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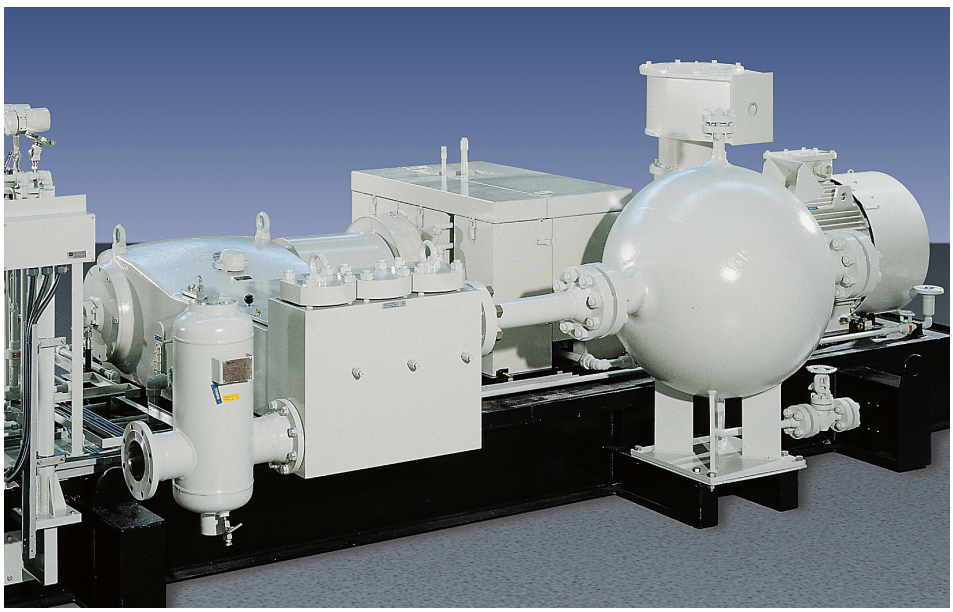
API 674 Analysis for Reciprocating Pumps

Reciprocating pumps are frequently used in many applications, because they can generate high head, independent of density. However, a reciprocating pump system also generates pulsations, which can lead to cavitation, fatigue pipe failures, reduction of efficiency and capacity limitations. TNO Science and Industry uses the digital simulation program PULSIM (PULsation SIMulation) to calculate the acoustical behaviour of the liquid in the pipe system.



Even when pulsation levels are within allowable levels, high vibration and cyclic stress levels can occur. Especially for very flexible pipe systems and variable speed pump systems, it can be difficult to achieve an optimum design from the dynamic point of view. Cavitation and vibration problems can be avoided, and consequently life cycle costs can be reduced when they are solved during the design stage of the project.

Pulsation and mechanical response studies have demonstrated to be effective tools to meet such objectives.

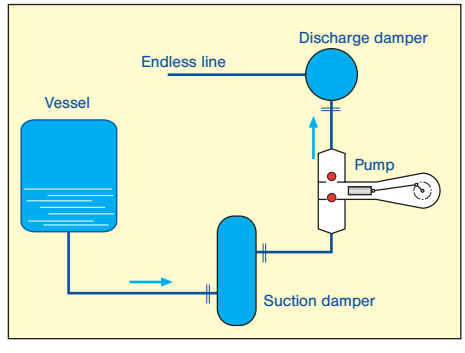
Importance of analysis

The PULSIM program has been developed by TNO Science and Industry. PULSIM solves the one dimensional flow equations with the method of characteristics in the time domain. The general purpose finite element program ANSYS is used to calculate the mechanical behaviour of the system.

Using these tools the system can be optimised from the dynamic point of view in such a way that cavitation, fatigue problems and inefficiently operating pump systems can be avoided. The importance of such an analysis is also reflected in the API Standard 674, 2nd edition of June 1995. TNO Science and Industry uses a three-step approach in the API 674 analysis.

Step 1: Prestudy or dampercheck

Projects can be delayed considerably when pulsation dampers are not designed well in an early stage of the project. To size bottles more accurately, and to prevent costly, time-consuming changes in a later stage of the project, an acoustic prestudy (also called dampercheck) of the damper is carried out.



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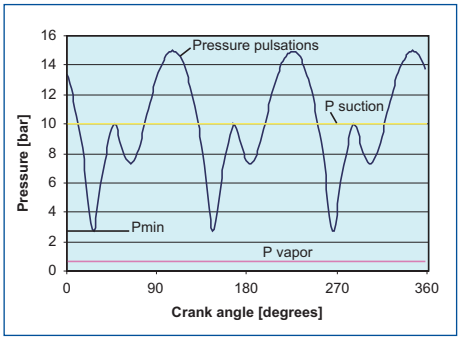
During this study the minimum volume and most-effective damper layout (in-line, off-line, with or without gas volume) is designed. To avoid cavitation caused by pressure pulsations the dampercheck is therefore carried out with the interaction of the pipe system, which includes acceleration, hydrostatic and friction effects.

Step 2: Pulsation study

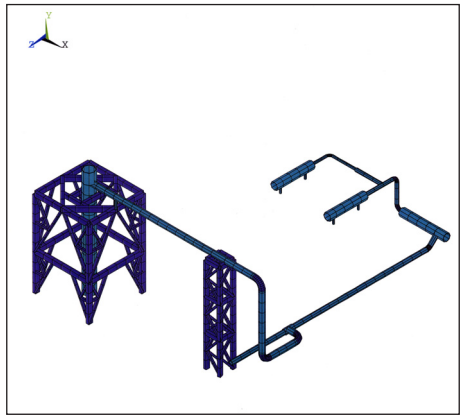
This step in the analysis is the pulsation study of the complete pipe system. The simulation model, as used by TNO Science and Industry, comprises the connected and interacting subsystems such as driving piston, cylinder volume, pump valves, internal passages, orifices, pulsation dampers, straight and curved pipe elements, etc.
The pulsations and pulsation-induced shaking forces are calculated and compared with allowable levels. In case of exceedings of these levels, modifications are investigated. Frequently advised modifications are: the installation of orifice plates, increasing the diameter of pipe parts, relocating closed valves, installation of additional volume etc.
The final aim of the pulsation study is the prevention of:

- cavitation
- high pressure losses
- unacceptable pulsations, vibrations an cyclic pipe stresses causing fatigue failure
- opening of relief valves due to pulsations
- inaccuracies of flow measuring devices



Step 3: Mechanical response study

One of the objectives of the pulsation study is to reduce the pulsation-induced shaking forces to a minimum. However, unallowable vibration and cyclic stress levels can occur in case a mechanical natural frequency is close to, or coincides with a frequency component of the pulsation-induced shaking forces, even in case the pulsation levels itself are within the allowable levels. To prevent fatigue failure of the pipe system, cyclic stresses in the system must not exceed the endurance limits of the material.
Therefore, TNO Science and Industry calculates the cyclic stresses in the pipe system with a full mechanical response analysis. This is in addition to the analysis as required following the API 674, because for pumps with variable speed, mismatch of acoustical and mechanical natural frequencies is difficult to achieve, especially for a wide speed range.



The mechanical model is built up with beam type elements and includes all important components, which influence the mechanical natural frequencies and cyclic stresses such as nozzle and flange flexibilities, pipe racks, stress intensification factors of T-joints and nozzles.

In case the vibration and/or cyclic stress levels exceed the allowable levels, modifications are investigated to achieve acceptable levels. This can be accomplished by the installation of additional pipe supports and/or by increasing the stiffness of the structures on which the system is mounted.

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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