SAND2015-4365R

Sandia National Laboratories

Operated for the U.S. Department of Energy by
Sandia Corporation
Albuquerque, New Mexico 87185

date: April 23, 2015

to: Leanne Jauriqui, Vibrant Corp.
Eric Biedermann, Vibrant Corp

cc: Diane Peebles, 01526, MS0346
John Martinez, 7933, MS1495

from: Jill Blecke, 1526, MS0346
Dan Rohe, 1522, MS0557

subject: NMSBA High Frequency Modal Analysis of a Solid Metal Cylinder using a Polytec 3D Scanning Laser Vibrometer

1 INTRODUCTION

This memo documents the results and methodology of the high-frequency modal test performed on a solid metal cylinder, provided by Vibrant Corporation, in April 2015 at Sandia National Laboratories in the Component Dynamics Laboratory. This work extends the FY14 project. The purpose of this extension test was to measure mode shapes of 3 units between 140 kHz and 160 kHz to determine if the shape order remains consistent from unit to unit.

2 TEST ITEM DESCRIPTION

The units tested were solid metal cylinders provided by Vibrant Corporation. The units were listed as part number TE_P_05_110068 with IDs 69W8E, 69W8K and 69W8M. The lengths of the units were 3.00 inches long with a constant diameter of 0.50 inches. The units all weighed in at 3.0 oz each.

3 TEST SETUP

A modal analysis was performed on the unit using a Polytec PSV-500 3D scanning laser Doppler vibrometer (LDV). Excitation of the unit was performed by a single piezoelectric device integrated into the test fixture provided by Vibrant Corporation. A pseudo random signal was used to drive the exciter at a single location on the unit. All tests excited the structure through CH-1 on the test fixture.

3.1 Boundary Conditions

The unit rests in the test fixture on four piezoelectric point locations. Two locations are positioned on each side of the unit at 45º below horizontal.

Normal use of the test fixture allows for actuation via one point location and sensing at two other locations. For this particular modal test, sensing was provided via laser, while the test fixture was used primarily to excite the unit via the piezo electric actuators. Two brackets were placed on each side of the fixture for 3D laser alignment.

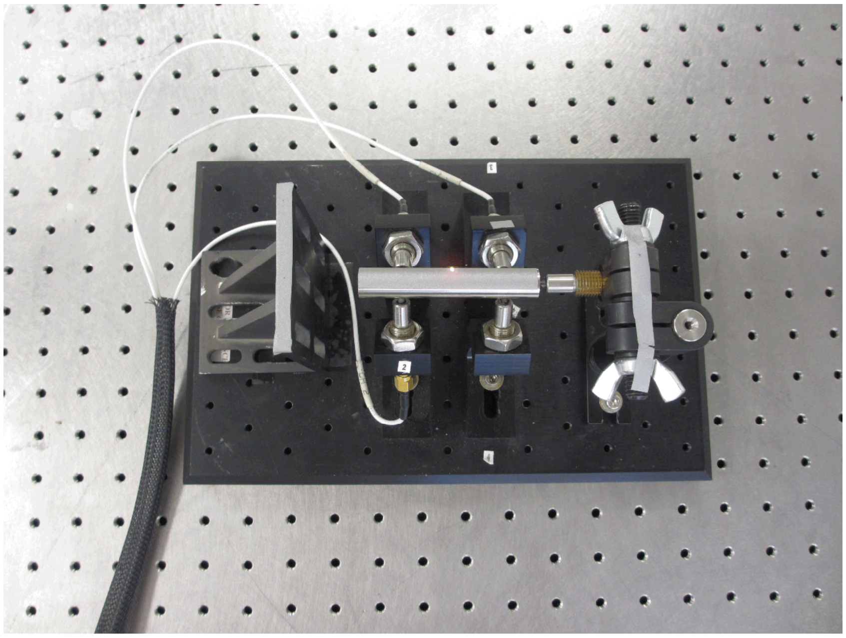

Figure 1: Unit in test fixture

The test fixture was placed on a small optical table and tripods were used to point the 3 lasers the test unit. An extension arm attached to the center tripod was used to mount a camera to for visualization of the test unit during alignment and testing. The image in Figure 2 displays the entire experimental test bed.

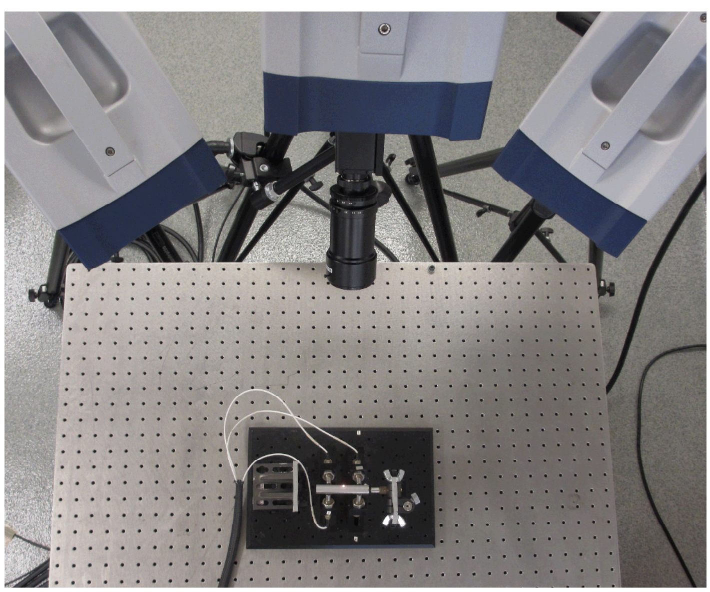

Figure 2: Experimental test set up including the test fixture, sample unit and 3 measurement lasers

3.2 Measurement Locations

A grid of 205 measurement locations was located on a portion of the outer surface of each unit.

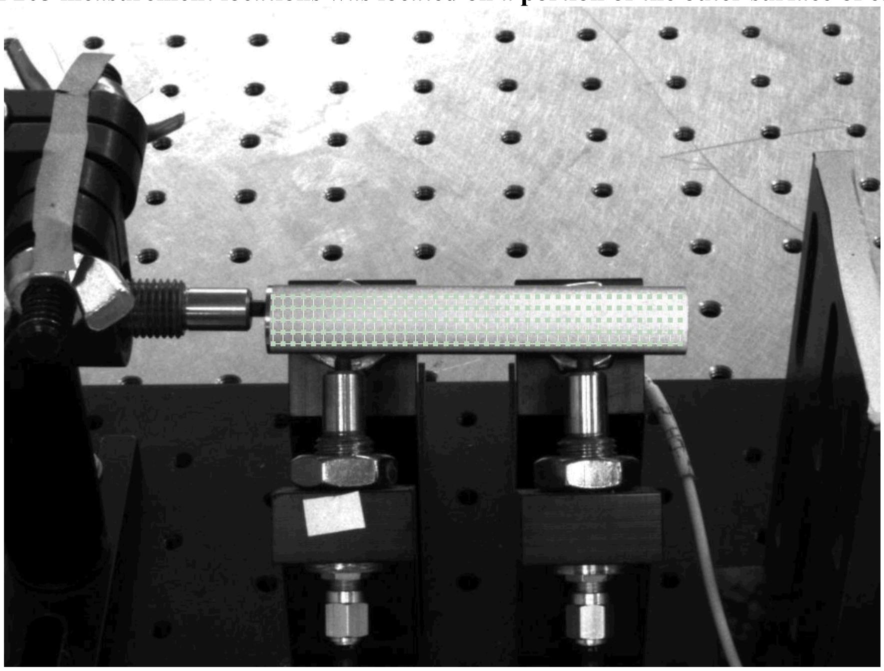

Figure 3 shows the measurement points overlaid on one of the units.

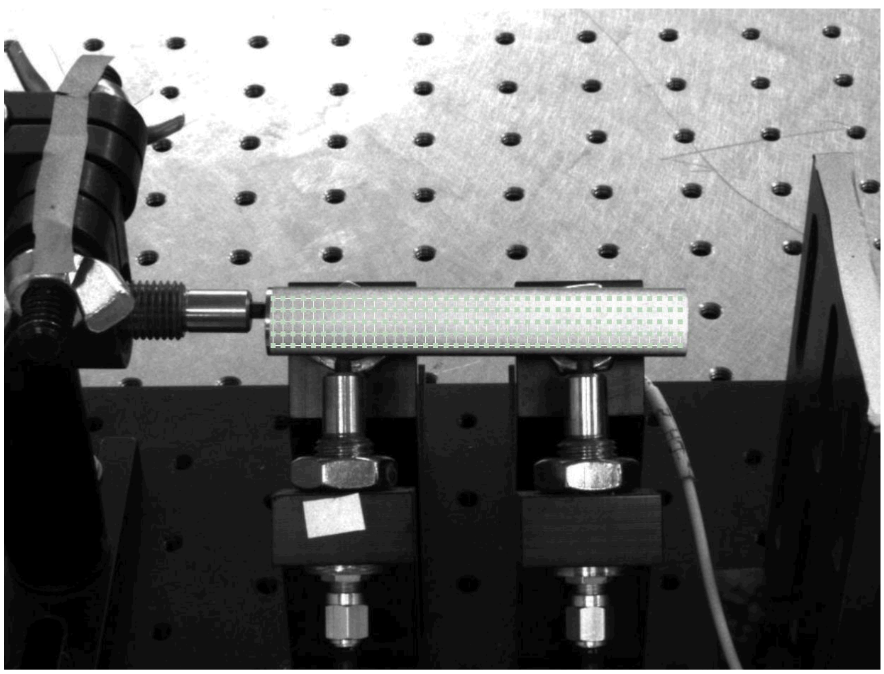

Figure 3: Image of measurement locations on a sample unit

3.3 Excitation

The reference excitation force was produced by providing a voltage to a piezoelectric exciter at the drive location, CH1 on the test fixture with a 2V pseudo random signal from 10 kHz to 200 kHz. A Krohn-hite Model 7500 amplifier was used to amplify the signal (10x) from the generator to the piezoelectric actuator.

3.4 DAQ Setup

The Polytec data acquisition system was set up to measure data between 10 kHz and 200 kHz. No windows were applied. The system recorded 15 averages at each measurement location to help reduce noise. While the bandwidth of the excitation and measurement ranged between 10 kHz and 200 kHz, the post processing of the data focused primarily on the response of the structures between 140 kHz and 160 kHz per customer priorities.

4 ANALYSIS AND RESULTS

Post-processing was conducted using both Polytec Data Presentation software and Matlab, utilizing both the add-in toolbox IMAT (AFPoly) and SMAC for curve fitting and modal parameter estimation. Post-processing focused on frequencies from 135 kHz to approximately 160 kHz. Nine modes were recorded on each of the three units in this frequency range. Figure 4 displays the Complex Mode Indicator Function (CMIF) of the measured response for each of the 3 test samples. The frequencies extracted from the measured data for each unit are listed in Table 1 and images of the corresponding mode shapes appear in Figure 5 through Figure 12. *Note: Mode shape animations (.avi files) will also be delivered to the customer.*

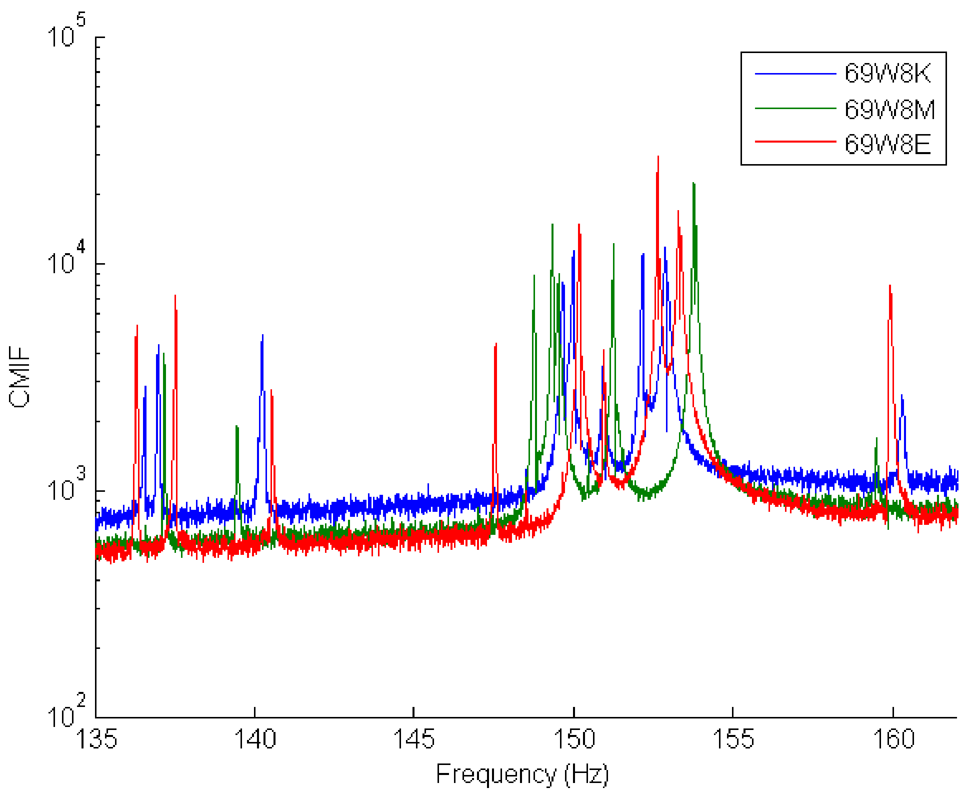

Figure 4: CMIF of measured response for all 3 test samples for the frequency range of interest

Table 1: Measured frequencies between approximately 135 and 160 kHz for each test unit

Mode	Measured Frequencies (kHz)	Mode Shape

	69W8K	69W8M	69W8E	Description
1	136.6	134.8	136.3	Bending mode pair
2	137.0	137.2	137.5	
3	140.2	139.5	140.5	Torsion
4	149.7	148.8	147.5	Bending mode pair with shear component
5	150.0	149.3	150.2	
6	150.9	149.5	150.9	*Not consistent across units*
7	152.2	151.3	152.6	
8	152.9	153.8	153.3	
9	160.3	159.5	159.9	Torsion

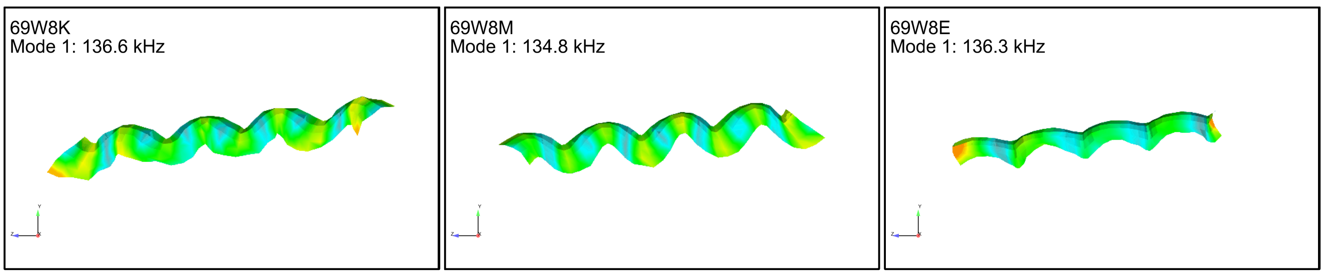

Figure 5: 1st measured mode for all test units – bending

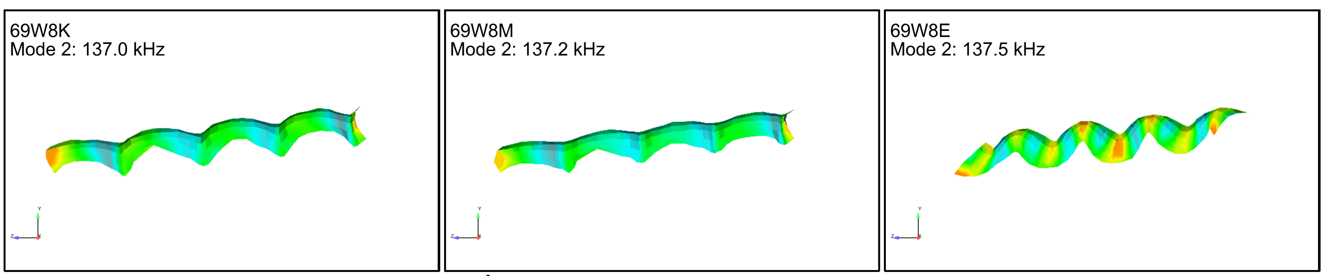

Figure 6: 2nd measured mode for all test units - bending

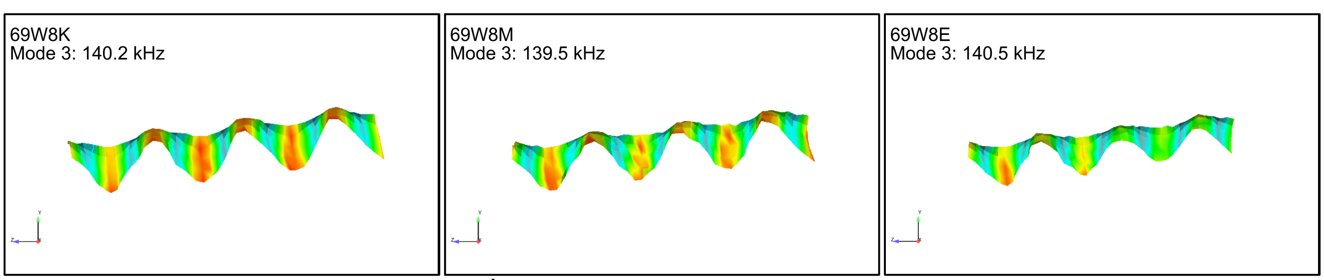

Figure 7: 3rd measured mode for all test units - torsion

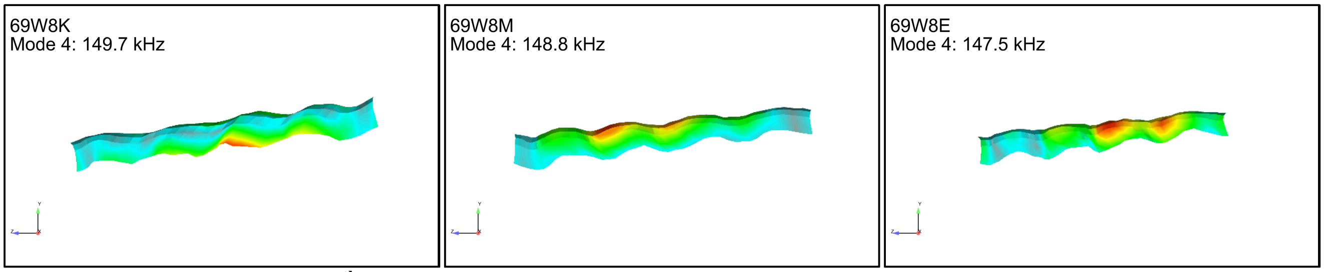

Figure 8: 4th measured mode for all test units – bending with shear component

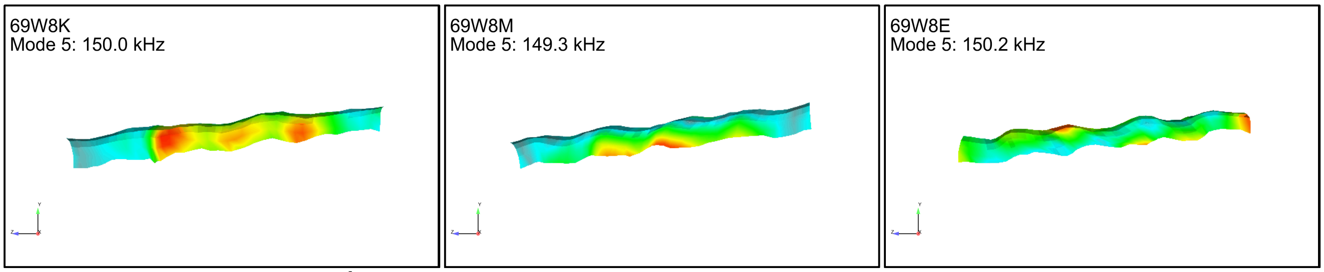

Figure 9: 5th measured mode for all test units – bending with shear component

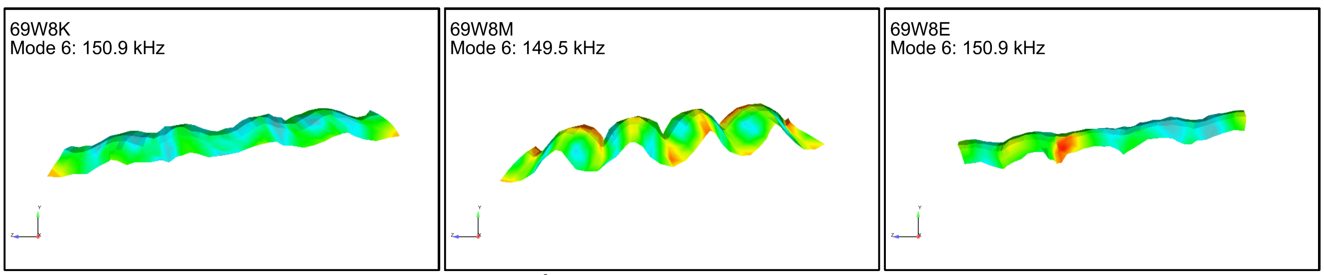

Figure 10: 6th measured mode for all test units

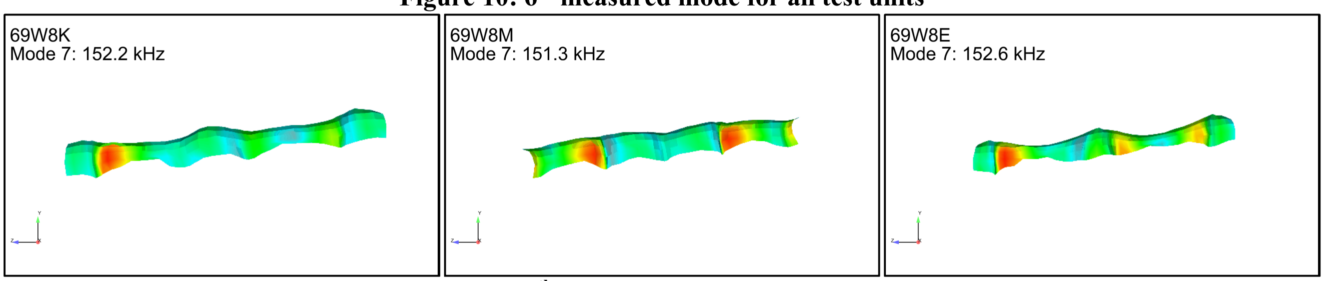

Figure 11: 7th measured mode for all test units

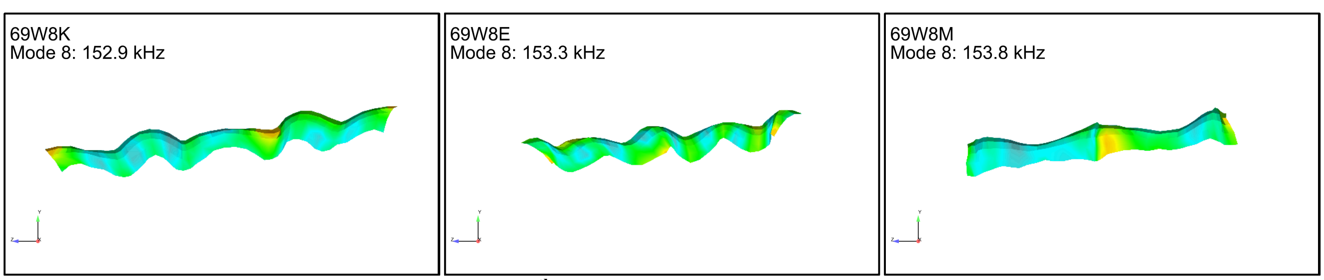

Figure 12: 8th measured mode for all test units

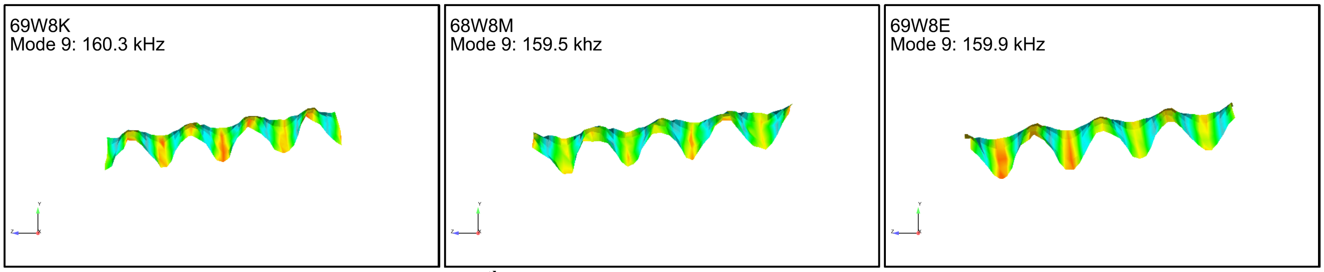

Figure 13: 9th measured mode for all test units - torsion

The mode shape order does not vary from component to component for the first 5 modes measured in the frequency range. The first two are a bending mode pair, the third shape is a torsion mode and the 4th and 5th measured modes are bending mode shape pairs with a shear-like component to the deflection. Also, mode 9 appears to be a torsion mode for all three testing components. Within the frequency band 150 – 153 kHz, the shapes were more challenging to identify, particularly the resonance near 153 kHz, which contains a dip in the frequency measurement at that resonance. Figure 14 displays the CMIF of the measured response for all 3 test samples focusing on the group of resonance peaks near 150 kHz. The gray dashed circles highlight the dip in the resonance peak that made extracting the shape at 153 kHz challenging. This feature could potentially be due to fixture-structure interactions or a resonance of the actuator.

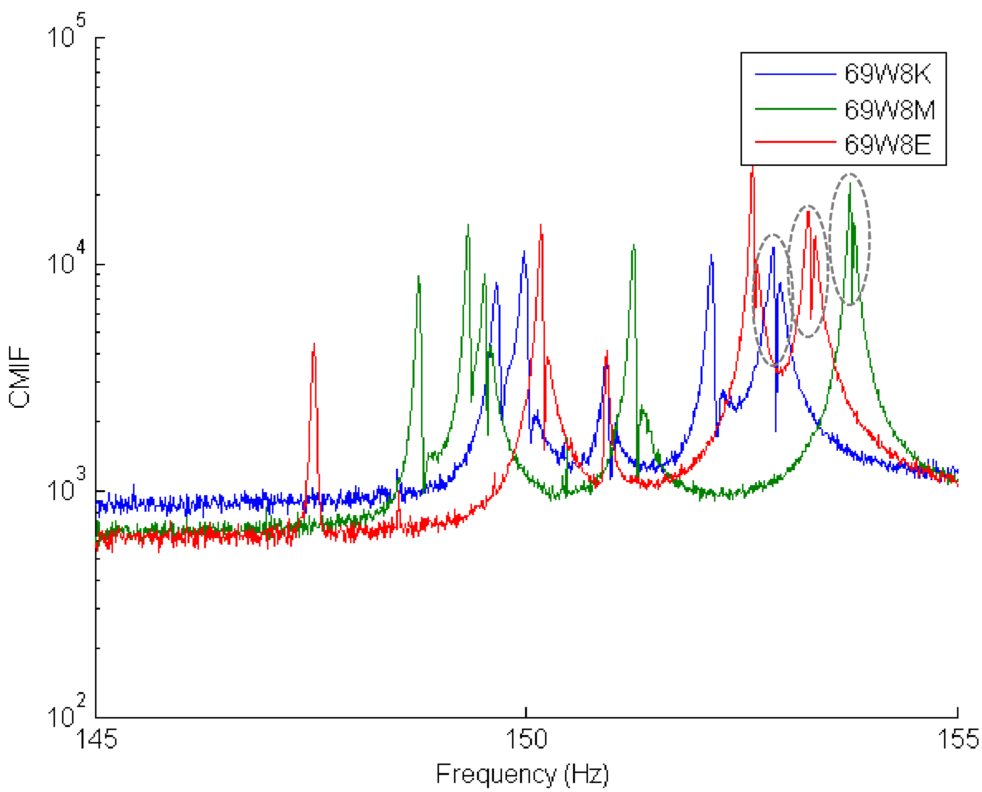

Figure 14: CMIF of measured response for all 3 test samples focusing on a group of resonances near 150 kHz

The modes in this region are difficult to identify qualitatively with the eye and there is some judgement to be made as to the exact order of shapes. Qualitatively, the mode shape order does appear to vary from unit to unit as the axial mode appears to split the bending mode pair for units 69W8K and 69W8E while it was measured subsequent to the bending mode pair for unit 69W8M. In order to assist with shape identification, modal assurance criteria (MAC) values were computed between each test component. For frequencies measured from 135 kHz – 149 kHz as well as frequencies near 160 kHz, computed MAC values were high, indicating similar shapes. However, frequencies surrounding 150 kHz generally had MAC values below 0.8, indicating that the modes measured across the units were not quite the same shape (Figure 15).

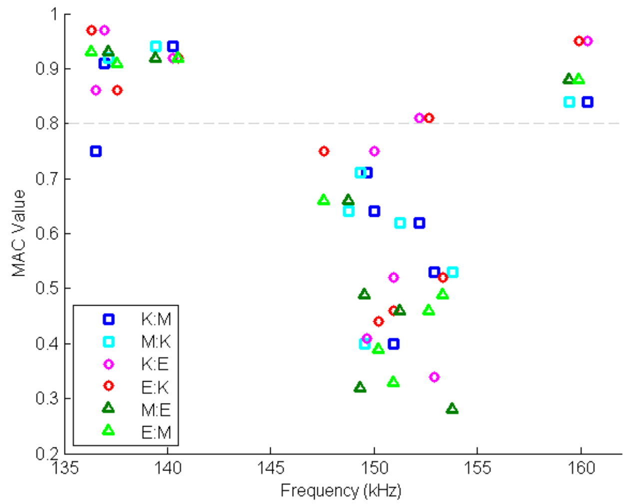

Figure 15: MAC values by component as a function of frequency

5 SUMMARY

The purpose of this extension test was to measure mode shapes of 3 units between 135 kHz and 160 kHz to determine if the shape order remains consistent from unit to unit. Nine modes were recovered for each of the 3 units tested. The mode shapes were consistent from unit to unit except approximately between 150 kHz and 155 kHz (measured modes 6, 7 and 8). However, these shapes were challenging to curve fit, particularly near 153 kHz. An alternate fixture and excitation method is recommended to determine if the issues in the data at this frequency are the result of fixture-unit interactions or an actuator resonance.

6 ATTACHMENTS

C1_Mode1.avi	Measured mode shape animation for unit 69W8K at 136.6 kHz
C1_Mode2.avi	Measured mode shape animation for unit 69W8K at 137.0 kHz
C1_Mode3.avi	Measured mode shape animation for unit 69W8K at 140.2 kHz
C1_Mode4.avi	Measured mode shape animation for unit 69W8K at 149.7 kHz
C1_Mode5.avi	Measured mode shape animation for unit 69W8K at 150.0 kHz
C1_Mode6.avi	Measured mode shape animation for unit 69W8K at 150.9 kHz
C1_Mode7.avi	Measured mode shape animation for unit 69W8K at 152.2 kHz
C1_Mode8.avi	Measured mode shape animation for unit 69W8K at 152.9 kHz
C1_Mode9.avi	Measured mode shape animation for unit 69W8K at 160.3 kHz

C2_Mode1.avi	Measured mode shape animation for unit 69W8M at 134.8 kHz
C2_Mode2.avi	Measured mode shape animation for unit 69W8M at 137.2 kHz
C2_Mode3.avi	Measured mode shape animation for unit 69W8M at 139.5 kHz
C2_Mode4.avi	Measured mode shape animation for unit 69W8M at 148.8 kHz

C2_Mode5.avi	Measured mode shape animation for unit 69W8M at 149.3 kHz
C2_Mode6.avi	Measured mode shape animation for unit 69W8M at 149.5 kHz
C2_Mode7.avi	Measured mode shape animation for unit 69W8M at 151.3 kHz
C2_Mode8.avi	Measured mode shape animation for unit 69W8M at 153.8 kHz
C2_Mode9.avi	Measured mode shape animation for unit 69W8M at 159.5 kHz

C3_Mode1.avi	Measured mode shape animation for unit 69W8E at 136.3 kHz
C3_Mode2.avi	Measured mode shape animation for unit 69W8E at 137.5 kHz
C3_Mode3.avi	Measured mode shape animation for unit 69W8E at 140.5 kHz
C3_Mode4.avi	Measured mode shape animation for unit 69W8E at 147.5 kHz
C3_Mode5.avi	Measured mode shape animation for unit 69W8E at 150.2 kHz
C3_Mode6.avi	Measured mode shape animation for unit 69W8E at 150.9 kHz
C3_Mode7.avi	Measured mode shape animation for unit 69W8E at 152.6 kHz
C3_Mode8.avi	Measured mode shape animation for unit 69W8E at 153.3 kHz
C3_Mode9.avi	Measured mode shape animation for unit 69W8E at 159.9 kHz