Conical Shell Modal Test and Finite Element Analysis

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The conical shell was a radome. Certain details about this test are omitted for proprietary reasons.

Introduction

The purpose of this test was to determine the fundamental frequency of the radome with free boundary conditions. The frequency is needed so that the elastic modulus can be determined indirectly via a finite element model.

The resulting fundamental frequency is 97.6 Hz with 0.6% damping for the free boundary condition.

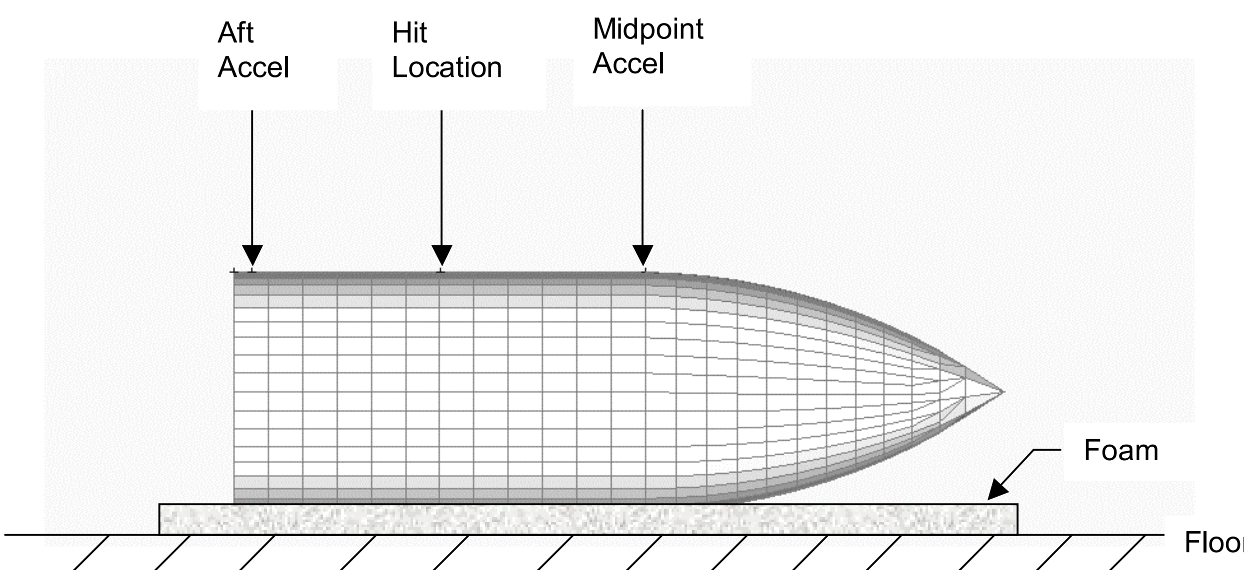

Figure 1.

Test Configuration

The radome was mounted on compliant foam for the initial test. A diagram is shown in Figure 1. The foam approximates a free boundary condition.

The radome was excited with an impulse hammer. The response was measured at two locations, via accelerometers. The instrumentation list is given in Appendix B.

Analysis Approach

A series of tests were performed by varying the hit location, accelerometer mounting locations, and even the radome's position and boundary conditions. The only results given in this report are for the configuration shown in Figure 1, however.

This subset is justified on the basis of the close match between the test results for the configuration in Figure 1 with the simplified finite element model, given in Appendix A. The purpose of this preliminary finite element model was to serve as a guideline for interpreting the test results. The simplified model only approximates the dimensions and geometry of the radome. Nevertheless, very good agreement was obtained for three of the four measured frequencies. The matching of the second mode was particularly important for verifying the entire approach.

The simplified finite element model is also useful for visualizing the mode shapes corresponding to the measured frequencies.

A refined finite element model with accurate dimensions will be needed to determine the elastic modulus.

Results

The measured frequency response functions for the aft and midpoint hit locations are shown in Figures 2 and 3, respectively. The functions are shown together in Figure 4.

Each frequency response function represents the average of ten hit and response pairs.

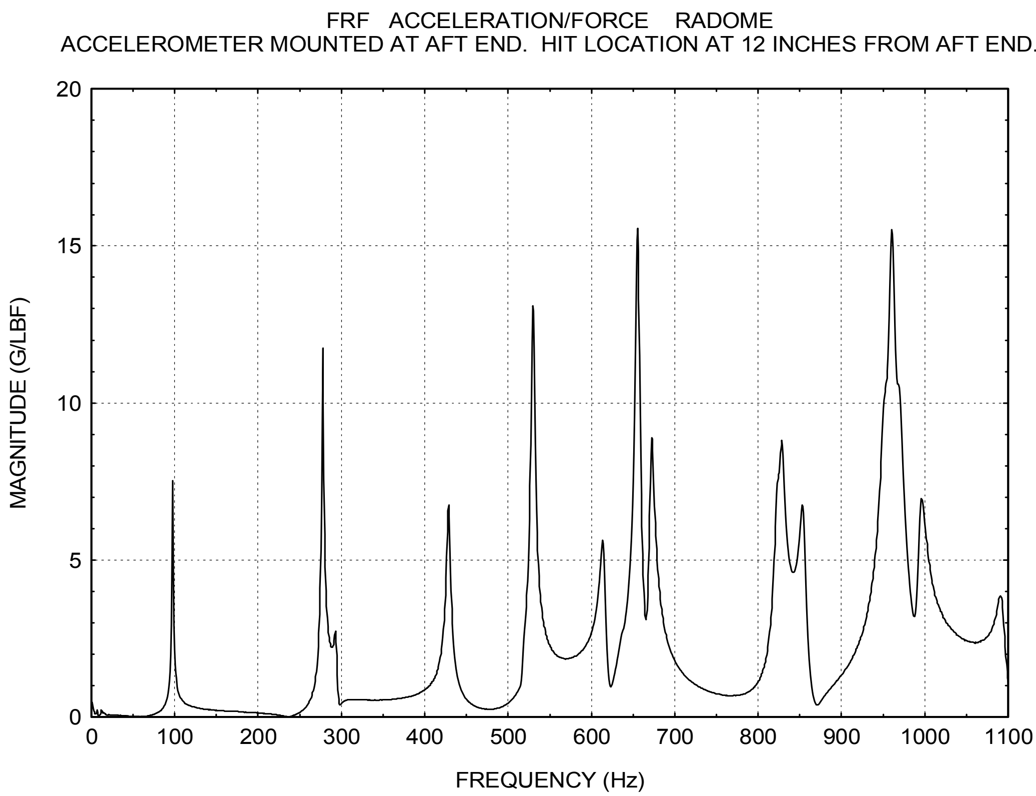
FRF ACCELERATION/FORCE RADOME
ACCELEROMETER MOUNTED AT AFT END. HIT LOCATION AT 12 INCHES FROM AFT END.
MAGNITUDE (G/LBF)
20
15
10
5
0
0
100
200
300
400
500
600
700
800
900
1000
1100
FREQUENCY (Hz)

Figure 2.

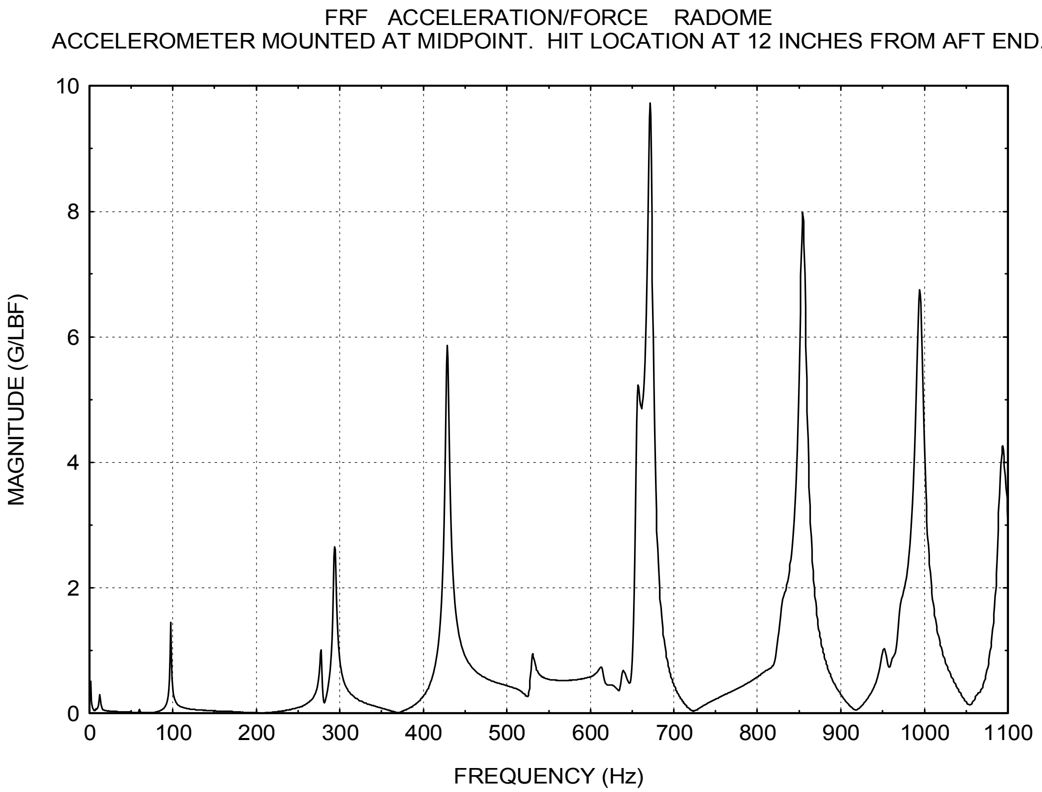
FRF ACCELERATION/FORCE RADOME
ACCELEROMETER MOUNTED AT MIDPOINT. HIT LOCATION AT 12 INCHES FROM AFT END.
MAGNITUDE (G/LBF)
FREQUENCY (Hz)
0
2
4
6
8
10
0
100
200
300
400
500
600
700
800
900
1000
1100

Figure 3.

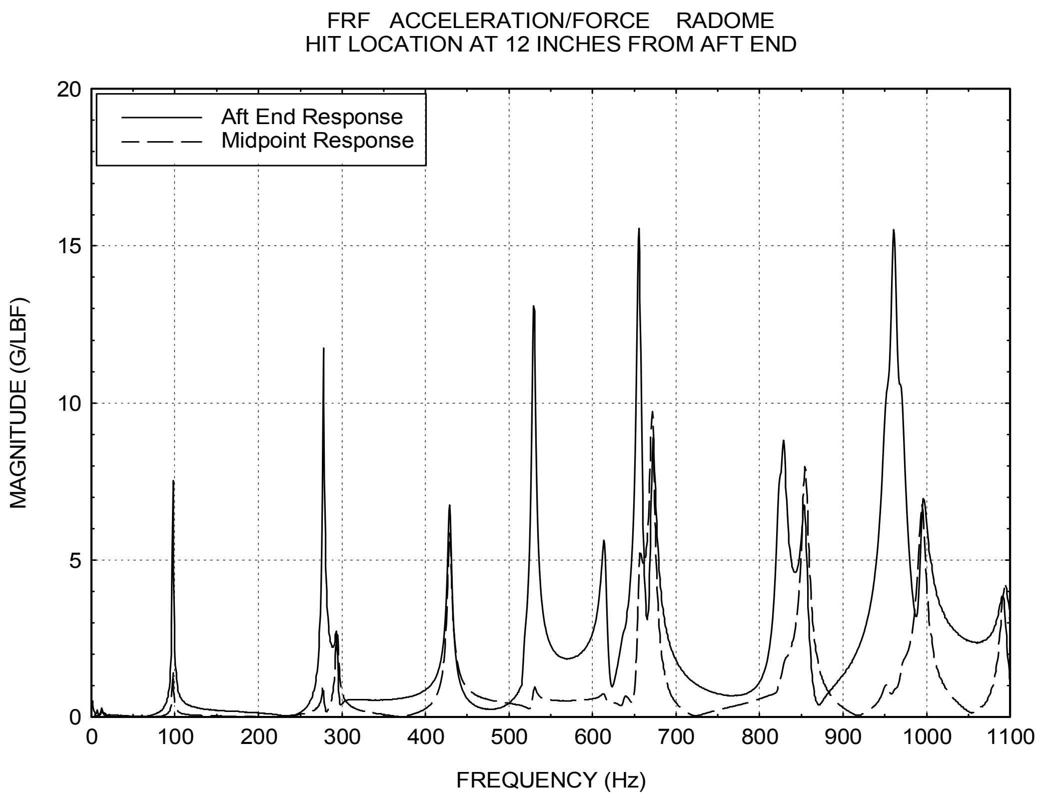
FRF ACCELERATION/FORCE RADOME
HIT LOCATION AT 12 INCHES FROM AFT END
Aft End Response
Midpoint Response
MAGNITUDE (G/LBF)
FREQUENCY (Hz)
0
5
10
15
20
0
100
200
300
400
500
600
700
800
900
1000
1100

Figure 4.

Frequency Comparison

The frequency comparison is shown in Table 1 using the measured results from Figure 2 and the finite element results from Appendix A. Again, the finite element results are from the preliminary model.

Table 1. Frequency Comparison

Measured (Hz)	FEA (Hz)
97.6	97.6
278	274
429	-
529	523

Conical Shell Frequency Equation

This section is included for reference only.

The natural frequency f_n for a complete conical shell with a free base is

$$f_n = \alpha_n \sqrt{\frac{E}{\rho}} \tag{1}$$

where

α_n is a constant that depends on the geometry and mode number

E is the elastic modulus

ρ is the mass per volume

Furthermore, the subscript n is the integer mode number.

Equation (1) is taken from Reference 1.

A refined finite element model is needed to solve for the elastic modulus E in an iterative manner given the measured fundamental frequency. This assumes the density ρ is known. The α_n constant will be effectively determined via the iterative finite element analysis, but it is not explicitly required.

Damping Measurement

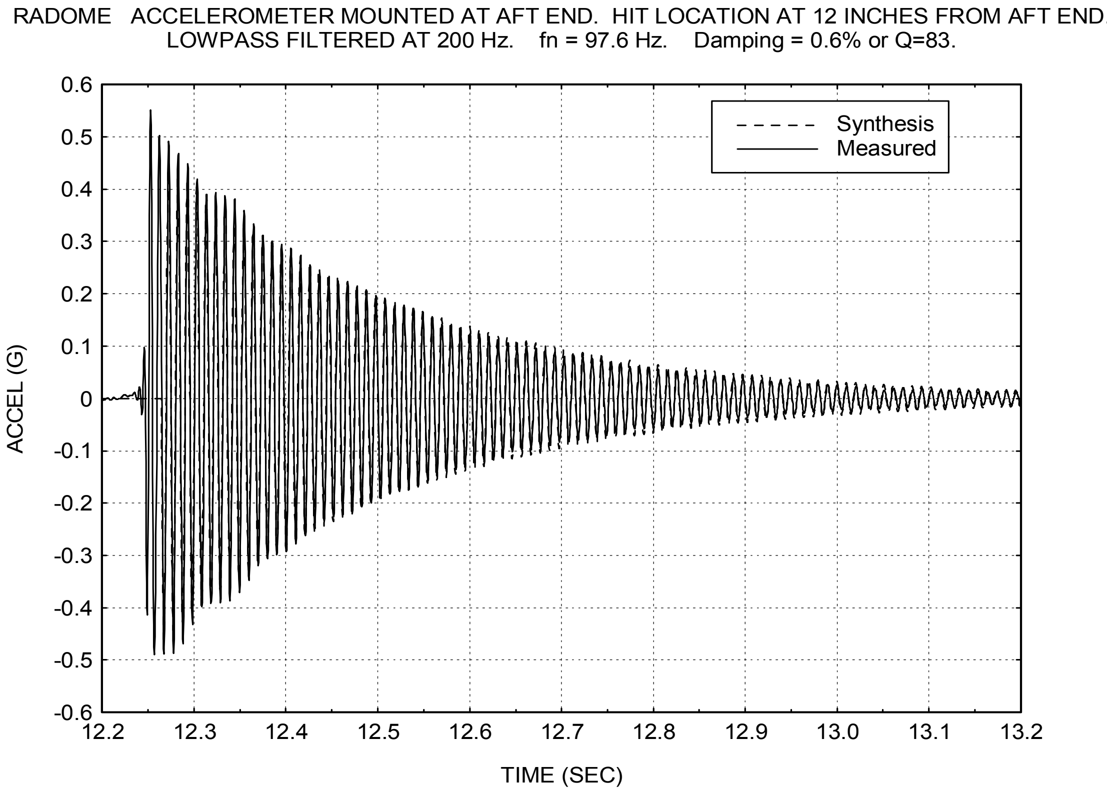

Figure 5.

Damping can be determined in either the frequency or time domain. A time domain example is shown in Figure 5. The method uses a trial-and-error curve-fit, as taken from Reference 2.

The two curves in Figure 5 are nearly identical and thus nearly indistinguishable from one another.

Reference

1. R. Blevins, Formulas for Natural Frequency and Mode Shapes, R, Krieger, Malabar, Florida, 1979.
2. T. Irvine, A Time Domain, Curve-Fitting Method for Accelerometer Data Analysis, Vibrationdata, Mesa, AZ, AIAA-2003-1972, 44th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, Norfolk, Virginia, Apr. 7-10, 2003

APPENDIX A

Simplified, Preliminary Finite Element Model

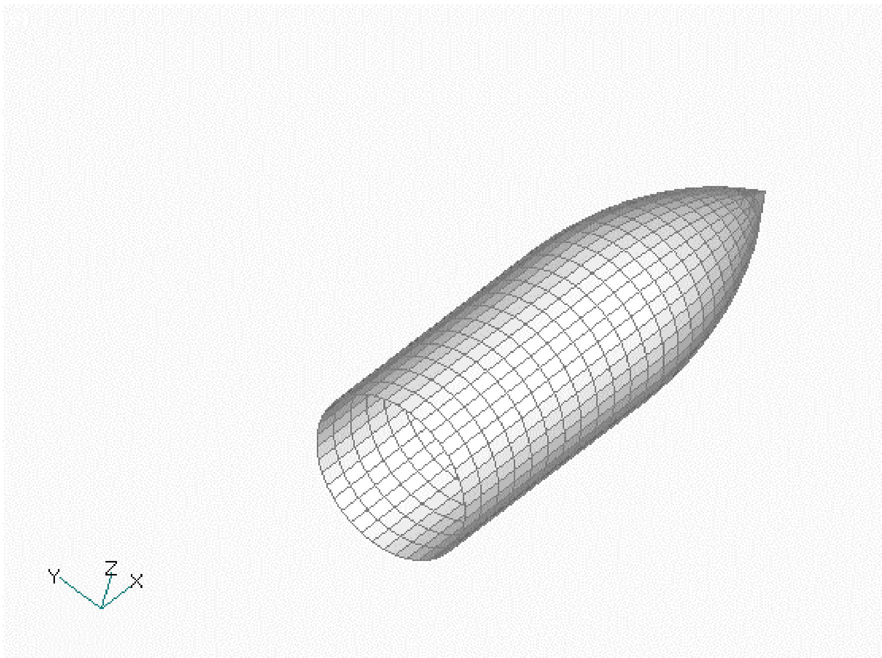

Figure A-1. Undeformed Model

The model name is conical_shell3.nas. It is included as an attachment file to this report.

The boundary conditions were completely free. The effect of the foam was not included.

The modeled used plate elements.

The elastic modulus, mass density, and the thickness in the model were chosen somewhat arbitrarily. These values were adjusted so that the finite element fundamental frequency matched the measured fundamental frequency.

Here is a summary of the model values:

Thickness	= 0.1 inch
Young's Modulus	= 16317180. lbf/in^2
Poisson's Ratio	= 0.33
Mass Density	= 1.26941E-4 lbf sec^2/in
Overall Length	= 45 inch
The base diameter	= 14 inches.

Furthermore, this approach yielded a very good match for three of the four measured frequencies, as shown in Table 1 in the main text.

The mode shapes in the following figures show that the radome undergoes shell deformation primarily at its aft end for the first four modes. The nose tip does not appear to participate in the modal responses.

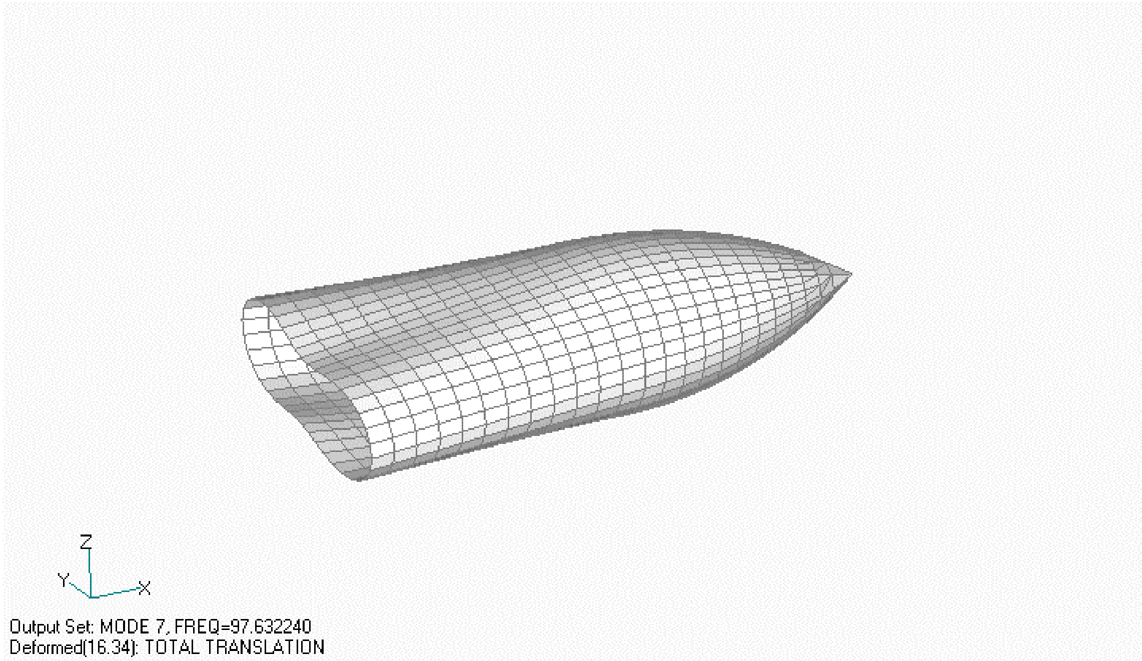

Figure A-2. Mode at 97.6 Hz

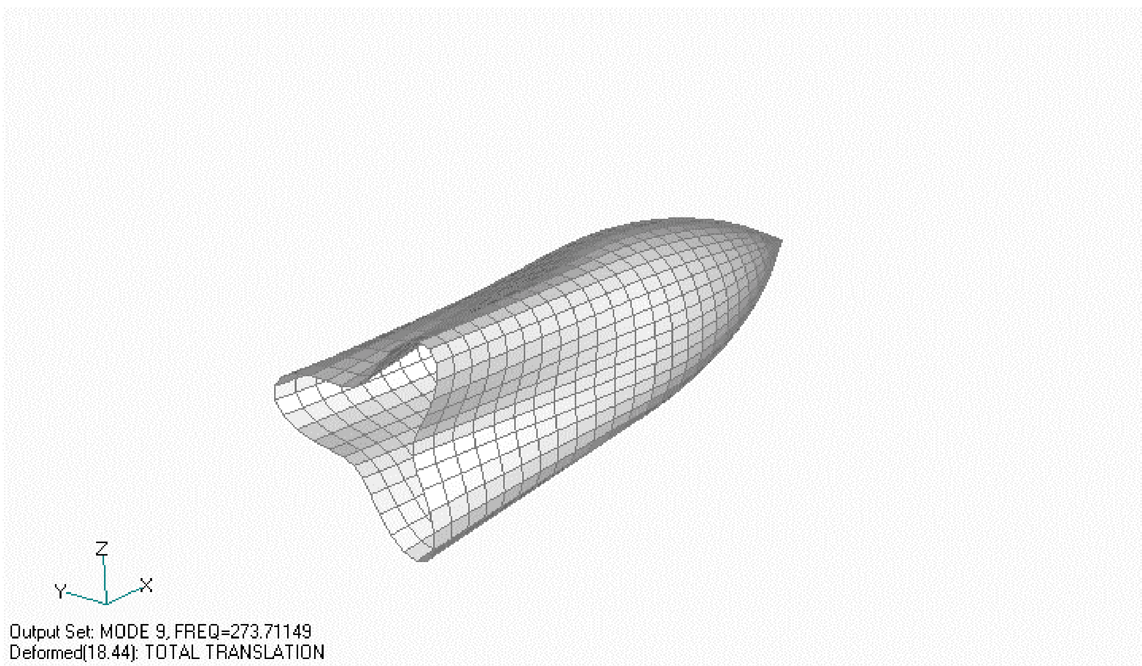

Figure A-3. Mode at 274 Hz

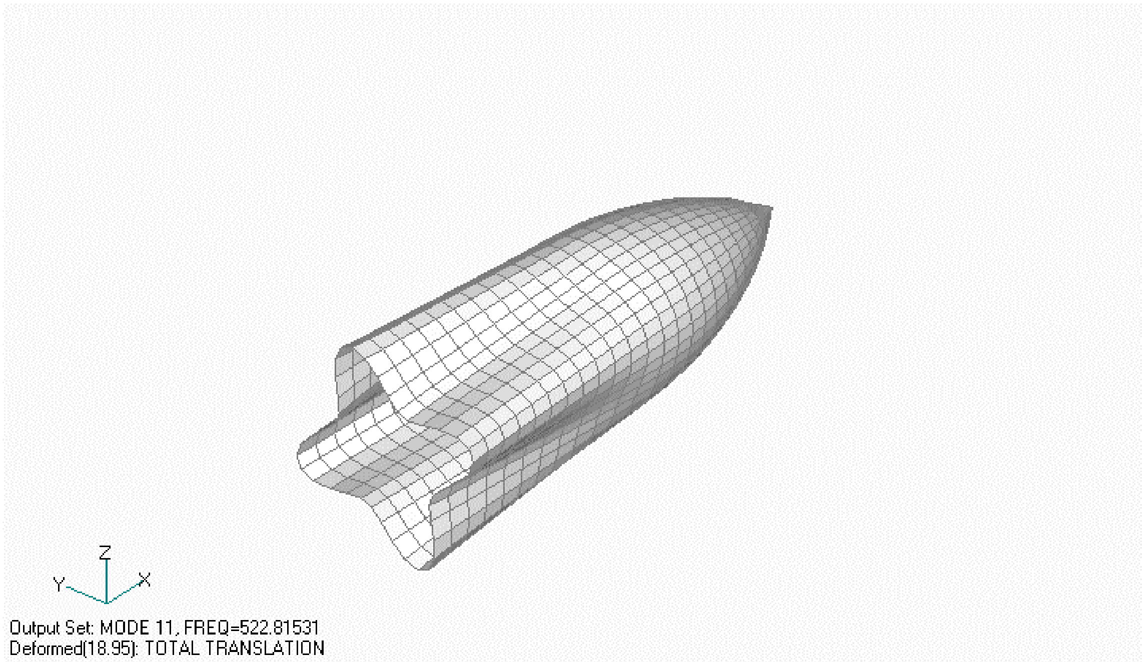

Figure A-4. Mode at 523 Hz

APPENDIX B

Instrumentation

Item	Model	S/N	Cal Date	Cal Due
Data Acquisition System	Nicolet Vision 16	ICN0301097	7/1/05	7/1/06
Accelerometer 1	PCB WJ356A22	27243	5/10/04	10/21/06
Accelerometer 2	PCB WJ356A22	27245	6/8/04	10/21/06
Impulse Hammer	Kistler 9722A2000	2036596	4/19/06	4/19/07

The impulse hammer was used with the steel tip and mass extender.