Managing the life cycle of pipeline pumps with retrofits

Improved lifetime performance

Around the world, over 460,000 km of pipelines are used to move crude oil from wells to ports and finally to refineries. These pipelines have to cross remote and hostile areas—often with extreme temperatures and weather conditions. The pumps, which transport the crude oil over significant distances, must be highly reliable, energy efficient, and perfectly designed to meet these challenging operating conditions. Sulzer Pumps optimizes pipeline pumps to meet continuously changing requirements and to ensure safe operation.

Pipelines represent a considerable investment, and their safety, efficiency, and reliability are essential for their success. The pipeline can be subject to internal and external corrosion, fatigue cracking, third-party damage, and manufacturing flaws. The pipeline operating company is required to monitor mechanical loads, pressure changes, corrosion rates, etc. to evaluate the risk of pipeline leaks. It is not enough to monitor the pipes themselves; the rotating equipment must be managed and maintained as well.

Pumps are the heart of pipelines, and their reliability determines the success of the operations. The American Petroleum Institute (API) has published standards with which the equipment has to comply. Over their entire life cycle, pumps have to be checked regularly, and...
they must be repaired or retrofitted if they do not meet the necessary performance criteria.

Certain pumps may also have to be hydraulically rerated because of the changing operating conditions of a pipeline. The following example shows how Sulzer adapted pumps to new requirements and ensured smooth operation, excellent reliability, and optimum efficiency.

Adapting to changing requirements
One of North America’s largest pipeline companies runs some of the world’s longest crude oil and products pipelines. These pipeline systems have been operated for over 60 years and comprise more than 10,000 km of pipes, which deliver over two million barrels of crude oil and products per day.

In one pipeline carrying oil in North America, the pump hydraulics needed to be changed. The light crude oil that had to be transported had a lower density than the oil for which the pumps had been originally designed. Additionally, the customer wanted the modified pumps to be able to operate at varying daily flow rates between 30,450 and 57,000 m³/d.

Reversible change provides flexibility
The client wanted to be able to reverse the modification after two years, at which point, following the completion of a new pipeline, it planned to return the pipeline to its original design operation. The pipeline was a 1600 km oil pipeline in North America, and it was integrated with the mainline oil pipeline system of the client.

Sulzer was asked to rerate 18 pumps for pipeline operation, taking into account the temporary change in density and flow. In order to meet these requests, the Sulzer engineers suggested four different rerates for four different best efficiency points (BEP) ranging from approximately 44,000 to 57,000 m³/d to meet the various pipeline flow rates. The shift of the BEP could be achieved by reducing the throat area and fitting low-capacity impellers. The throat area of a pump is the end section of the volute development, and it has a major influence on the pump performance.

Reduced inventory cost
As interchangeability with the existing pumps had to be ensured, Sulzer supplied suitable impellers. In addition, mechanical seals and bearings are interchangeable among all rerated units, which significantly reduced the client’s inventory cost.

Before the modification was carried out, one of each of the four hydraulic designs with rerated hydraulic dimen-
sessions went on the test stand in Sulzer’s facility in Burnaby, Canada. After the tests had confirmed that the adapted pump would perform according the specification, the rework on the other pumps started. To accommodate the customer’s tight schedule, Sulzer managed to reduce the required time to three weeks per pump—with the work split between Sulzer’s Edmonton (Canada) and Midwest (Chicago, IL, USA) service centers.

Since the successful commissioning of the rerated pumps, the client has needed less power to run its pipeline because the pumps work near their best efficiency point at the various flow conditions. With their design point adapted to the system conditions, the pumps operate at beneficial hydraulic conditions over a wide flow range with low vibrations.

Retrofit ensures safe operation
Vibrations and off-design operation of pipeline pumps can compromise the safe performance of a pipeline. A pump retrofit carried out by Sulzer for the main oil line (MOL) pumps on a world-scale pipeline shows how proper pump design can reduce pressure pulsations and improve safety.

This pipeline transports crude oil from offshore oil fields in Eurasia to the closest harbor, from where the crude oil is shipped by tanker to refineries in the European markets. It runs mainly over-ground along its entire length of more than 1500 km and is designed for a throughput capacity of one million barrels of oil per day. The pipeline facilities include several pump stations located across Europe.

Reducing the risk of pipeline failure
Four of the pumping stations were equipped with Sulzer pumps, while the remaining ones had pumps supplied by a different original equipment manufacturer (OEM). The Sulzer pumps performed reliably, but the pipeline operator noticed intense pressure pulsations in suction and discharge lines on some of the non-Sulzer pumping stations. The pumps had been delivered by a third-party supplier during the construction of the pipeline in the early 2000s. These single-case, axially split, two-stage pumps were designed to deliver a discharge of 1674 m$^3$/h with a pump head of 1000 m.

The pressure pulsations caused by the MOL pumps caused cracking of welds on the units themselves, on small-bore ancillary pipes, and on several pipe support brackets. Also, the vibrations, which could be felt on the pump house floor, had led to compaction of up to 200 mm of the subsoil supporting the suction and discharge pipes where these connected to the station. When the client approached Sulzer in search of a solution, the pipeline was operating at full capacity. However, it was in serious danger of being shut down due to the excessive vibrations.

Analysis of dangerous vibrations
Sulzer presented a retrofit and upgrade solution as a way of improving the reliability and the mean time between failures (MTBF) on the third-party pumps. In a first step, the Sulzer specialists analyzed the first-stage impeller. It was equipped with four vanes, which led to strong periodic interaction with the double volute casing. The throat of the suction impeller was over-designed, which meant that the flow area was too large for the required discharge. This characteristic placed the duty point very close to the onset of inlet backflow. When a pump operates with inlet recirculation, efficiency drops, and noise and vibration level increase.

The second-stage impeller had six vanes. This even blade number also increased the risk of strong periodic interaction of the runner with the double volute casing. Also, neither of the vane outlet tips were significantly skewed. Straight impeller vane outlet edges very often give rise to strong periodic rotor/stator interaction.

Improving pump hydraulics
The Sulzer engineers identified the hydraulic interaction of stator and rotor as the root cause of strong pressure pulsations at blade-passing frequency. These pulsations excited the small-bore piping and an acoustic resonance in the station pipework. From this analysis, it was clear
Successful reduction of vibrations

On-site measurements clearly showed that the pumps equipped with the new impellers operated at acceptable pressure pulsation levels. With the root cause of the vibrations thus eliminated, the fatigue cracks in the weld of the pipe supports and the small-bore ancillary pipes did not occur anymore. Consequently, the floor vibration was also significantly reduced. Overall, the retrofit by Sulzer Pumps reduced the risk of pipeline failure and made possible the safe operation of the pipeline at the design flow of one million barrels daily.

After Sulzer had delivered the last of the ten upgraded rotors, the client attested that recent pump house vibration surveys had confirmed significant improvements in all pipe vibrations from the earlier damaging levels. In addition, measurements near the operating pumps showed clearly reduced noise levels.

Extended life cycle

Complex systems such as pipelines require careful monitoring during their useful operational life. In the event of imminent failure, the operator has to identify the critical components and to decide whether they have to be replaced, repaired, or retrofitted. Often, upgrading or retrofitting critical components can efficiently extend the product life cycle by providing a reliable system. Because every situation is unique, Sulzer Pumps provides proven customized solutions within tight deadlines, thus contributing to the success of its customers.

that reducing the system excitation from rotor/stator interaction was the key to improving the performance of the pumps.

The specialists from Sulzer Pumps decided to change the number of impeller vanes to shift the phase of the periodic excitation caused by the passing impeller vanes. The redesign of the suction impellers increased the vane count from four to five, and the number of vanes in the second-stage impeller was increased from six to seven. Moreover, the vane exit tips of both impellers were skewed to soften the hydraulic interaction with the casing. Sulzer Pumps manufactured precision cast impellers according to the improved hydraulic design and delivered new shafts made from a higher-grade material than the original ones were.

Sulzer reduced the risk of pipeline failure.

Sulzer maximizes pipeline profitability by reducing the life cycle costs of pumping systems.

Pipeline pumps have an expected lifetime of more than 20 years. Over time, however, changing conditions and equipment degradation can have negative effects on pump reliability and efficiency.

More than 90% of a typical pipeline pump’s life cycle cost originates from energy use. For this reason, Sulzer focuses on efficiency issues and identifies possible optimization strategies and retrofits.

More information: www.sulzer.com/retrofit

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