Common Issues and Solutions for Cryogenic Pumps

By Fluensys | Sept 12, 2024 | Cryogenic Pumps

Cryogenic pumps have greatly evolved since their emergence in the mid twentieth century, and now their design is seen as highly reliable and efficient. They fall into two categories, submerged motor pumps (SMP) and external motor pumps with air cooled systems. The latter is mainly used for small land and marine applications.

For LNG applications, SMPs are used. The submerged pump and motor assembly is located in the tank and cooled and lubricated by the cryogenic liquid. This provides a highly reliable and robust compact solution due to the short shaft length and low NPSHr. Seal issues are avoided as there are no mechanical seals in the submerged solution.

These pumps have single or multi-stage hydraulics specifically designed for the application. The common pumped liquids are LNG (Liquefied Natural Gas), LPG (Liquefied Petroleum Gas), liquid ethylene and various others (see in-tank version below).

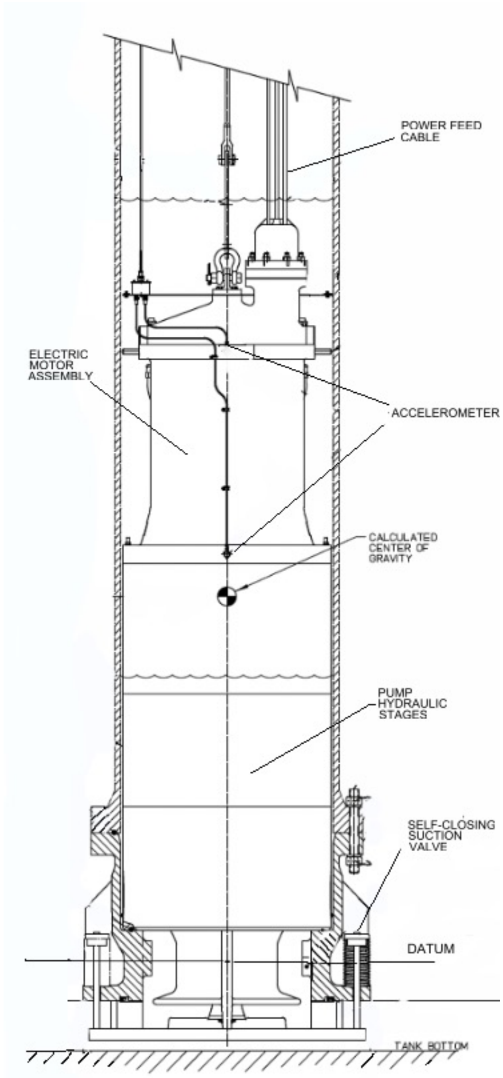

Fig 1: Submersible Cryogenic Pump

Most cryogenic liquids are non-conductive and non-corrosive, and do not pose a risk for the motor in an oxygen free environment for pump operation. Typical uses are to load and unload LNG carriers and high pressure send-out duties.

Reliable, long term operation depends on providing a dynamic method of balancing the generated axial loads on the rotor support bearings, One such method is the TEM (Thrust Equalising Mechanism) which eliminates axial thrust, which would otherwise severely reduce the pump's service life. Direct cooling by the pumped fluid of the motor allows for a compact frame size to be used.

Due to the low NPSH available, a high performance inducer is fitted in front of the first stage. It reduces NPSHr and allows for a low-level drawdown of the tank. The liquid at pump suction is near to its boiling point and can cavitate under unexpected pressure drops. But it should be noted that cavitation effects are not as severe as in water applications, due to the lower energy in the fluid.

Materials of construction (MOC) are specifically selected for their mechanical and thermal properties at cryogenic temperatures. Cryogenic liquids have low viscosities and poor lubricity, requiring non-galling properties for wear parts.

It is notable that unlike common pump assemblies, the cryogenic pump cannot be mass balanced in factory. At room temperature, impellers and bushings are fitted with a clearance on the shaft; they shrink tight on the shaft at cryogenic temperatures. Only individual components are mass balanced dynamically; hence the expected overall vibration levels is only an analytical prediction, until tested at the vendors cryogenic test stand.

The cool down of the submerged pump is a critical operation as its components have varying thermal behaviours. This operation must be carried out in a controlled manner as per vendor's instructions.

	Boiling Temperature	
Liquid	**^{0}C**	**^{0}F**
LNG	-162	-260
Propane	*-42*	*-44*
Butane	*0.6*	*33*
Ethylene	-104	-155
Nitrogen	-196	-321
CO2	-79	-110
Hydrogen	-253	-423

Fig 2: Typical Cryogenic Liquids

Cryogenic pumps can be vessel mounted, retractable in a tank column or fixed to the supporting structure. The equipment design life is in excess of 20 years.

Common Issues

The common issues experienced with cryogenic pumps in LNG applications are given below:

- **Seal Failures**: External motor cryogenic pumps can experience seal failures due to extreme temperatures and pressure variations.
- **Shaft Breakages**: Excessive vibration levels can cause catastrophic shaft failure and fatigue at localised high stress points, especially at undercuts.
- **Cavitation**: This can occur when the cryogenic liquid being pumped vaporizes due to heat or low pressure, causing damage to the pump though effects are not expected to be as severe as for water.
- **Vibration and Noise**: High levels of vibration and noise can lead to mechanical failures (*see first point above*) and operational inefficiencies. Part-load operation can be a trigger. The overall assembly (pump, column pipe and supporting structure) can also experience resonance issues in the absence of sufficient separation margins between natural frequencies.
- **Maintenance Challenges**: Regular maintenance is difficult due to the specialized nature of cryogenic pumps and the need for specific expertise. *However, over 2 years operation is normal*.

Troubleshooting and Analysis

The troubleshooting of problematic pumps should be carried out in a methodical manner, starting with a system audit. The review is to verify that the pump construction, rating and system design meet the current operational philosophy and environment. A vibration signature is key to diagnose any issues in the pump and nowadays, pump assemblies are sufficiently instrumented to allow for adequate monitoring and early failure prediction.

The investigation may require a rotordynamic stability analysis. For external motor solutions, excessive vibrations can happen at the above tank section of the assembly, where the motor, pedestal and mounted plate are located. It can also be observed along the shaft due to excessive forces on the cantilevered assembly.

A *bump test* of the support structure should be performed to check for possible resonance with motor speed. A validated rotordynamic model of the pump assembly should be used to confirm then critical speeds and safety margins, identify and confirm high vibration points along the rotorshaft and test solution scenarios. Both experimental and analytical approach are typically used to resolve issues.

Typically, tighter imbalance levels and adjusting component stiffness help to create sufficient margins between excitation forces and critical speeds. Fluid related effects can cause large instabilities if clearances are worn, due to the loss of the ‘Lomakin’ stabilising effect.

Other Common Solutions

- **Improved Seal Designs**: Using advanced materials and designs to enhance the durability and performance of seals. (*for external motor pumps only*)
- **Cavitation Prevention**: Implementing measures such as maintaining adequate suction pressure and using anti-cavitation devices.
- **Material Selection**: Choosing materials that can better withstand the extreme conditions of cryogenic operations.

- **Vibration Control**: Employing techniques such as tighter dynamic balancing, stiffening and vibration dampening to reduce vibration and noise.
- **Regular Maintenance**: Establishing a robust maintenance schedule and training of personnel for the specific requirements of cryogenic pumping system.

Summary

This article discussed the common issues observed with cryogenic pumps, particularly in LNG applications, and the solutions adopted in industry. These pumps are critical to the LNG operations and down time can be costly. Performance monitoring is critical to maintaining uptime and reducing operational costs with the possibility of early fault detection and optimised maintenance scheduling.

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