TNO Science and Industry

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The PULSIM approach: 'Prevention is better than cure'

API 618 Analysis for reciprocating compressors

Reciprocating compressors are frequently used in many applications, because they can compress gas in a wide range of pressure ratios, with a large range of flow rates. However, a reciprocating compressor also generates pulsating flow, which can create a number of problems. These include severe vibrations, pipe failure due to fatigue, reduction in efficiency of the compressor, 'hammering' of compressor, check and safety valves and errors in flow measurements.

Even when pulsations are within allowable levels, high vibration and cyclic stress levels can occur. Pulsations and vibrations can be controlled and life cycle costs consequently reduced if the problems are solved during the design stage of the project. Pulsation and mechanical response analyses have proven to be effective tools in meeting such objectives. TNO Science and Industry has developed the digital simulation program PULSIM (PULsation SIMulation) in order to calculate the acoustical behaviour of a pipe system.

PULSIM solves the one dimensional flow equations by using the method of characteristics in the time domain, up to a frequency of at least 32 times compressor speed. The general purpose finite element program ANSYS has been coupled with PULSIM and is used to determine the mechanical response of the system to the calculated pulsation induced forces. In terms of dynamics, these tools can optimise the system in such a way that all pulsation related problems are controlled. TNO Science and Industry uses a three-step approach in the analysis, according to the design approach 3 of the API Standard 618, 2nd edition of 1995. This includes items M2 to M8 of the standard's appendix M. The three steps are outlined below.

Step 1: Prestudy or dampercheck

In order to prevent costly and time-consuming changes to the damper design, an acoustic prestudy (also called dampercheck) of the damper is carried out at an early stage of the project. This analysis involves a detailed simulation of the internal cylinder gas passage, the pulsation damper and the pipe system is replaced by an infinitely long line. A calculation and optimisation is carried out related to the following areas: the pulsation levels near the compressor valves, the in- or outlet of the dampers and the pulsation induced forces on the damper. In addition, PV charts are calculated in order to predict the effect of pulsations on power consumption and capacity. Furthermore, there can be an optimisation of the interaction between the pulsations and the dynamic mechanical behaviour of the compressor valves, in order to avoid compressor valve problems.

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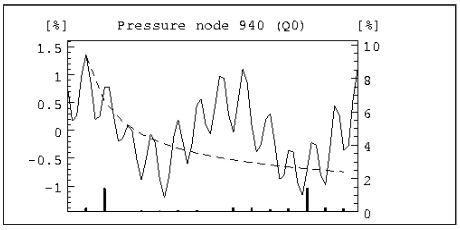
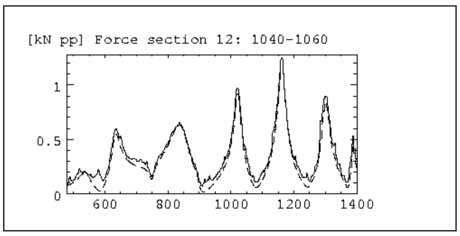
Step 2: Pulsation analysis of the piping

Step 2 involves the precise modelling of the complete pipe system, including T- joints, check and control valves, and such equipment as heat exchangers and separators. The pulsations and pulsation-induced shaking forces are calculated and compared with allowable levels. If these are exceeded, possible modifications are investigated. Those which are frequently advised necessitate the following changes: Installation of orifice plates, increasing of the diameter of pipe parts, relocating of closed valves and installing additional volume. It is very rare that a redesign of the pulsation dampers is necessary subsequent to the dampercheck. The final aim of the pulsation study is the prevention of the following areas of difficulty:

- Unacceptable levels of pulsations and vibrations and cyclic pipe stresses causing fatigue failure
- Increased power consumption and capacity loss
- ‘Hammering’ of compressor valves, relief valves and check valves due to pulsations
- Inaccuracies of flow measuring devices.



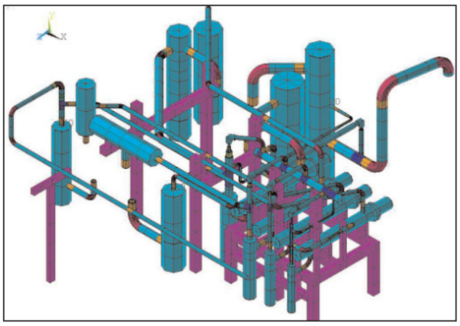
Time function and spectral analysis



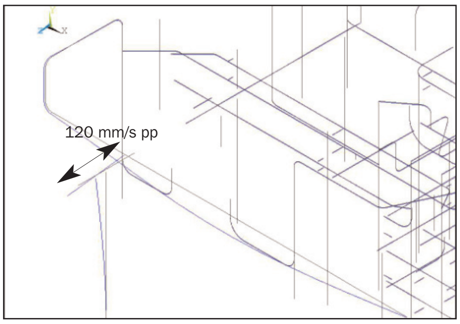
Pulsation as function of compressor speed

Step 3: Mechanical response study

Even if the pulsations are within allowable levels, unacceptable vibration and cyclic stress levels can occur if a mechanical natural frequency is either close to, or the same as a frequency component of the pulsation-induced shaking forces. It is particularly difficult for compressors with variable speed to achieve a mismatch of acoustical and mechanical natural frequencies.The mechanical ANSYS model is built up of beam type elements and includes all important components which influence the mechanical natural frequencies and cyclic stresses. These include the nozzle and flange flexibility, supporting beams and pipe racks and stress intensification factors of



Solid model plot



Vibration mode with maximum vibration level in mm/s peak to peak

T-joints and nozzles. The mechanical model is excited by the pulsation induced forces calculated by PULSIM and includes the right phase. Subsequently, the vibrations and cyclic stresses in the pipe system are calculated. If a full design approach 3 study is carried out, this also involves the detailed modelling of the compressor manifold (cylinders, crosshead guide and distance piece). Then the so-called compressor manifold vibrations are calculated. If the calculated vibration and/or cyclic stress levels exceed the allowable levels, modifications are investigated which lead to recommendations abouthow to achieve acceptable levels.

Process Industry

The team of the ‘Flow and Structural Dynamics’ department: your partner in solving questions about the dynamics of your installation. Modelling, measuring and optimising of dynamic flow and vibration phenomena is our specialty.
We use modelling techniques like PULSIM to enhance the reliability and safety of your process installation.

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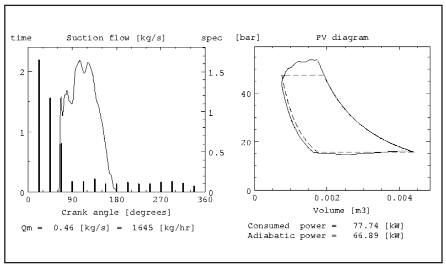

Time function and spectral analysis

This normally involves advice concerning the modification of existing supports, the installation of additional pipe supports and/or the increase of the stiffness of the structures on which the piping is mounted.

Results of the three step approach

If a full design approach 3 analysis is carried out, we have experienced that 90 to 95% of the systems can be started without any pulsation related problems. This eliminates the need for subsequent costly and time consuming measures.