

IMPROVING EQUIPMENT RELIABILITY

REQUIREMENTS OF SMALL BORE ATTACHMENTS ON COMPRESSORS, PIPING AND PUMPS

JORDAN GROSE

Centrifugal compressors and pumps can emit low- and high-frequency excitations within the piping system, creating reliability concerns on small bore piping. Small bore connections (SBC) generally refer to piping connections of 2-inch size or less. This includes standard pipe, tubing, thermowells or any other attachment to main process piping.

SBC vibrations are not generally considered at the design stage. They are left for implementation in the field or during piping spool design and fabrication. As a result, every SBC tends to be different. Their usual configuration — long, thin, unsupported pipe spans with heavy valves and instrumentation on the end — results in flexible piping attachments with low mechanical natural frequencies (MNFs) susceptible to excitation forces (Figure).

Why do SBC failures occur?

Excitation can originate from the rotating equipment or the process flow in the piping. Impeller vanes, for example, can cause pulsations at multiples of the number of vanes on the compressor or pump wheel at what is called Vane Passing Frequency — a source of high-frequency energy that can affect shorter, stiffer SBCs.

Excitation can also come from pulsations generated by the flow of the fluid past dead legs (normally no-flow side branches); this is called Flow Induced Vibration (FIV).

FIV generally occurs at lower frequencies, affecting long, flexible SBCs. Acoustical Induced Vibration (AIV) is caused by high velocity flow through partially opened valves. AIV excitation is usually a high frequency broadband energy source, which can affect shorter and stiffer SBCs. Turbulent flow, cavitation, flashing, rapid valve openings and closings, and rapid machinery starts and stops can all be sources of excitation for SBCs.

Most SBC designs involve a small bore tap from a large diameter main line, a variable length of pipe, a flanged connection, an isolation valve, another variable length of pipe, instrumentation or valve equipment, and associated cables, vents, piping and tubing. The vibration response is based upon: The type and method of main line tap; length, mass, and geometry of pipe and flanges; length and mass of the isolation



Figure. Long lengths create cantilevers susceptible to excitation and failures

valve; and length, mass and geometry of associated piping and instrumentation.

A common first step in the SBC-related failure analysis is to check the welding and material quality. While these have obvious importance in terms of stress, they have little effect on the mechanical vibration response. Vibration amplitude and the relative vibration between main line and SBC are usually more fruitful investigative paths.

Another misconception relates to the specification for double block and bleed for maintenance of valves, sensors and controls. However, when applied to SBCs, this leads to extra long and extra heavy arrangements that are highly susceptible to vibration and fatigue failure. Similarly, redundancy is not an answer. Redundant instrumentation can multiply the risk of SBC-related leaks.

Design and analysis

One workable standard is, “Guidelines for the Avoidance of Vibration Induced Fatigue Failure in Process Pipework,” from the Energy Institute (London, UK). It provides useful guidance for SBCs at the

design stage to help determine the likelihood of failure (LOF).

Vibration measurement techniques are provided with guidelines to help screen SBCs in a facility. If LOF is high, then analysis is required, such as, finite element analysis (FEA) and design modifications. In addition, the Gas Machinery Research Council (Dallas, Texas) has the “Design Guideline for Small Diameter Branch Connections.”

GMRC design philosophy places the lowest MNF of the SBC above the frequencies of most significant excitation that would occur at the base of the branch line. An FEA approach can be utilized to calculate the allowable stress per unit of deflection (stress/mil) of the SBC to provide a guideline where vibration levels are not yet known.

When considering whether SBCs will fail, fatigue stress is important. However, it is not practical to measure stress at every SBC. The trick is to relate a measured vibration of an SBC to stress at the likely location of failure. The deflection or vibration of the SBC with respect to its main connection is the important characteristic to measure.

“Fatigue of Cantilevered Pipe Fittings Subjected to Vibration,” by Hamblin of Woodside Energy, provides a method of calculating stress using a measured vibration acceleration reading from the SBC. It attempts to calculate stress with a relatively standard and simple vibration collector. The EI standard also supplies guidelines for measuring in the field. The underlying assumption in both cases is that main line vibration is much lower than the SBC vibration, so they must be used with caution.

Bottom line: There is no simple guideline that can be applied to every SBC. Evaluation involves measuring, calculation, and in some cases FEA. **■**

Author

Jordan Grose is manager of pump services at Beta Machinery Analysis, a machinery consultancy specializing in rotating and reciprocating machines. www.betamachinery.com

