STRUCTURAL ANALYSIS OF
A WESTFALL 2800 MIXER, BETA = 0.8
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By

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INTRODUCTION

Alden Research Laboratory Inc. (Alden) was contracted by Westfall Manufacturing Inc. (Westfall) to determine the structural loading on an 84" 2800 mixer with a Beta of 0.8. This report will describe the analysis and results of the calculations used to determine the maximum stress and deformation under three velocities tested.

COMPUTATIONAL MODEL DESCRIPTIONS

Two computational models were used in this analysis. First, a CFD analysis of the mixer in pipe flow was completed over a range of velocities to determine the pressure on the upstream and downstream faces of the mixer. Next, these pressures were used as inputs to a structural model of the mixer to determine the material stress, deformation, and natural frequencies.

The CFD model geometry was developed using the commercially available three-dimensional CAD and mesh generation software, GAMBIT V2.4.6. The computational domains generated for the model consisted of 1.1 million hexahedral and tetrahedral cells. Simulations were performed using the CFD software package FLUENT 13.1, a state-of-the-art, finite volume-based fluid flow simulation package including program modules for boundary condition specification, problem setup, and solution phases of a flow analysis.

Alden used FLUENT to calculate the full-scale, three-dimensional, incompressible, turbulent flow through the pipe and flow conditioner. A two-equation realizable k-ε model was used to simulate the turbulence. Detailed descriptions of the physical models employed in each of the Fluent modules are available from Ansys/Fluent, the developer of Fluent V13.1.

The structural finite element analysis (FEA) model was created in COSMOS with 74,000 nodes (Figure 1), using the results of the CFD analysis.

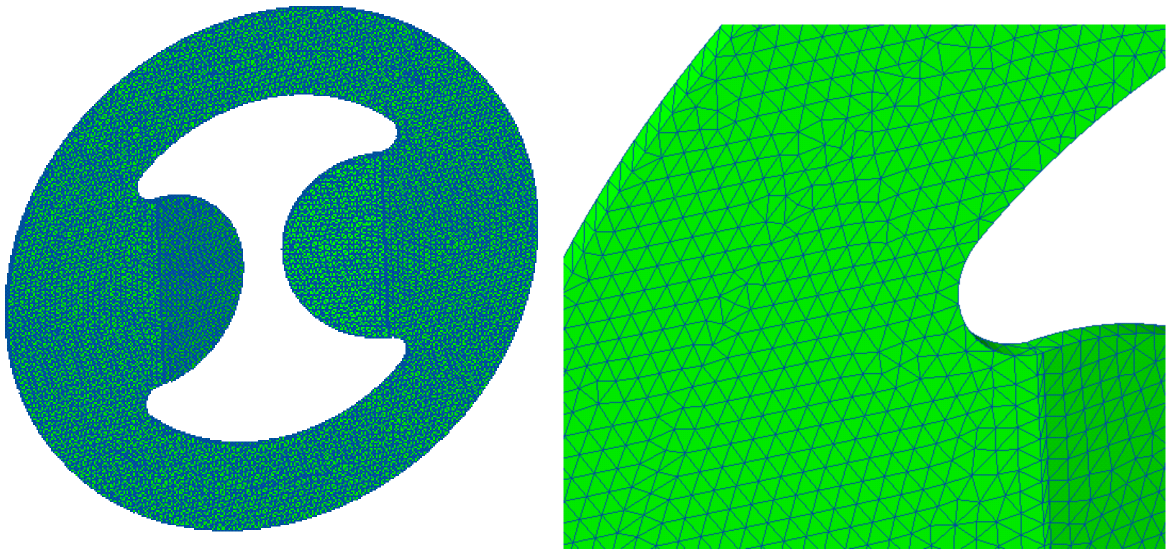

Figure 1 - Structural Analysis Mesh

CFD MODEL BOUNDARY CONDITIONS

The tests were conducted in an 84-inch ID pipe using water at ambient pressure and temperature at velocities of 1.4, 5.0 and 8.6 ft/s. A uniform velocity inlet was imposed at the model inlet, which was placed 5 pipe diameters upstream of the mixer inlet, and a uniform static pressure boundary was imposed at the model outlet, which was placed at least 5 pipe diameters downstream of the mixer outlet. On all surfaces, no-slip impermeable adiabatic wall boundary conditions were applied with roughness heights set to 0.00015-ft as appropriate for steel pipe. A turbulence intensity of 5% was imposed at the model inlet, which is consistent with fully developed pipe flow.

FEA MODEL BOUNDARY CONDITIONS

The 2800 mixer plate was restrained in the flange around the perimeter of the mixer, and a uniform pressure differential calculated by the CFD model for the given flow rate was applied to the portion of the mixer that is inside the pipe.

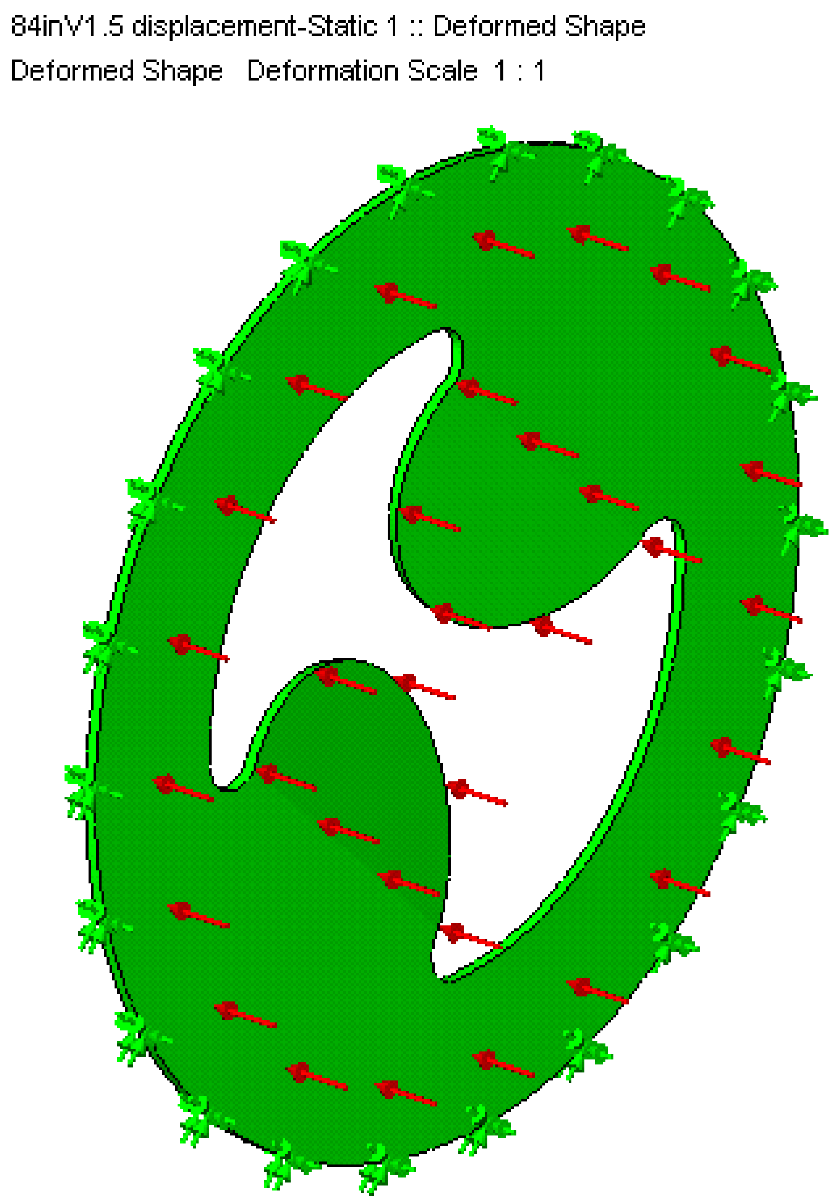

Figure 2 - Loading (red arrows) and Restraint (green arrows)

The plate was 1-¼” steel plate with the following material and mass properties (Table 1):

Table 1 - Mixer Material and Mass Properties

Property Name	Value
Elastic modulus	30463138 PSI
Poisson's ratio	.28
Shear modulus	11459943 PSI
Mass density	0.2781802 LB/CU-IN
Tensile strength	105000 PSI
Yield strength	90000 PSI

Mass: 2115.1744 lb
Volume: 7603.6140 in^3
Surface Area: 1.3531e+004 in^2

RESULTS AND DISCUSSION

For each of the water velocities tested, a differential pressure was calculated across the mixer. The pressure on each face of the mixer was quite uniform (Figure 3), so there is no loss of accuracy in the structural analysis by assuming a constant pressure differential across the mixer.

The differential pressures were applied to the structural FEA model, allowing the maximum stress, maximum strain, maximum deflection, and minimum safety factor to be calculated (Table 2).

Table 2 - Test Results

Velocity ft/s	Load psi	Max Stress psi	Max Strain	Max Deflection in	Minimum Factor of Safety (Yield)
1.4	0.286	472	0.0000089	0.005	191.0
5.0	3.67	6,051	0.000114	0.064	14.9
8.6	10.87	17,887	0.000338	0.189	5.0

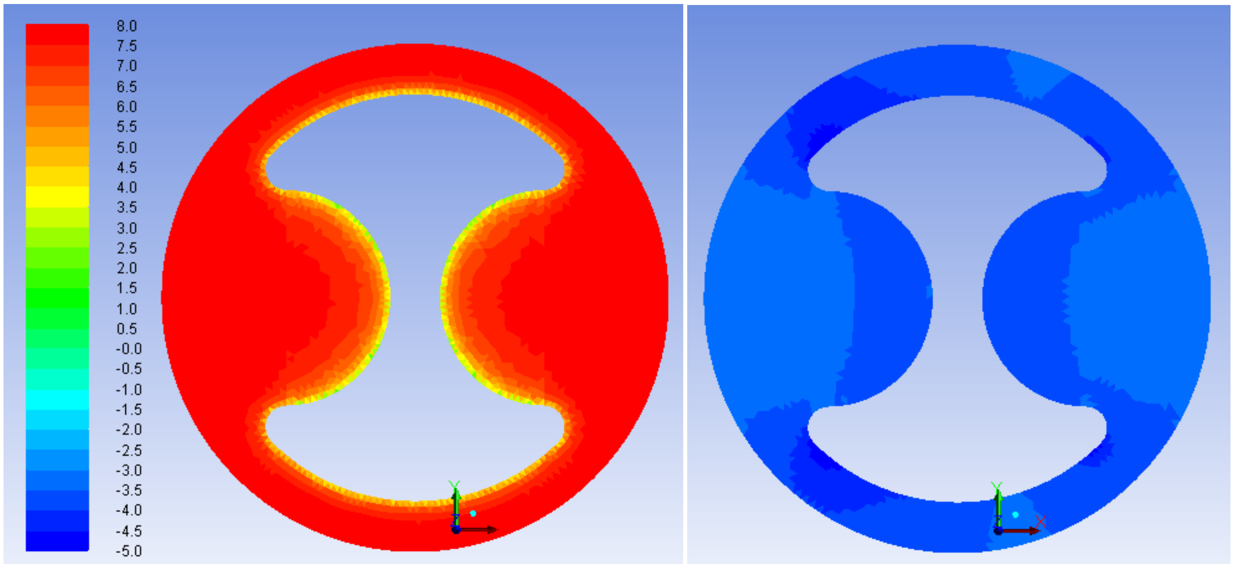

Figure 3 - Pressure Profiles on Upstream (left) and Downstream (right) Faces of Mixer

As one would expect, the differential pressure across the mixer scales with the square of the velocity; and the stress, strain, and deflection all scale linearly with differential pressure across the range of flows tested. Because of the excellent agreement with this scaling, and the fact that the highest loads and deformation occur at the highest velocity, only the results for the 8.6-ft/s case will be shown.

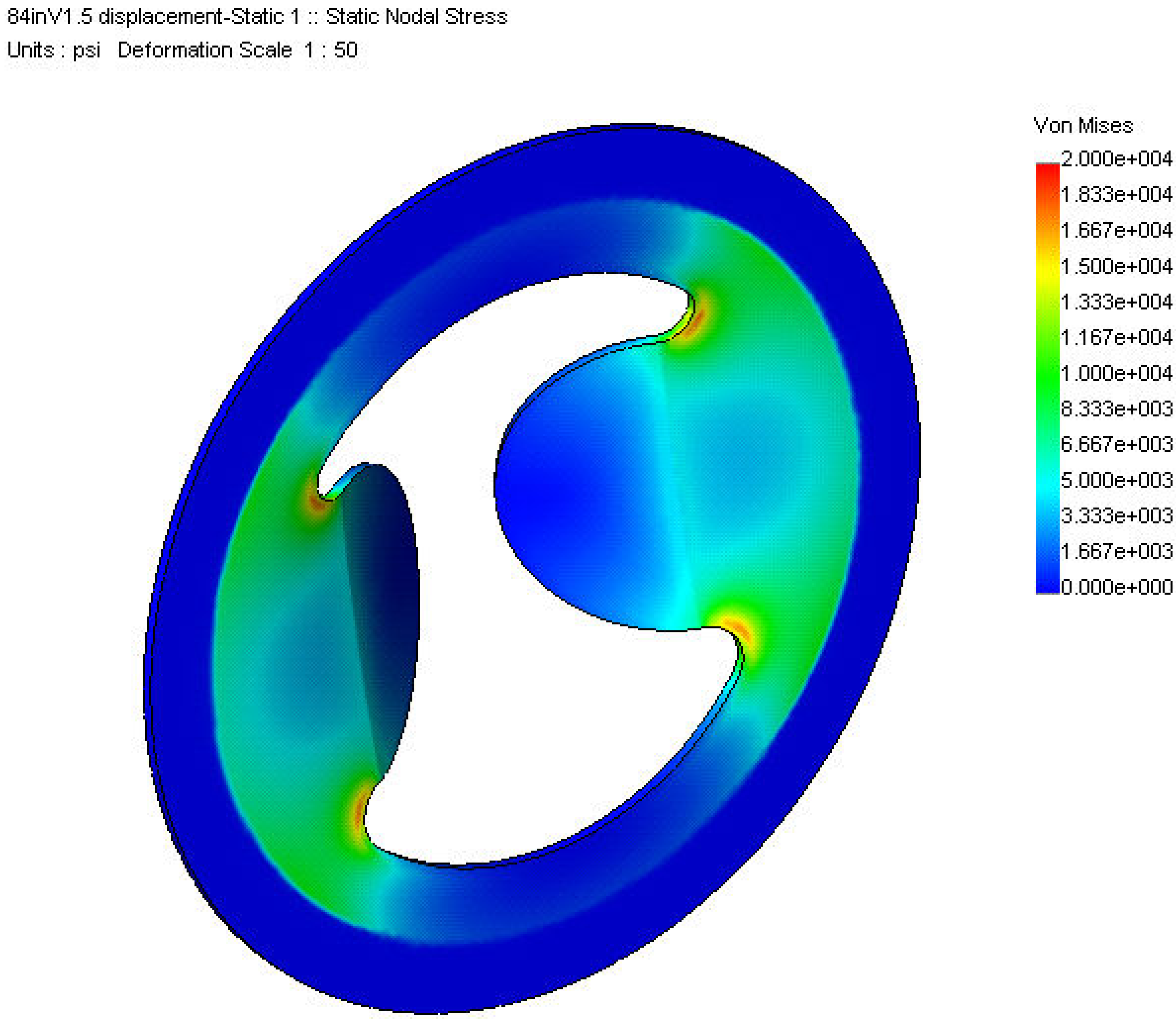

Figure 4 - Stress Results at a Velocity of 8.6-ft/s

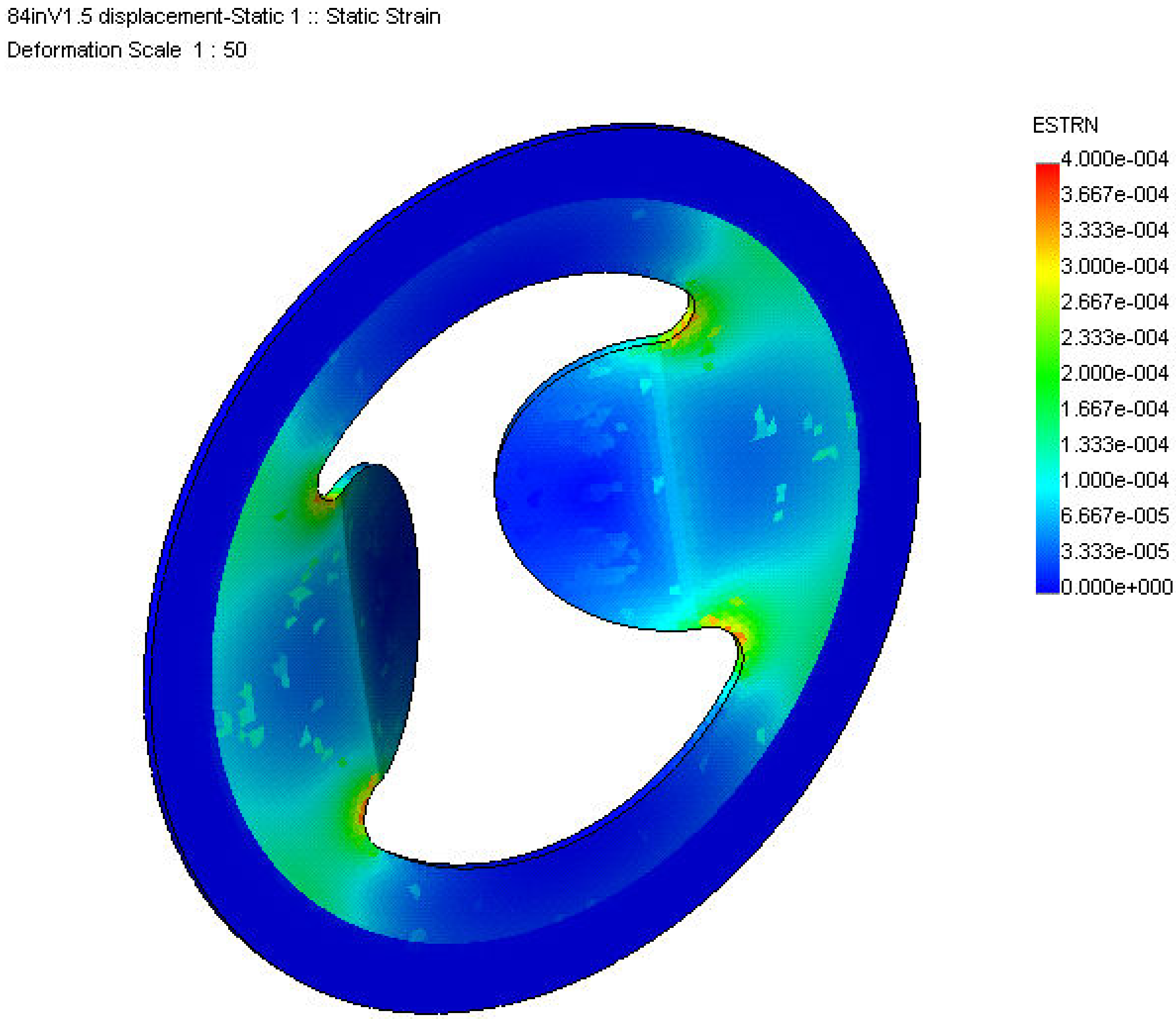

Figure 5 - Strain Results at a Velocity of 8.6-ft/s

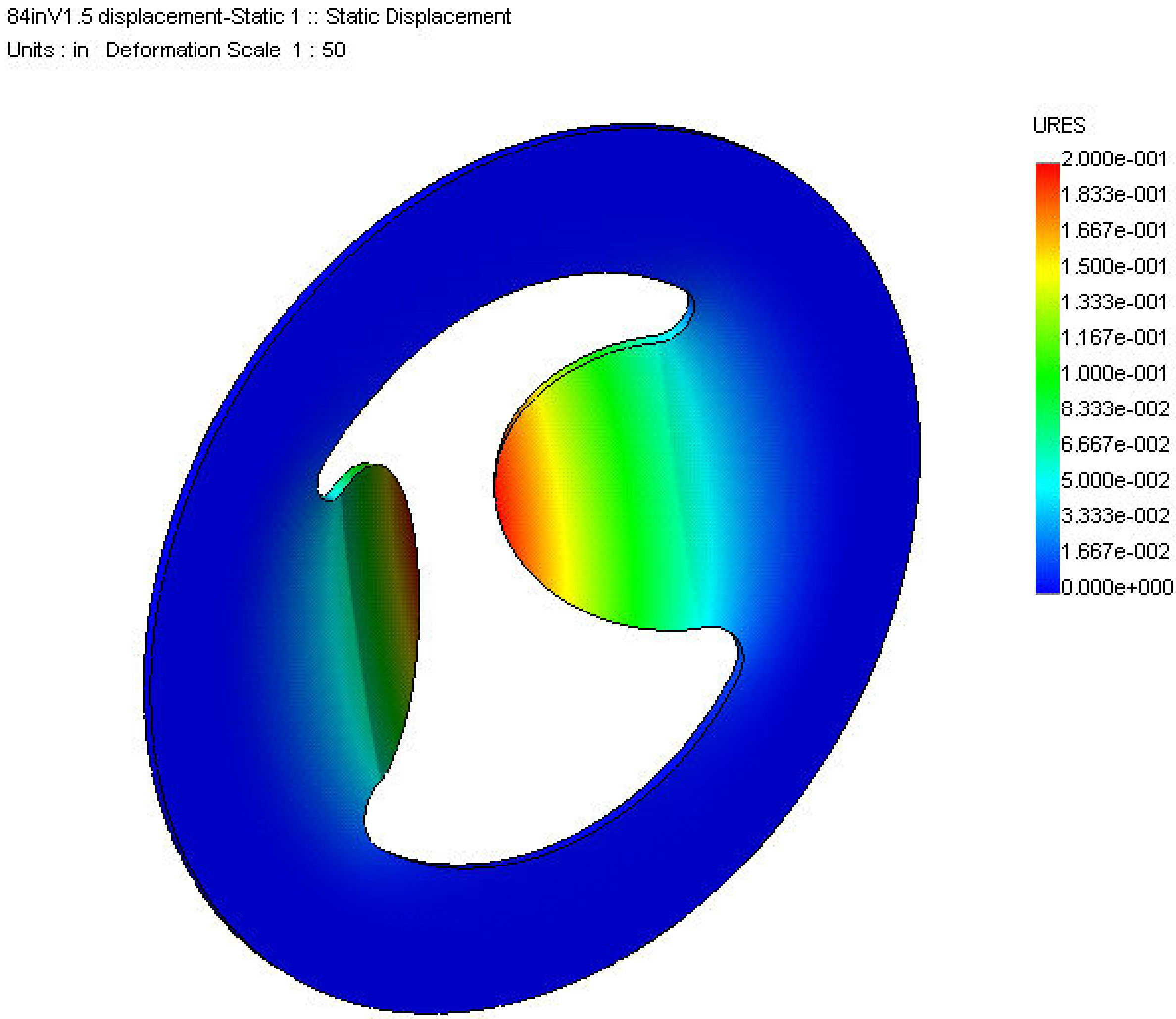

Figure 6 - Displacement Results at a Velocity of 8.6-ft/s

In addition to static loading, the structural analysis calculated the lowest three natural frequencies of the mixer, which were 52.4-Hz (first and second modes) and 152.2-Hz (third mode) (Figure 7). These frequencies are quite high for any large scale flow oscillations with low damping rates that would be required to vibrate the mixer lobes.

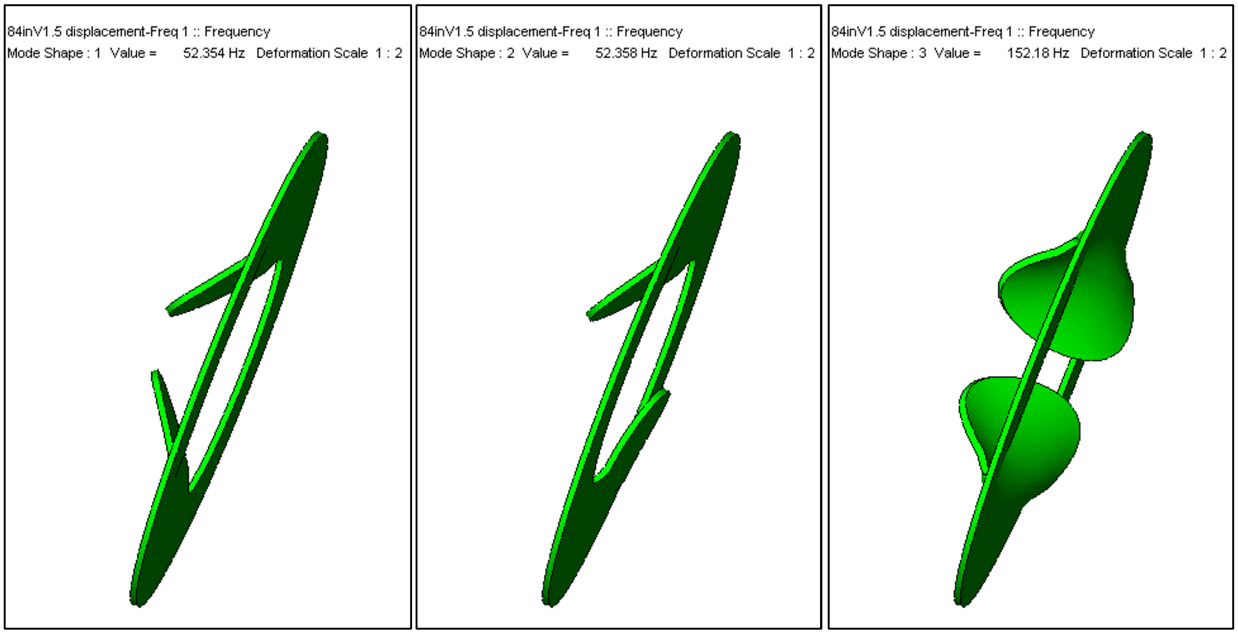

Figure 7 - First Three Vibrational Modes

CONCLUSIONS

This analysis has determined that a Westfall 2800 mixer with a beta of 0.8 can withstand a uniform inflow water velocity up to 8.6-ft/s with a minimum safety factor of 5.0 to yield. The lowest natural frequency calculated was 52.4-Hz, which is far above any expected flow-related frequencies for this mixer.