Title: Vibration and Stress Analysis of Submerged Vertical Turbine Pump per ASCE 4-98

Main Graphic:

Caption: Vertical Turbine Pump – Vibration and Stress Analysis for submerged structures per ASCE 4-98

Objective: The vibration requirements of this project state that "The complete pumping unit…shall be free from dangerous critical speeds from 20 percent below to 30 percent above the operating speeds required to achieve the specified performance characteristics." In simpler terms, this means it was imperative to identify the normal modes of the structure and ensure that they would not be excited by operation of the equipment (see Figure 1).

In general, this is an easy and straightforward analysis. In the case of this project, a bit more preparation was required before running through the standard steps of the FEA procedure. Submerging a structure into fluid will have a dramatic effect on the damping and natural frequency of the structure. With the guidance of *Wambsganss, et al., "Added Mass and Damping of a Vibrating Rod in Confined Viscous Fluids"* the mass of the structure was adjusted to account for the effects of the fluid surrounding the pump within the confines of the pump can. This reference also refers to the ground breaking work by R.J. Fritz "The Effect of Liquids on the Dynamic Motions of Immersed Solids", Journal of Engineering for Industry, 1972. According to this discussion, the effects of surrounding fluid can be modeled as added-mass terms in the component structure mass matrix. Aside from some support plates, the internal components in the vessels are all cylindrical objects.

This same procedure and formulation was used for a seismic analysis where internal vessels were submerged in a non-newtonian fluid. During a vertical seismic excitation a pressure distribution is exerted by the fluid on the vessel surfaces. The exact methods for estimating the maximum magnitude and distribution of this pressure are provided in ASCE 4-98

The FE model was built with a combination of plate, beam, mass and rigid body elements (see Figure 2). A heavy emphasis was placed on creating an efficient model with quick run times. These quick run times allowed for many iterations of model adjusting and analysis over a short period of time.

The result of this analysis was assurance for the customer that the pump would meet the strict requirements of the end client without physical testing.

Keywords: Femap, NX Nastran, vertical turbine pump, vertical propeller pump, axial flow propeller pump, vertical mixed flow pump, dynamic analysis, vibration analysis, natural frequency, normal modes, frequency response, fatigue analysis, MIL-STD-167, Fritz, R. J., "The Effect of Liquids on the Dynamic Motions of Immersed Solids", Journal of Engineering for Industry, 1972, ASCE 4-98,

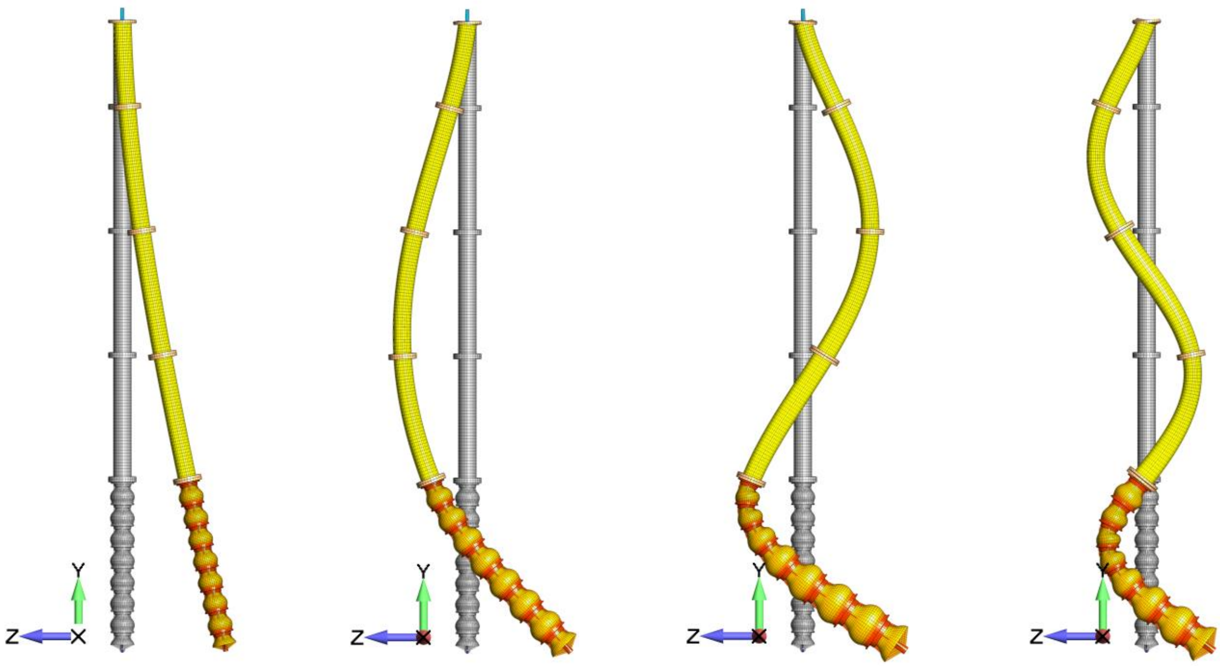

Figure 1: The normal mode shapes of the vertical pump with added mass (Fritz)

The FEA model was build using plate, beam and mass elements. The mass of the vertical pump was matched to physical weights. The fluid mass effects were calculated according to Fritz and then added to the structure as a distributed mass to the beam elements to evenly represent the effects of the surrounding fluid.

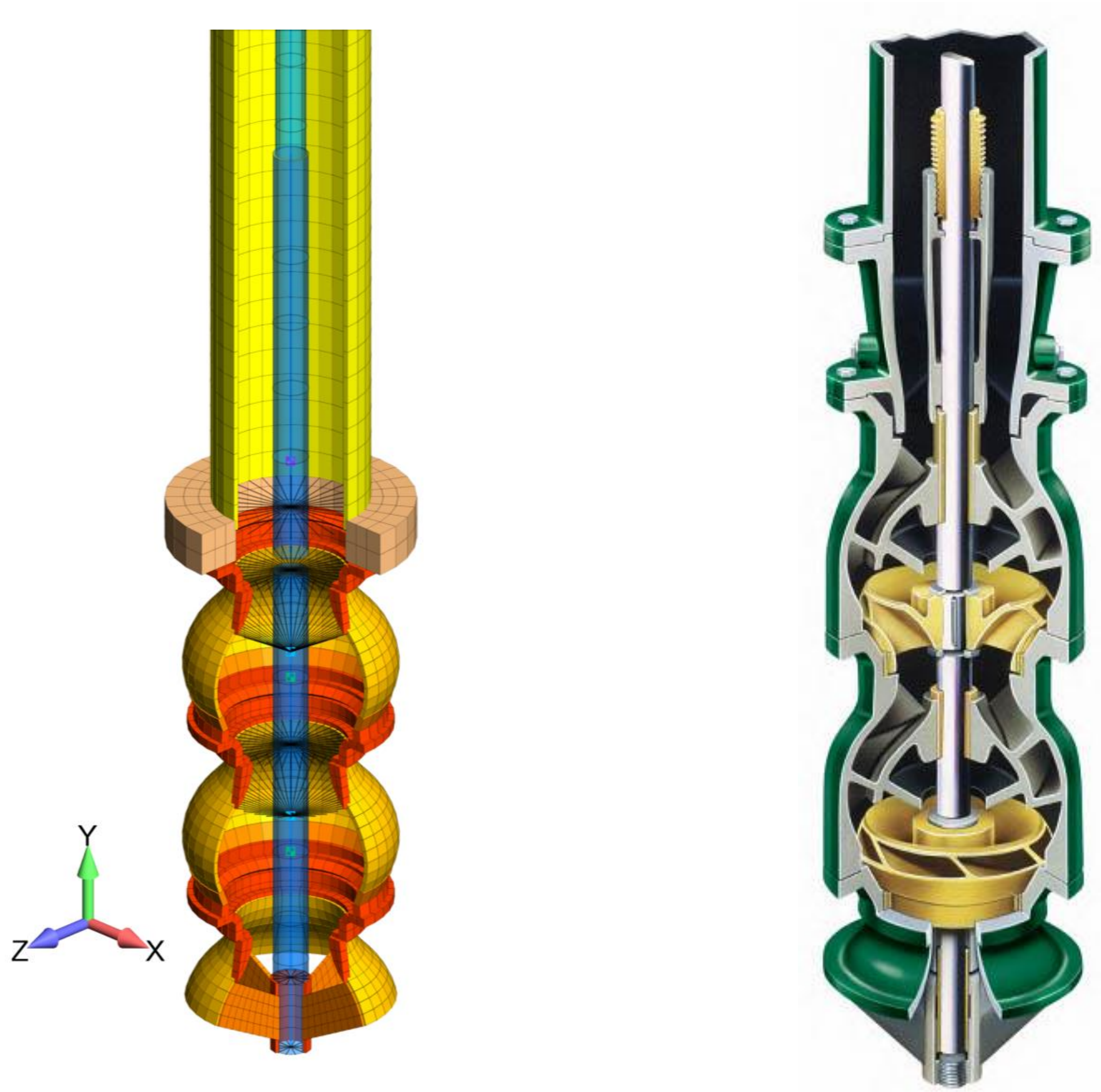

Figure 2: The above images show in detail, the FE modeling and idealization techniques using plate elements, beam elements, mass elements and rigid body elements.

Although the model appears simple, elegant simplicity is deceptively dificult to achieve. The model runs in seconds but getting the vibration frequencies correct is a bit more difiicult. The normal modes were checked via hand calculations and against prior work done by the client. At the end, it was assured that the results fell within acceptable engineering accuracy of reality.