Nozzle Loading

Nozzle loads are the net forces and moments exerted on equipment nozzles. In pump systems, excessive nozzle loading occurs when forces and moments acting on the inlet and discharge ports of a pump combine to give resultant forces which overcome a certain limit. When this limit is exceeded damage occurs to the system and performance is lost.

Figure 1 shows the forces and moments acting on the ports of a pump at any given time.

Pump nozzles may not always be subject to the maximum allowable resultant force and resultant moment simultaneously. Thus an increase in either the resultant applied force or the resultant applied moment may be permitted. Expecting zero resultant forces and moments is unrealistic. Loading can be minimised with good system design but obtaining zero system loads is impractical.

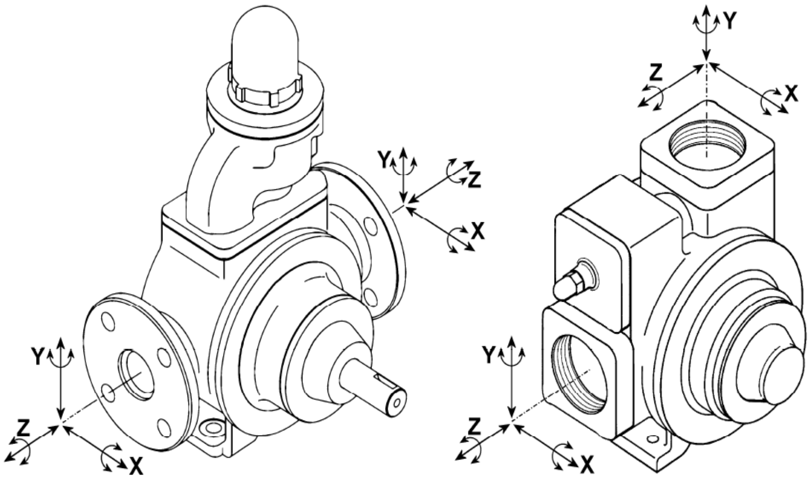

Figure 1: A diagram depicting the forces and moments on the inlet and discharge ports of a pump. X denotes horizontal (parallel to shaft), Y denotes vertical and Z denotes horizontal (perpendicular to shaft).

Issues

Nozzle loads are predominantly affected by misalignment in the system, thermal expansion of piping material and how the connected equipment and piping are supported. Misalignment and its effects are discussed in detail in our Misalignment Article.

Thermal expansion is the change in the length of a particular metal as a result of the change in temperature of that metal. Hot fluid systems can cause pipe-work to expand with temperature, the expansion being equal to the coefficient of thermal expansion of the piping material used. The expansion intensifies nozzle loading along all three axes. It is therefore vital to select appropriate piping material when designing a pumping system.

Insufficient support for piping may alter resultant force directions, which can potentially increase nozzle loads. This is principally due to sagging from the intrinsic self weight of piping plus the weight of the fluids. Piping sized incorrectly can also contribute to nozzle loading in the same manner, with oversized pipe-work creating excessive vertical forces.

Nozzle loading can create stresses across pipe-work, pumps and supports. In centrifugal pumps, these stresses may distort pump casings, and lead to excessive wear of shaft sleeves and bearings. Shaft misalignment may occur, altering the impeller angular speed of rotation from constant to variable. This angular acceleration can produce residual out of balance forces, increasing the rate of shaft and bearing wear.

In external gear pumps, torsional stresses often lead to uneven gear wear and in some circumstances contacting of the pump housing with gears. For internal gears the result is the same as the centre housing becomes distorted from the uneven wear. Even in less severe situations the irregular wear will affect tight clearances designed to cater for shaft deflection, and as a result slip will occur. To compensate for this, the pump must run at higher speeds to maintain the required flow. When pump components begin to wear, more power is required to meet the demands of the application, hence associated running costs increase and overall efficiency is lost.

Excessive nozzle loading can also lead to increased vibrations throughout the pumping system. Should the frequency of vibration of a system component reach its natural frequency then resonance will occur. This can have a significant effect on residual out of balance forces, exacerbating existing nozzle load issues and potentially leading to catastrophic pump failure.

Solutions

To minimise nozzle loading, all piping should be externally supported on both the inlet and discharge sides of the pump. Pipelines must be supported by external means at regular intervals to prevent them from sagging due to their intrinsic self weight and the weight of the fluids inside the pipe. If sagging were to occur then nozzle loading on the pump would rapidly increase. Where possible all pipes should be supported at the same level as the pump so as to reduce the number of bends and potential loading sites in the system.

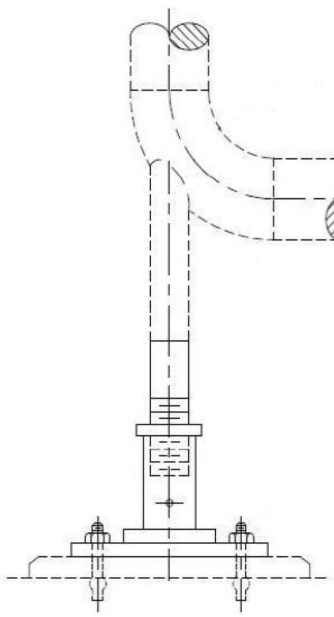

Figure 2: A typical adjustable base support

The first piping support before or after a nozzle should be an adjustable base support or a spring. Both options provide changeable support which can be altered to meet the requirements of the pumping system on site. Springs take the weight load without imposing a reaction load on the piping, and are the preferred option.

When it is necessary to isolate a pump from piping to reduce noise, vibrations or to provide insulation; a flexible link, hose or bellows should be considered. These devices will aid in reducing moments and forces on the inlet condition. The pumping system should be designed with sufficient inherent flexibility to withstand thermal expansion without creating excessive forces at the flanges.

Correct material selection is vital for prevention of thermal expansion in piping. When dealing with high temperature applications, materials with a low coefficient of thermal expansion should be considered.

Summary

- Expecting zero resultant forces and moments is unrealistic. Loading can be minimised with good system design but obtaining zero system loads is impractical.
- All pipe-work should be externally supported on both the inlet and discharge sides of the pump. Pipelines must be supported by external means at regular intervals to prevent them from sagging due to their intrinsic self weight and the weight of the fluids inside the pipe.
- The pumping system should be designed with sufficient inherent flexibility to withstand thermal expansion without creating excessive forces at the flanges.
- Correct piping material selection is vital to avoid the negative effects of thermal expansion.

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