

Photo 2: Detailed vibration measurements.

significant issues were discovered.

With the ODS compiled from the many vibration test points, it was found that:

- The motor was moving in a circular motion in both the vertical, and axial (parallel to motor shaft) plane. This meant that the motor drive end was moving towards the gearbox and away again, while rocking back and forth about its center.
- The pump and gearbox were moving back and forth in the horizontal direction (perpendicular to motor shaft, in the direction of plunger motion) at the same time the motor motion was occurring.
- The base plate was very flexible underneath the motor and pump, allowing the rocking motion of the motor.
- The platform beams were moving in phase with the base plate motion, showing good connection between the base plate and platform deck. The motion also showed significant flexibility of the platform beams.

Beta's investigations into the skid construction found that it was made with 4 in. (100 mm) channel perimeter beams, 2 in. (50 mm) angle cross members, and 0.25 in. (6 mm) seal pan. The I-beams added to the platform structure underneath the pumps during the client's trial-and-error activities were 12 x 16 in. (305 x 406 mm) and 12 in. (305 mm) deep.

With the ODS compiled into a detailed animation of all the components (see Figure 1), it became clear why the gearbox failures were occurring. The following conclusions were made:

- Excessive flexibility in the base plate was a major contributor to damaging motion of the drive train.
- Platform flexibility underneath the pump base plates was also contributing to damaging motion.
- Connections between the base plate, and platform foundation were good (no loose connections).

- Connections between the motor, pump, and base plate pedestals were good (no loose connections).
- The gearbox failures were due to the combined motion of motor, pump, skid, and platform structure.

Finding a Solution

Due to the excessive costs of off-shore structural modifications and urgency of finding a workable solution, Finite Element Analysis (FEA) was used to find modifications that would be effective in reducing the component motions noted above and improve the equipment reliability.

The first step was to create the FEA model. The model included the main deck structure and major components, both pump base plates including pedestals, motors, pumps and gearboxes.

The next step was to test the model with a forced response analysis to check if it produced similar results to the vibration ODS shapes and amplitudes measured in the field. Very similar forced response shapes were produced at the same frequencies as measured in the field.

Beta Machinery Analysis then could test the modifications in the model and have confidence that they would work in reality. Many potential modifications were tested to correct the excessive base plate and platform structure flexibility.

The challenge with correcting a flexible base plate was that all the modifications were required to be implemented offshore, as the pumps could not be removed from the platform without major dismantling of the piping.

The client agreed to the final modifications that involved stiffening the pump pedestal with grout, increasing the stiffness of the base plate by adding a structural beam on top of

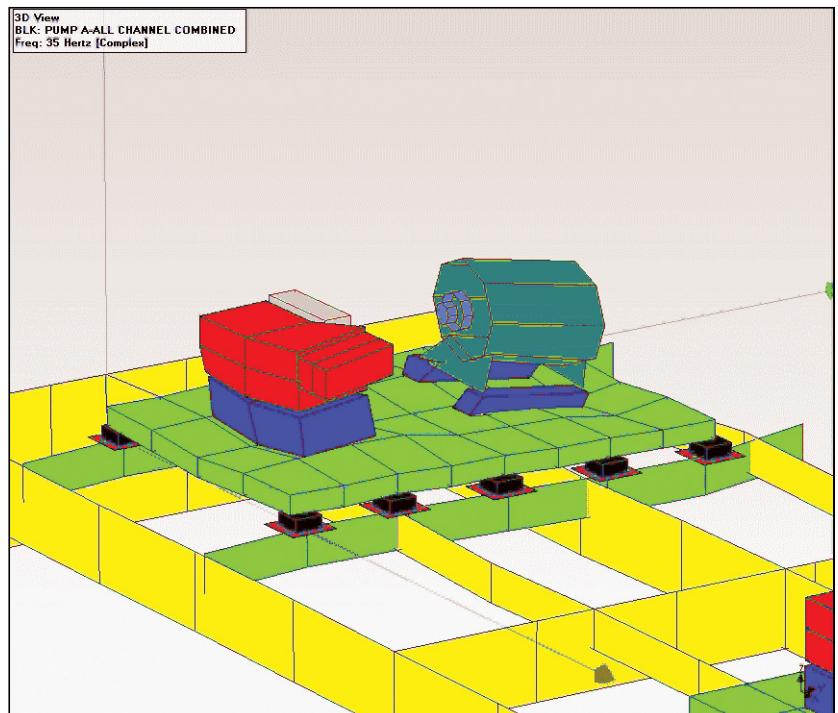


Figure 1: Image of pump, motor, base plate and platform ODS.

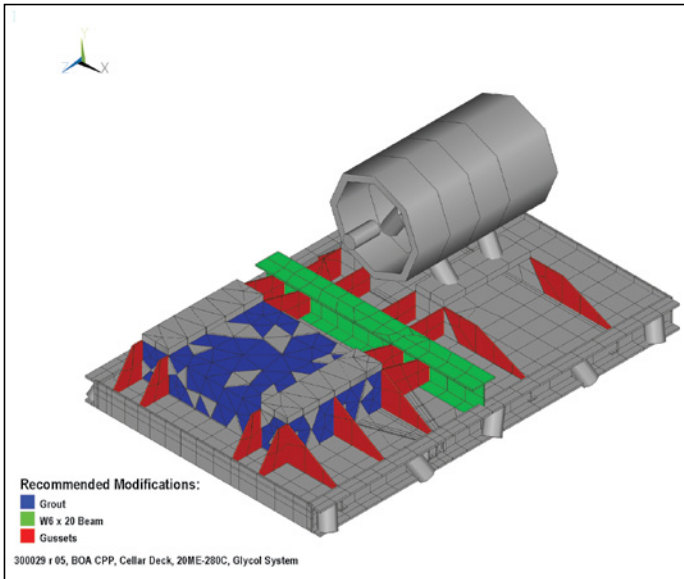


Figure 2: Base plate modifications available for topside access only.

the seal pan, triangular gussets to increase the horizontal and axial stiffness of pump and motor pedestals, and deepening beams under the pumps by welding T-sections underneath selected locations. (See modifications in Figures 2 and 3.)

Conclusions

This case study illustrates the importance of foundation considerations in pump design, even for relatively small applications where spare units are available.



Figure 3: Key beams requiring stiffening.

This is especially true in offshore environments where the foundation is flexible as compared to typical onshore applications where the equipment base is grouted to a concrete pad.

ODS vibration measurements can be helpful while troubleshooting to reveal hidden problems that individual vibration measurements do not show.

FEA can provide specific and effective recommendations when the model is validated with real-life vibration data. ©