second. Run statistics are tabulated in Table 4. The SOL 66 run required over 24 hours and data block DB01 was by far the largest (38.6 megabytes). This run reduced system storage availability by 28 percent.

Figure 4 shows a threaded structure finite element model. Although 2800 GRIDs were used, total DOF was modest for the TRIAX6 elements (2 DOF/GRID). The male part was constrained on the right. The female part was loaded axially and radially (PLOADX). MPC equations engaged threads.

Table 4 compares data storage requirements for uncheckpointed and checkpointed runs. Data reported to the client consisted solely of AOS/GRAFAX color stress contour plots.

Figure 5 shows a crane structure component finite element model. This component was represented by 2008 GRIDS, 2371 CQUAD4 and CTRIA3 elements, 13 RBE2s, and 11000 DOF. Table 4 summarizes the Apollo run statistics.

AOS/MAGNETIC Analysis

Figure 6 shows a half model of a two pole brushless DC motor. The finite element model consists of approximately 350 GRIDs and 450 triangular elements. A nonlinear B-H curve was used in the iterative solution requiring approximately 2100 seconds on the Apollo. The figure also shows a 4014 flux plot made by transferring the OUT file to the IBM main-frame.

CONCLUSIONS

Experience with Apollo MSC/NASTRAN at A. O. SMITH suggests the following conclusions:

- AOS/GRAFAX and AOS/MAGNETIC color stress contours and magnetic flux density plots eliminate the need for printed output.

- An MSC/NASTRAN and AOS/MAGNETIC analysis may be executing simultaneously and keyboard operations (editing, color plotting, etc.) can be accomplished with some system degradation or the jobs may be simply suspended and continued later at will.

- The most severe limitation on the present A. O. SMITH Apollo computer is lack of disk storage. This could be partially remedied with a 300 Megabyte disk.

REFERENCES

1. McCormick, C.W., "MSC/NASTRAN and the Apollo Computer" MSC/NASTRAN User's Conference Proceedings, Pasadena, CA, March 24-25, 1983.
2. Lambert, J. L., "AOS/GRAFAX - Interactive Pre- and Post-Processor for MSC/NASTRAN", MSC/NASTRAN User's Conference Proceedings, Pasadena, CA, March 15-16, 1979.
3. Riley, E. L., et al, "AOS/GRAFAX Interactive Processing of MSC/NASTRAN Superelements", Proceedings of the Conference on Finite Element Methods and Technology, Pasadena, CA, March 19-20, 1981.
4. Webster, J. L., et al, "AOS/GRAFAX Interactive Processing of MSC/NASTRAN Dynamic Results", MSC/NASTRAN Users Conference Proceedings, Pasadena, CA March 18-19, 1982.
5. Lari, R. J., "Comparison of Eddy Current Programs", COMPUMAG Conference Proceedings, Genoa, Italy, May 30-June 2, 1982.
6. Bodine, R. Y., "Computer Size and Finite Element Analysis", SAE Paper 830807, Presented at Earthmoving Industry Conference, Peoria, IL, April 11-13, 1983.

TABLE 1. CPU TIME:
Real Double Precision Operations for
Apollo Microcomputer and IBM 3033
Computer.

Timing* Constant	Time IBM	(Microseconds) Apollo	Apollo/IBM
M	1.1	53	48.2
P_S	2	50	25
P	2	65	32.5
P_I	10	210	21

*Timing constants description:

M = Arithmetic time for multiply/add loop.

P_S = Pack or unpack one term in a string of nonzero matrix terms.

P = Pack or unpack one element in a column of a matrix.

P_I = Pack or unpack one nonzero term in a column of a matrix.

TABLE 2. APOLLO COMPUTER CONFIGURATION

Unit	Description	AOS Computer	MSC Recommendation*
DN420-IMB	CPU, Display	yes	yes
PEB	Floating point processor on a chip	yes	yes
PNA	Peripheral to Node Adapter (needed for 300M MSD)	yes	yes
MSD-1.2M	Floppy disk drive	yes	yes
MSD 158M	Winchester disk	yes	yes
MSD 300M	300 megabyte disk	no	yes
MSD 1600	Tape drive (1600 BPI)	no	yes
HCD 600	High speed printer (600 LPM)	no	yes
SFW-FTN	Fortran 77	yes	no
SFW-Core	Plot routines	yes	no

---

*MacNeal-Schwendler Corporation recommendation for large problem capability.

TABLE 3. MSC/NASTRAN SMALL PROBLEM TIMING SUMMARY

		CPU Time (seconds)			ELAPSED TIME (seconds)**		
Example*	SOL	IBM	APOLLO	APOLLO/IBM	IBM	APOLLO	APOLLO/IBM
A	24	9	337	37.4	288	672	2.3
B	24	13	590	45.4	293	1039	3.5
C	24	36	2041	56.7	366	1210	3.3
D	66	83	3535	42.6	2454	8832	3.6
				----			---
			Average	45.5			3.2

---

*See Figure 2.

**Elapsed time is job time from start to finish. No other Apollo jobs; twelve other IBM jobs.

TABLE 4. MSC/NASTRAN Large Model Run Statistics

Item	Steering Wheel (Fig. 3)			Threaded Connection (Fig. 4)		Crane Component (Fig. 5)
	SOL 24	SOL 64	SOL 66	SOL 24	SOL 24 (Chkpnt)	SOL 24
GRIDs	1065	1065	1065	2800	2800	2008
Elements						
Beam	66	66	66			6
QUAD4	816	816	816			1739
TRIA3	102	102	102			624
TRIAX6				1256	1256	
Assembly (Sec)	634.6	634.6	634.6	2638	2638	1438
Solution						
Bandwith (RMS,GRIDS)	42.2	42.2	42.2	58	58	36.3
Decomp(6 DOF/GRD,Sec)	9831	9831	9831	48015	48015	10383
CPU (Sec)	13794	59155	68047	9345		41474
I/0 (Sec)	1363	8475	12318	1046		4159
Elapsed (min)	677	1805	1578	184		956
Storage (Megabytes)						
Data	0.106	0.106	0.106	0.331	0.331	0.221
F04	0.007	0.014	0.017	0.006	0.007	0.02
F06	0.464	0.307	0.347	1.05	1.05	8.70
DB01	--	34.04	38.5	--	--	--
NPTP	--	--	--	--	4.424	--
OUT (AOS/GRAFAX)	0.152	--	--	0.013	0.013	--

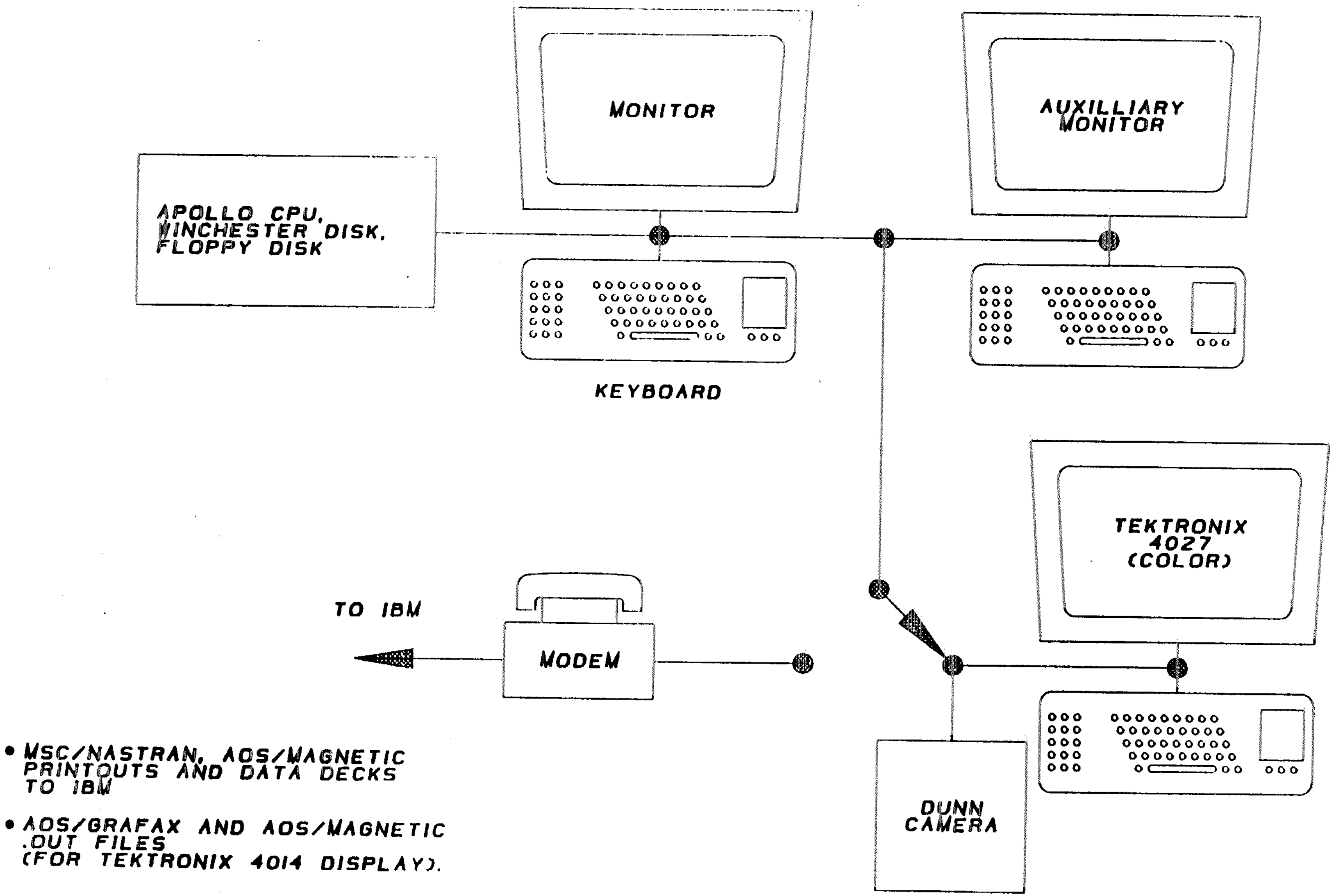
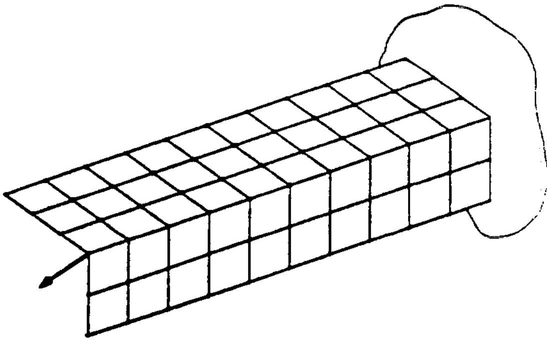
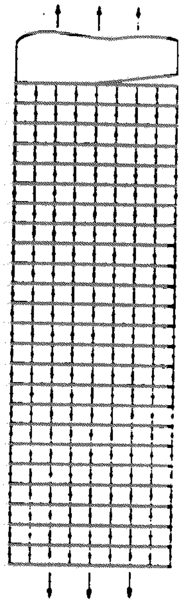


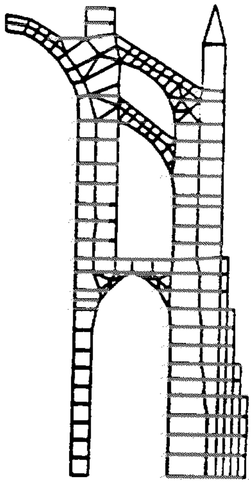
FIGURE 1. A. O. SMITH APOLLO NETWORK



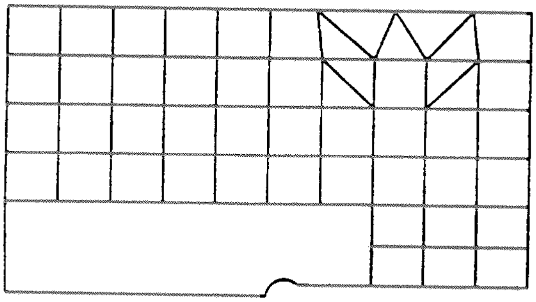
EXAMPLE 2A -
50 CQUAD4 ELEMENTS
66 GRIDS



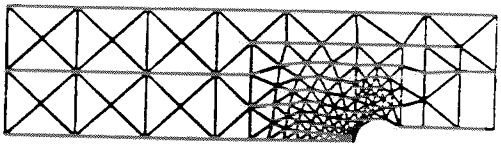
EXAMPLE 2C -
192 CQUAD8 ELEMENTS
610 GRIDS



EXAMPLE 2B -
188 CQUAD4 ELEMENTS
244 GRIDS



EXAMPLE 2D -
45 CQUAD4 ELEMENTS
207 CTRIA3 ELEMENTS
174 GRIDS



NOTCH REGION OF EXAMPLE 2D

FIGURE 2. SMALL STRUCTURAL MECHANICS EXAMPLES

GRIDS: 2800

ELEMENTS:
  PLATES - 918
  BEAMS - 66

BANDWITH (GRIDS)
  RMS - 42.2

DECOMP TIME (APOLLO)
  6 DOF/GRID - 9831 SEC.

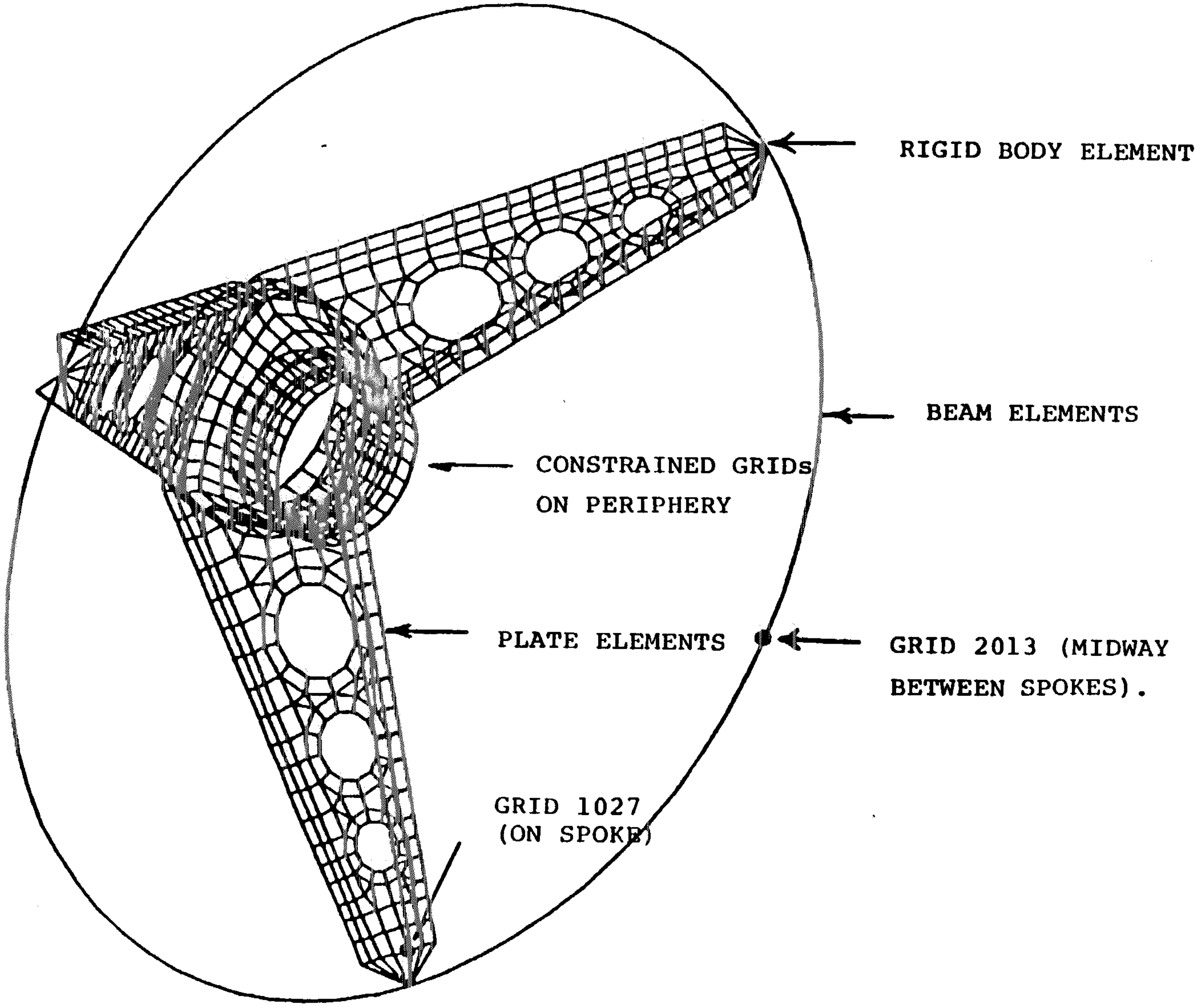
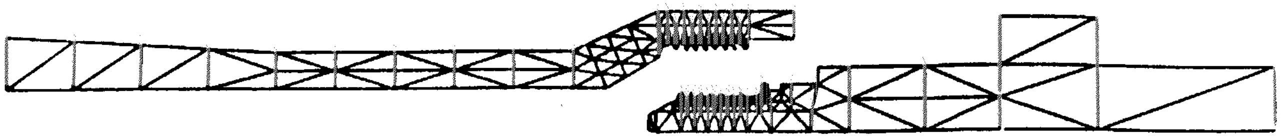


FIGURE 3. STEERING WHEEL FINITE ELEMENT MODEL



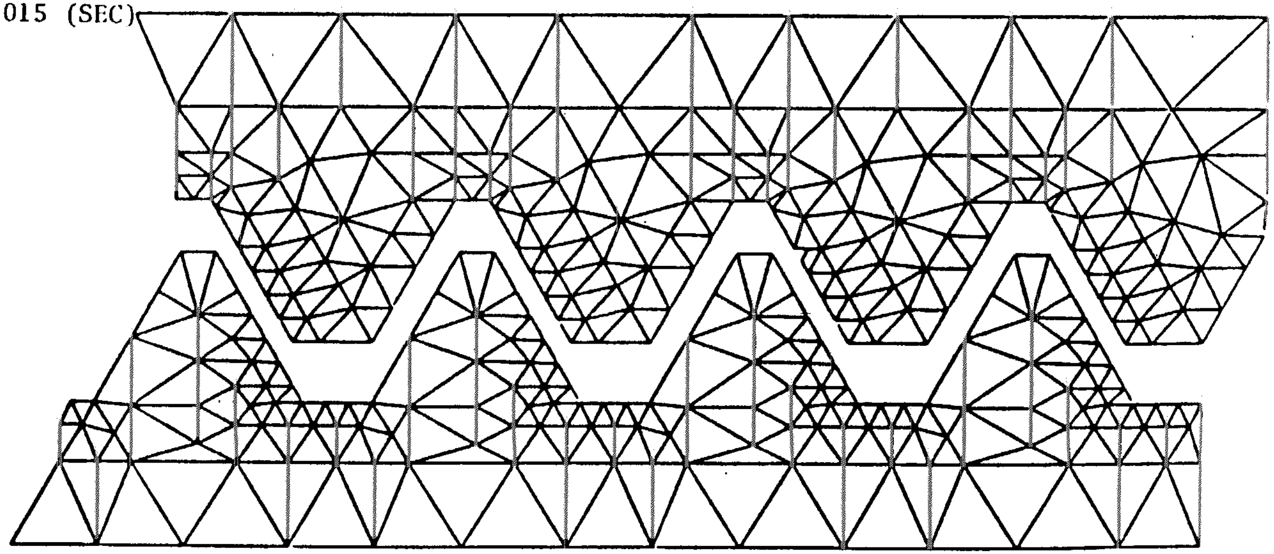
a. **Complete Assembly**

GRIDS: 2800

ELEMENTS:
  TRIAX6 - 1256

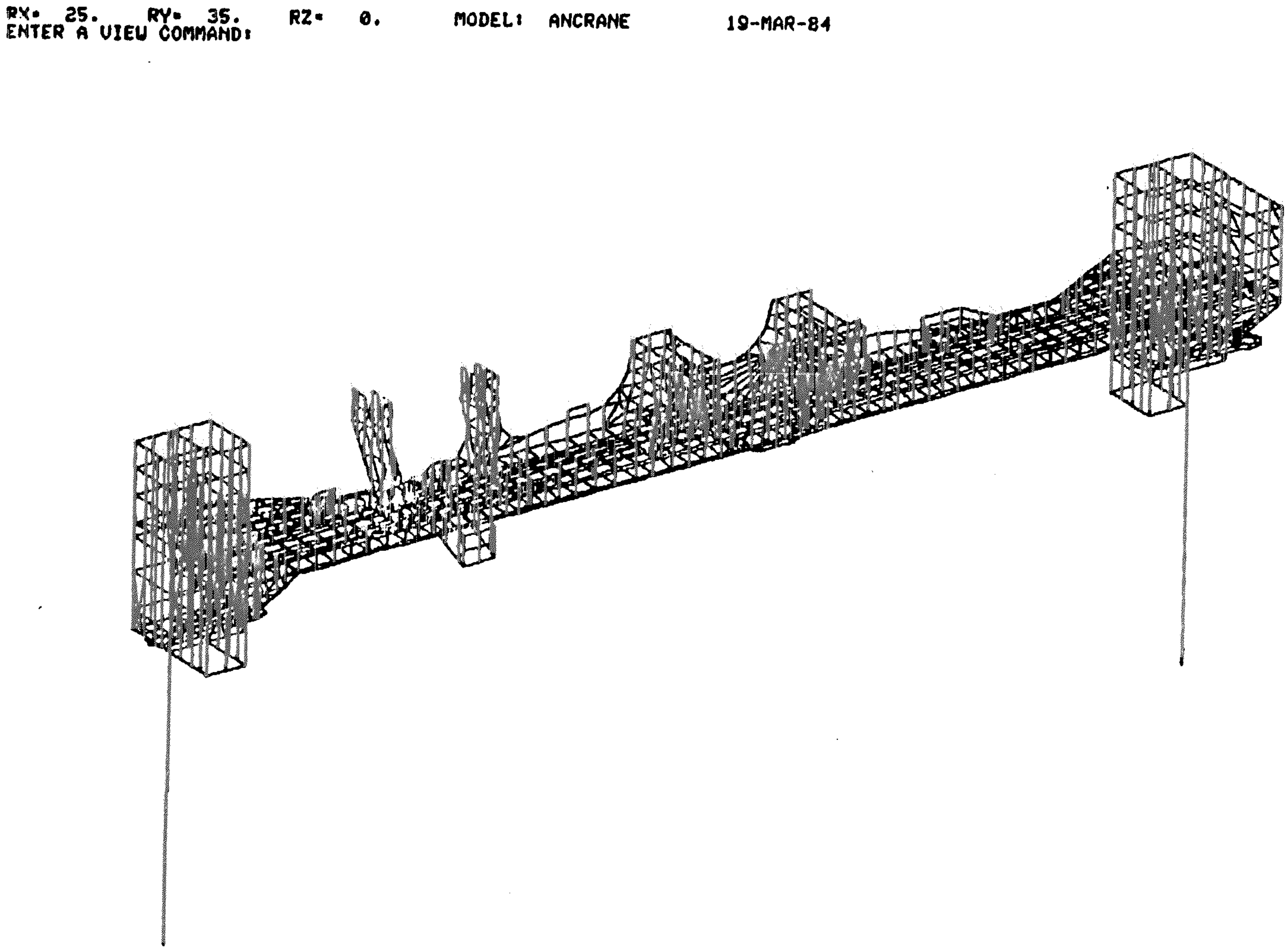
BANDWIDTH (GRIDS)
  RMS - 58

DECOMP TIME (APOLLO)
  6 DOF/GRID - 48015 (SEC)



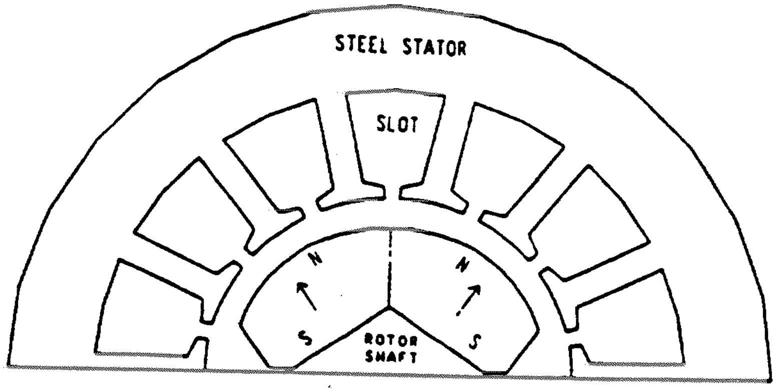
b. **Thread Detail**

FIGURE 4. THREADED STRUCTURE FINITE ELEMENT MODEL

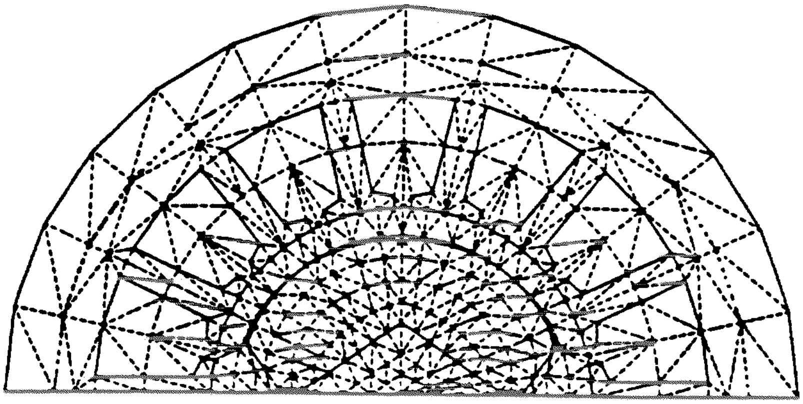


```
RX= 25.    RY= 35.    RZ=  0.      MODEL: ANCRANE        19-MAR-84
ENTER A VIEW COMMAND:
```

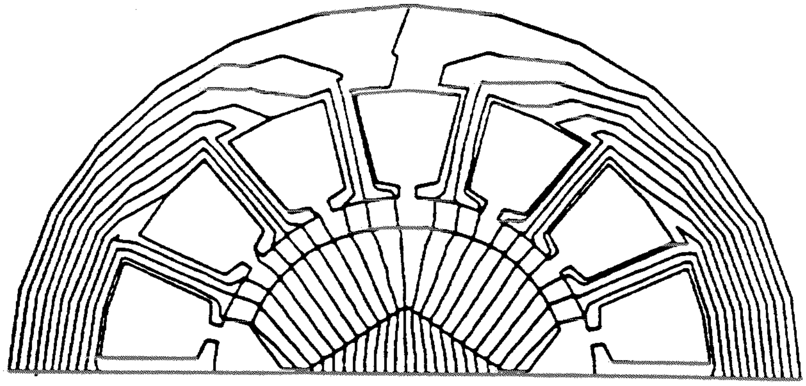
FIGURE 5. CRANE COMPONENT



A. GEOMETRY



B. FINITE ELEMENT MODEL



C. CALCULATED FLUX DISTRIBUTION

FIG 6. ONE-HALF OF MOTOR