RECIPROCATING PUMP DESIGN FLAWS SHUT DOWN OIL PLATFORM

In this case study, two small glycol pumps caused problems at an offshore facility

By Jordan Grose

Relatively small reciprocating pumps, usually considered non-critical, can create operational and production headaches at onshore and offshore facilities.

At one large offshore production platform, two reciprocating glycol triplex pumps, 150 hp (110 kW) each, were driven through a gearbox by a 1500 rpm motor (see Photo 1). The system was designed with one pump operating and the second pump as a spare.

These low-power pumps were not significant when compared to the thousands of kilowatts located in three gas turbine compressor trains on the production deck.

But when the gearboxes of these pumps began to fail every four weeks, and the lead time for replacements offshore was six weeks, there was a problem.

That problem was magnified when the spare pump gearbox failed, shutting down production of the entire platform for a few weeks.

Trial-And-Error Activities

A number of actions were initiated with the first gearbox failure, including vibration measurements, numerous hot and cold alignments, gear oil changes, OEM service callout offshore, laser measurements of pump mounting pad levelness/flatness, and installation of additional platform beams underneath the pumps.

This was a huge undertaking. Adding new platform beams on this cellar deck required a scaffold to be constructed from the edge of the platform and built underneath the deck and over the water to the right location. The scaffold had to be secure enough to hold the material, workers, welding equipment, etc.

The latter was a big job in itself, plus the significant time required for engineering, procurement and supply boat transport to the offshore location.

But none of these trial-and-error activities ended the gearbox failures.

Troubleshooting

Beta Machinery Analysis was contracted to conduct a detailed vibration and troubleshooting analysis of the gearbox failures.

Vibration data was collected on the pump frame, motor frame, gearbox, pump and motor pedestals, base plate (skid), platform mounting pads, and platform beams (see Photo 2).

All vibration data was collected to allow for compiling an operating deflected shape (ODS) of the pump, motor, base plate, and platform beams. The ODS analysis provided the opportunity to examine how each component of the equipment was moving relative to the other.

Beta Machinery Analysis did not find the measured vibration levels to be especially alarming. However, when it examined the relative motion of the pump components,

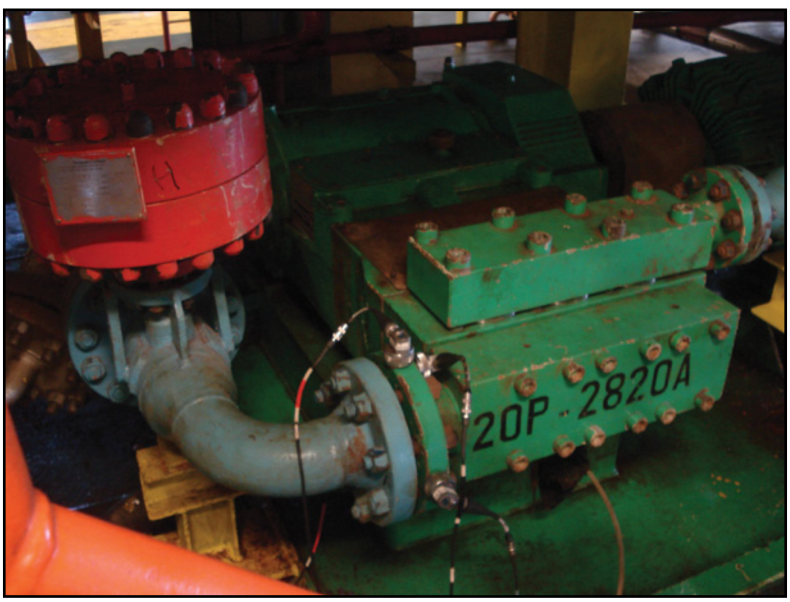

Photo 1: Small glycol pumps cause major production platform shutdown.

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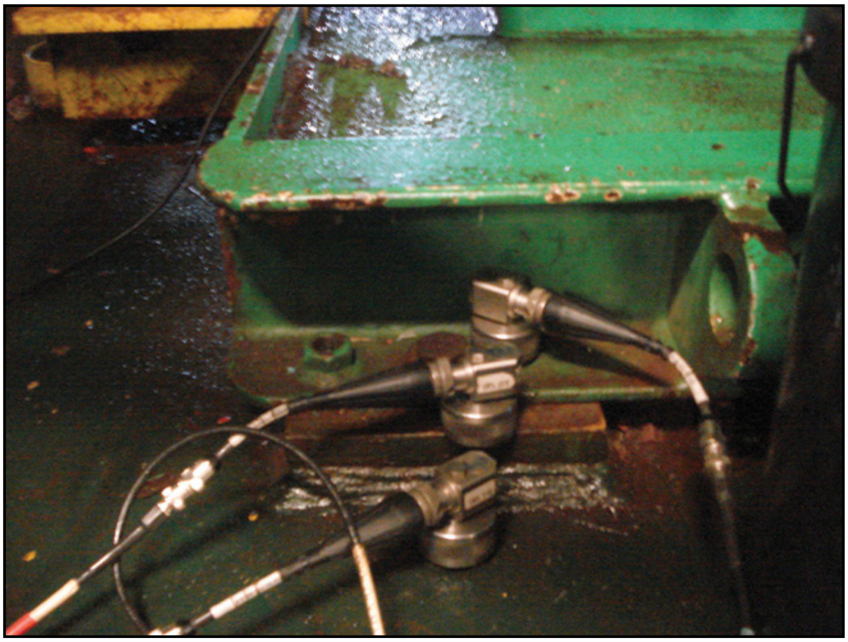

Photo 2: Detailed vibration measurements.

- 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 offshore 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

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).

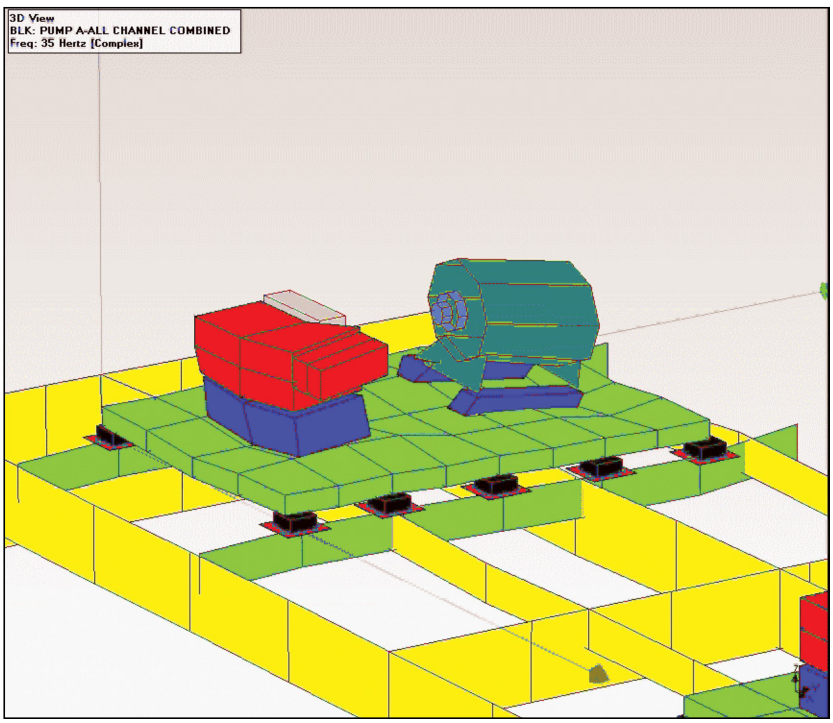

Figure 1: Image of pump, motor, base plate and platform ODS.

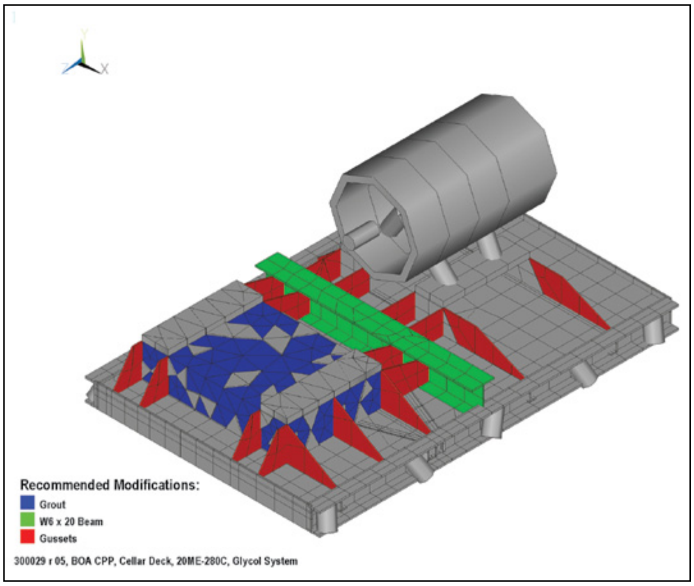

Figure 2: Base plate modifications available for topside access only.

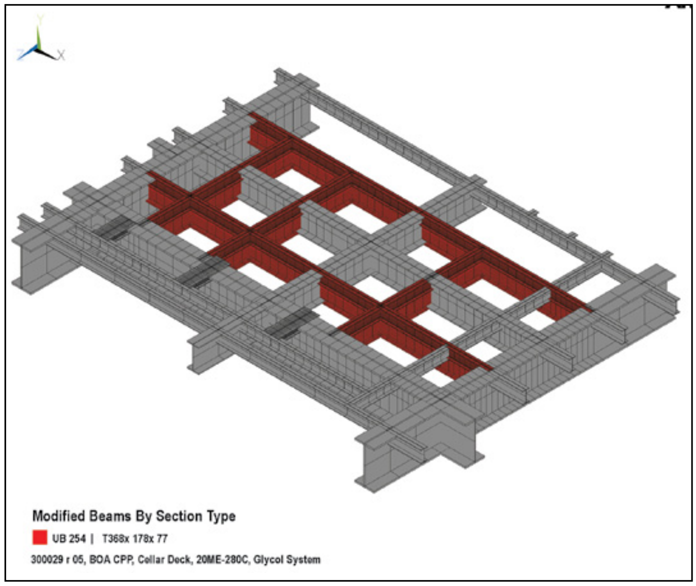

Figure 3: Key beams requiring stiffening.

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.

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.