Liquid Pumping Systems (Including Liquid Pipelines)

Pumps and the associated piping system can experience vibration integrity risks including steady operation vibrations and transient vibrations (water hammer). For the system to accommodate these vibrations, special attention is required to predict, anticipate, and accommodate your system's unique vibration characteristics.

For example, reciprocating pumps, given the pulsations in the suction and discharge lines, require special design considerations for a safe installation.

While centrifugal type pump systems are generally very reliable, they also can experience resonance and dynamic problems.

Integrity risks are even higher for systems that experience fluctuating operating conditions that lead to transient-related vibration, failures, and the associated loss of containment.

This summary outlines the major design and troubleshooting considerations for addressing vibration on all types of pumping systems.

1 STANDARD DESIGN REQUIREMENTS FOR ALL PUMPING SYSTEMS

1.1 WATER HAMMER ANALYSIS (TRANSIENT PRESSURE SURGE)

Transient momentum changes in the liquid piping system can create large and sudden pressure surges that can lead to ruptured piping, cracked fittings, and fluid release in a phenomenon known as water hammer or transient surge.

The Water Hammer Analysis evaluates the effects of water hammer on the piping system from transient events such as pump startup, shutdown, emergency shutdown (ESD), relief valve activation, valve swings, and check valve closures.

Accurate dynamic simulation is a requirement for most large piping systems. BETA considers the range of operating conditions for your system and calculates the system response of each transient scenario using a proven transient simulation solver. This ensures accurate recommendations to prevent water hammer in your piping system.

- More on Water Hammer Analysis (pdf)

1.2 SMALL BORE CONNECTION (SBC) ASSESSMENT

The most often overlooked integrity/reliability risk affecting pump facilities is small bore piping vibration and failures. Vibration-induced fatigue can cause component failure and liquid release. Small bore attachments are usually branch connections less than 2" nominal pipe diameter used for instrumentation, transmitters, vents, drains, bypass, etc.

These items are rarely considered for vibration characteristics at the design stage and, as a result, represent the single largest risk of vibration failure for your facility. Small bore vibration problems and failures represent over 60% of the issues that our field troubleshooters attend to globally.

Each small bore connection in your facility should be evaluated and tested for vibration failure risk.

- More on Small Bore Connection Assessment

2 LIQUID PIPELINE SYSTEMS

Large pipeline systems often handle different fluids (densities, viscosities, bulk moduli), pressures, and flow rates. For example some stations have multiple pumps in series, and the system may change between 0, 1, 2, or 3 pumps as required by operations.

Starting, stopping, and changing fluids can create many transient operating conditions that can excite the small bore connections.

Based on hundreds of field tests at pumping stations, BETA has identified that transient vibration is a significant integrity risk. For these systems, a comprehensive Site Assessment (baseline test program) is required to identify high risk locations and mitigate the risks.

- More on Site Assessment Service

3 RECIPROCATING PUMPS

Reciprocating pumps (including plunger pumps) can create high vibration and piping failures due to pulsations and mechanical forces. The increased use of variable speed drives (VSD or VFD) in pumping systems creates more likelihood for mechanical and acoustical resonance and this results in more complicated vibration analysis.

3.1 PULSATION AND MECHANICAL ANALYSIS

API 674, 675, and 688 define the required Pulsation (acoustical) and Mechanical analysis. The analysis will recommend the appropriate pulsation control solution, piping layout, and pipe support design.

- More on Reciprocating Pump Pulsation & Mechanical Analysis

3.2 SMALL BORE CONNECTIONS

see above, Section 1.2.

4 FOUNDATION DYNAMICS

Different types of pump foundations whether base plate, steel structure, or concrete foundations, require different dynamic design considerations for new installations and revamps. For example, pumps mounted on a steel module or platform require a Foundation Design and Dynamic Analysis, whereas large pumps (such as slurry pumps) on concrete foundations and piles require a Structural Vibration and Dynamic Design Analysis – a dynamic simulation of the piles including the surrounding soil conditions.

- More on Foundation Design And Dynamic Analysis
- More on Structural Vibration And Dynamic Design Analysis

5 OPTIONAL DESIGN REQUIREMENTS

5.1 REED CRITICAL FREQUENCY (RCF) ANALYSIS

Vertical turbine pumps have critical frequencies that can resonate during startups, shutdowns, and regular operation. These critical frequencies are known as RCFs, or cantilever mode mechanical natural frequencies. It is important to determine if the RCF will fall into the operating speed range of the pump. This would cause high vibration leading to above ground and below ground component failures.

- More on Reed Critical Frequency

5.2 TORSIONAL VIBRATION ANALYSIS (TVA)

Torsional vibration can occur during the start-up and steady operation of the pump system. Transient events can be an important issue with new systems. The TVA will mitigate the transient and steady state torsional risks by modeling the drive train, calculating dynamic torsional stresses, and ensuring each drive train element can handle those stresses without failure.

- More on Torsional Vibration Analysis

5.3 LATERAL VIBRATION ANALYSIS

Lateral vibration of a pump drive train can be visualized as the actual bending of the shaft elements while the shaft is in rotation. Lateral vibration of the pump shaft is normally considered by the pump OEM, but this often does not include consideration of the coupling, driver shaft, and any speed reducing elements such as a gearbox. Lateral vibration problems can cause premature bearing failures, excite structural resonance, and cause high vibration. Considering lateral vibration is especially important for vertical pumps due to their inherent excitability of lateral mechanical natural frequencies (MNF) causing resonance.

- More on Lateral Vibration Analysis

BETA Machinery Analysis is a global expert in advanced vibration services, including design, testing and troubleshooting. Our leadership in this industry is based on our extensive field experience, practical design solutions, and responsive service.