Run Times
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A few days ago I reviewed a service trip report written by one of our engineers following a recent visit by him to witness an equipment installation at a new petrochemical facility. While on site, the equipment installation was delayed because of modifications that were required to correct misalignment between the pump nozzle and the connecting piping. Piping misalignment is a major cause of pump and seal reliability problems that is both preventable and correctable. This issue provides a brief overview of the effects of piping misalignment and provides some guidelines for avoiding alignment problems.

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Any mass will deform in response to applied stress. It is a defining characteristic of a solid that it will deform temporarily while stress is applied, and will return to its original form once the applied stress is removed, as long as the applied stress is below the yield strength for the material. The amount of deformation is related to the magnitude of the applied stress, and the physical characteristics of the material under load.

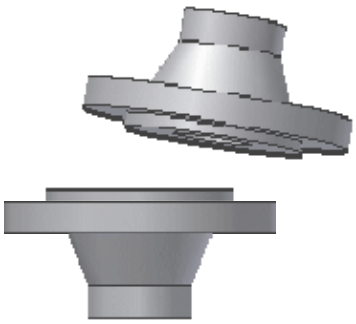
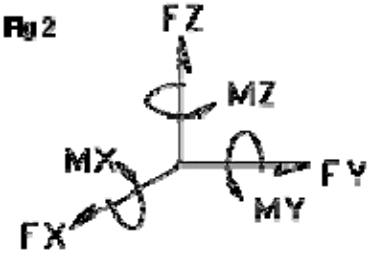


Fig 1

Pipe stresses that are applied to a pump are transmitted through the pump casing and base plate to the pump foundation. Pipe stress may originate from thermal expansion, hydraulic reaction forces or, more commonly, from misalignment at installation, such as is depicted in figure 1. As with any mass, a pump will deform as a result of an applied stress. Deformation, or distortion, of the pump and the baseplate will manifest itself in the form of misalignment of the pump rotor to the coupled driver, and misalignment of the rotor to the seal chamber and wear ring fits.

Any stress applied to a pump flange is the sum of forces along the x, y, & z axes and the moments, or overturning forces, about each axis. (fig. 2).

Fig 2



Recognizing the critical importance of managing piping loads on rotating equipment, engineers have established standards for allowable forces and moments for rotating machinery. These standards become design criteria for the equipment manufacturer and establish allowable limits for the piping system designer. The American Petroleum Institute standard for centrifugal pumps provides a table for the maximum allowable forces and moments for various flange sizes[1]. The standard stipulates that pressure casings are to be designed to twice the maximum allowable values[2], and limits the allowable coupling-end shaft displacement under specified test conditions.[3].

[1] ANSI/API-610:10th edition, ISO 13709, Centrifugal Pumps for Petroleum, Heavy Duty Chemical, and Gas Industry Services; Table 4

[2] Para 5.3.3 of ISO 13709. Note: This is a casing design criteria only and is not part of the allowable piping loads available to the piping designer.

[3] Para 6.3.5, 6.3.6 of ISO 13709

Many individuals have trouble visualizing that a pipe that is wedged, levered or pulled into position, may place unacceptable loads on a pump. For example, assume there is a 200mm (8") schedule 40 steel pipe that is rigidly supported 2m (6.5') away from a pump. The pipe flange has a parallel offset of 5mm (.2") from the pump nozzle. Solving for the force (W) using the equation for deflection below yields a resulting force of 12,000N (2700lb) force acting against the pump! This example is oversimplified in that it assumes an infinitely rigid pipe support. In practicality, pipe support flexibility would lower the resultant load. This calculation also assumes simple parallel misalignment. Angular misalignment calculations are significantly more complex. The point remains that small pipe offsets can result in large stress values.

$$y = \frac{W L^3}{3EI}$$

Fig 3

As a general guideline, piping flanges should be concentric to pump nozzles to within the flange bolt hole clearance tolerances. Flanges should be parallel to within .01mm per cm (.001" per inch) of flange outer diameter. Flange separation spacing should be within gasket spacing plus or minus 1.5 mm (1/16").[4] It is also a good practice to weld piping starting at the pump flange and weld away from the pump. Proper flange alignment helps assure a stress free pump installation.

Unfortunately, despite the efforts of engineers to establish guidelines, as well as inspections such as described at the beginning of this newsletter, we all too often find critical equipment being installed with excessive piping misalignment. Pipe stress often starts a lifelong cycle of premature pump failures. Causes of piping stress include piping practices that allow welding completion before the installation of equipment, and the practice of leveraging misaligned piping into position to avoid reworking the connecting piping. In both cases the solution lies in continued education and diligent inspection to ensure that the engineers' specified tolerances and procedures are adhered to.

[4] Pump Users Handbook, Bloch et al; 2004 Marcel Dekker, ISBN 082474814X