POOR PUMP DESIGN CONSIDERATIONS CAN LIMIT OPERATIONS

In this case study, a reciprocating diaphragm metering pump installation was held to 25% of rated capacity

By Jordan Grose, Beta Machinery Analysis

Relatively small reciprocating pumps, smaller than 47 hp (35 kW), are usually considered noncritical but they can create operational and production headaches at onshore and offshore facilities.

This article will discuss a case where a reciprocating diaphragm metering pump installation was limited to 25% of rated flow capacity.

Operators of two diaphragm amine pumps were very concerned about high vibrations around the pumps once the flow rate went above 25% of rated flow. These pumps had three fluid ends, and were flow controlled with a variable speed electric motor drive (see Photo 1).

Above 25% flow, much of the process piping — especially the auxiliary small-bore piping — would shake violently. The operator had to run both pumps to make up the process flow shortfall, thus eliminating their 100% redundant operation scheme.

This example illustrates how high operating risk is completely avoidable with adequate considerations at the design stage.

A troubleshooting team investigating this problem observed much auxiliary small-bore piping around the pumps to accomplish the triple redundant control system strategy for this facility (see Photo 2).

Photo 1. Reciprocating diaphragm pump

The auxiliary systems were most often piped high in the air and were poorly supported with flimsy pipe racks. This made for highly flexible small-bore piping arrangements with very low mechanical natural frequencies (MNFs).

The system had bladder-type pulsation dampeners installed on both the suction and discharge systems. Pressure pulsation measurements showed that the pulsation dampeners were not adequately controlling the pulsations in the suction and discharge piping at all speeds (flows) of the pumps, even though they were being properly maintained.

What was causing these problems?

An important but often overlooked pump design consideration is variable speed operation. When the speed of the pump changes, so does the frequency of excitation, which in this case was mainly from pulsation-induced unbalanced forces in the piping.

This changing of excitation frequencies means that at some speeds, vibration may be acceptable, but at other speeds it could be dangerously high.

Changing pump speeds also causes the pulsation characteristics within the

Jordan Grose is manager of Pump Services for Beta Machinery Analysis, Calgary, Alberta, Canada. Grose is a rotating machinery engineer specializing in vibration and reliability issues for reciprocating and centrifugal pumping systems including pulsation and mechanical analysis, water hammer and transient studies, small-bore piping analysis and other related design work. Beta Machinery Analysis is a market leader in providing engineering services for rotating and reciprocating machinery.

Photo 2. Triple redundant control system

piping to change. Often pulsation dampeners are sized for a given volume using rule-of-thumb calculations based on the concept of acceleration head. With variable speed and variable operations, this method will usually produce ineffective pulsation control for most, if not the entire operating map.

A common misconception is that sizing pulsation control devices for pumps using acceleration head sizing calculations is equal to an API 674 pulsation study.

Dynamic pressure, or pressure pulsation, in pump systems historically has been referred to as acceleration head. Calculation of acceleration head is a technique by which the pressure fluctuation is estimated by simplifying assumptions and empirical techniques.

Acceleration head calculations cannot take into account acoustical resonances in a piping system. Acoustical resonances can result in very high pressure pulsations because of the low damping and high amplification of pulsations at resonance.

A computer model that calculates the acoustical properties of the piping system as well as nonlinear pressure and flow fluctuations is required to accurately determine the suction system pressure pulsations. Acceleration head calculations are not as effective at characterizing pressure pulsations as a pulsation computer model.

Pulsation dampener location is another important aspect of pulsation control for pumps. Diaphragm or bladder-type dampeners are most effective when placed at a location of maximum pulsation, known as a pressure "antinode." But if the dampener is placed at a "node" location (where there are low pulsations in the piping standing wave), the dampener will do nothing at all.

This is where the problem lies in variable speed installations. The locations of nodes and anti-nodes in the piping change with speed. This means that if the pulsation dampener is at a fixed location, it will be effective for a narrow range of speeds, and ineffective at most of the other speeds of the pump. This was the situation for the operator in this case study.

To better understand the pulsation-induced vibration problems found onsite, a computer pulsation model was created. See graphs above for the resulting predicted pulsation and unbalanced forces in the manifold.

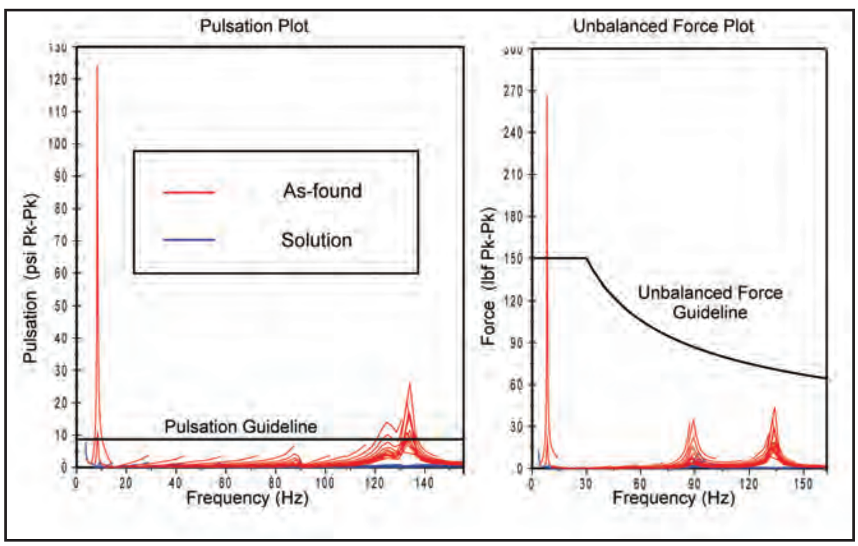
The plot shows the pulsation and unbalanced forces predicted at each order of run speed for the entire machine speed range. The pulsation levels exceeded the guideline by more than 12 times and unbalanced forces were nearly double the guideline.

A new solution was needed to accommodate these high pulsations and unbalanced forces. The pulsation and unbalanced force levels in the piping system also had to be extremely low to account for the plethora of poorly supported small-bore piping attached to the pump main lines. In this case a second dampener was required for each manifold of this pump installation to control pulsation over the wide speed range required.

A pulsation study based on the specifications described in API674 3rd Edition is recommended at the design stage for pump installations. Such a study would specify the appropriate dampener design, location and other system modifications necessary to control pulsations.

A mechanical analysis should be included with this study to address piping layout issues and avoid resonance with piping and small-bore attachments.

Addressing these issues at the design stage will help avoid operational, safety and production issues with small and large pumping systems.



As Found: Pulsations are 12 times over guideline, forces are nearly double.