A steadying influence

Stephan Martiny, RM Invest GmbH, Germany, and Vitaly Pestunov, TechPromArma, Russia, discuss the emergency protection of pipelines and equipment using pressure auto-stabilisers.

Pressure pulsations, vibrations, hydraulic impacts, and different transient processes such as switching on, switching off, and switching over of pumping units intensify the mechanism of pipeline degradation and accelerate internal corrosion processes. These processes stimulate the accumulation of fatigue characteristics of the material in stress concentration areas, and can cause emergency breakdowns of the pipeline. Hydrodynamic processes cause approximately 70% of all accidents and breakdowns.

Water hammer

Water hammer is a short-term wave process. Wave propagation occurs in 1 km of pipeline in less than 1 second. The result of water hammer is the movement of large volumes of liquids (discharge). The process of liquids movement lasts a few seconds.

Water hammer is distinctive from discharge under pressure, in that during water hammer the pressure wave moves, and volumes of liquids move during discharge. However, pressure wave has a destructive effect if it is propagated with transonic speed and acts upon the walls of the pipeline with dynamic load.

One dynamic loading cycle is the effect of hydrodynamic wave on the walls of the pipeline until pressure fluctuations are completely damped.

There are several types of vibration damping and water hammer, including the use of passive damping elements, remote chambers with elastic members, pressure accumulators, and the introduction of special automatic control systems, as well as the use of pressure sensors and mechanisms for regulating external energy sources, and heating elements for the creation of steam fractions. The disadvantages of these designs are short service life and wear of damping elements and membranes, restrictions on the flow ripple frequency, the need for energy costs to maintain the system activity, and the possible failure of the automatic system. The main problem of these systems is that they do not act upon pressure waves, and do not remove pulsations and surges in the pipeline. They can only reduce the consequences of water hammer (discharge the excess volume of liquid, and reduce increased pressure in the pipeline).

The other main type is pressure auto-stabilisation (PA) – the development and installation of structures with the auto-stabilisation effect. This has the advantages of not requiring energy costs, with damping elements that do not wear; the self-stabilisation impact is that the damping element is the medium itself (its compressibility). The device is also passive; it does not require energy, does not contain wear and repair parts, and there are no limits in the frequency range, because they work at all frequencies and with any water hammers.

The factor of dynamic safety of PA is:

$$K_{din_{ssd}} = \frac{B}{A} \approx 4500$$

It allows for operation of systems and equipment at design life, even inclusive of unrecorded dynamic loads.

The principle of pressure auto-stabiliser operation

In steady-state mode a working fluid such as water, steamed water, oil or liquid natural gas fills up all the chambers from the stabiliser. At this time the pressure in all chambers is equal, i.e. the same as the pressure in the pipeline. The appearance of the pressure-pulse of any magnitude or polarity at the input of the PA (generated from hydraulic impact or vibrations) leads to pressure change through perforated holes in the small expansion chamber, and in the corresponding part of the damping chamber. As a result of interaction with the piston, the hydraulic wave is damped. With some delay, the same input pressure pulse has an effect on the piston from the opposite side. The pressure pulse effect generated successively from the both sides of the piston leads to energy pulse dissipation, caused by hydraulic impact with high efficiency.

The principle of the PA operation was based on the following damping effects: after getting into the stabiliser, the hydro-percussion wave dissipates on a group of straight and skewed holes; the wave amplitude decreases due to the increase in the liquid volume under the body; and the scattered waves of pressure are residually damped in damping chambers, due to the piston ductility and the medium compressibility.

The design of the PA therefore allows the waves to spread out and direct the impulse towards itself. The impulse is used as a resilient element of definite rigidity in the damping chambers instead of resilient elements themselves. As a result, the PA does not depend on pressure pulse amplitude and frequency of input pulse. Piston movement is insignificant (0.08 - 0.1 mm) and it does not cause wear on the springs installed in the pressure stabiliser for piston centering.

Hence, the PA does not depend on different values of input impulse. That is, no matter how strong a pressure surge is, almost the same pulse value of the opposite sign neutralises it. The absence of special resilient elements eliminates their ageing and limited resource, and ensures the device's operation in a wide range of working fluids and environments, at different temperatures.

The effectiveness of the auto-stabiliser shows up in different ways for different environments. At the same time, damping occurs at any liquid medium, regardless of impurities. The software package was used to study the performance of auto-stabilisers in different environments.

Analysis

In addition to hydrodynamic studies, the specialists at TechPromArma performed cross-spectrum analysis to assess the strength of pipelines. Two simulation cases were considered: a pipeline without pressure self-stabiliser, and a pipeline protected by PA. The effect of the hydro-percussion wave at the pipeline walls on the complete pressure vibration damping was recognised as one loading cycle. As follows from the analysis, pipeline without PA can reach its critical state (appearance of micro cracks) after 135 cycles. Pipeline protected by PA can reach its critical state after 609 129 cycles (hydraulic impact) under the same conditions. It should be noted that this result does not include other accumulated damage to the pipeline during its operation (for example, pressure testing, changes in the medium temperature, etc.).

Efficiency of PA manifested differently for various fluids. At the same time, damping occurs on any liquid, regardless of impurities. The study of the PA operation was carried out on different medium in the software complex. The graphs show the diagrams of calculation results – the pressure in two sections of model before installation of the PA during water hammer (blue line) and after installation (red line).

PA were supplied and operated at the following power engineering and heat facilities: RUE 'Belnipiprom', PJSC 'LUKOIL', Kalinin NPP, Leningrad NPP, Smolensk NPP, Rostov NPP and more. PA can be installed on pipelines of any systems, including the power industry, municipal water and sewage systems, the oil and gas industry, metallurgical engineering, and the chemical industry.

Purpose of a pressure stabiliser

Pressure stabilisers are designed to ensure a trouble-free operation of equipment and pipeline systems by damping hydraulic shocks, pressure fluctuations, vibrations and resonance phenomena arising in pipelines as a result of factors including:

- Emergency shutdowns and power failures.
- Failures of automation and control systems.
- Stop valves actuation.
- Fast switching.
- Maintenance errors.

They are also designed to prevent large-scale accidental ruptures of pipelines, as well as damage to the valve and pump units due to water hammer, pressure surges and vibration. They also increase corrosion-fatigue durability of pipelines by

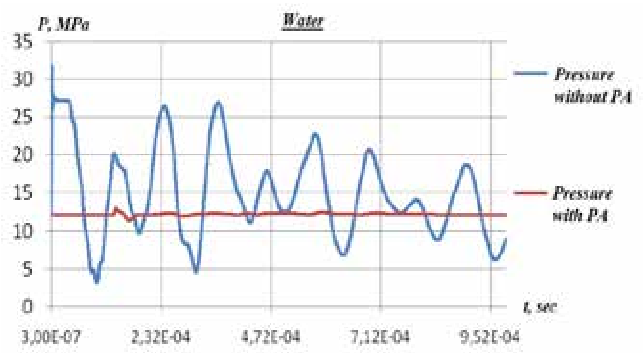
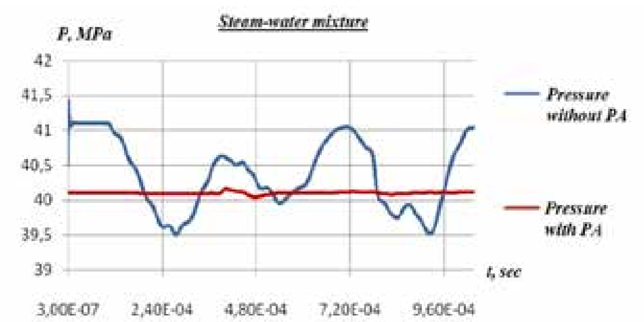


Figure 1. Please provide caption.



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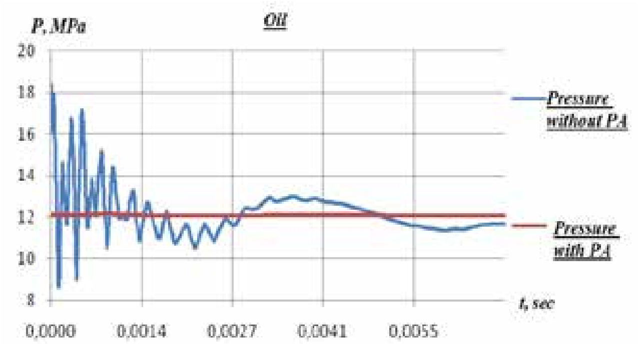

Figure 3. Please provide caption.

reducing amplitude-frequency pulsations to the required level at operating frequencies of pumping units and in transient conditions, and increase pipeline service life (by 50-70%, considering the accumulated wear and actual operating conditions).

One or more stabilisers installed in the circuit can be a passive safety system that protects the pipeline from water hammer and vibrations, and prevents wear and destruction of equipment elements.

The pressure stabiliser does not have controls, so it does not burden the system for which it is designed. Pressure self-stabilisers have the form of inserts into the pipeline, and so do not create additional resistance.

Installation

It is recommended to install PA according to the following conditions:

- In the immediate vicinity (not more than 10 m), before and after the valves, pumps and other sources that create a disturbance including high-speed (cut-off), regulating, reverse valves with any control, so that the arrow on the PA housing points towards the disturbance source.
- After the pumps, so that the arrow on the stabiliser housing points towards the pump.
- In systems where the pumps serve as devices that increase the pressure in the pipeline, the PA is installed before and after the pumps (arrows on the stabiliser housing shall point towards the pump).
- In places of the possible occurrence of two-phase modes (steam-water mixture).
- On the straight sections of the pipeline, one after another, at a distance of 300 to 1000 m.

The practical results of the installation:

- Reduction of the accident rate of pipelines and equipment.
- Increase of corrosion-fatigue life of pipeline systems.
- Extension of the service life of severely worn pipeline systems by more than 1.5 - 2 times.
- Reduction of direct and indirect costs of accident recovery works.
- Reduction of costs related to emergency replacement of emergency areas.
- Reduction of operating costs of pipeline systems in the planned preventive mode.

Practice of pressure stabiliser installation

The first practice of this installation was in 2013. Since that time, stabilisers have already been introduced at nuclear and thermal power stations, sites of production, transportation and processing of petroleum products and energy facilities.

For example, a partial modernisation was carried out at one station – the adjustment system was replaced, and the stabilisers were introduced in critical systems to prevent dynamic disturbances in transients.

When designing a pipeline system, designers calculate all loads correctly, but they calculate them under static conditions, rather than dynamic. According to the rules and standards of design, they include a 'safety factor', but it is again static. Dynamics cannot be calculated, only modelled; however, this is rarely practiced. Also, problems arise just with dynamic impact, which was the process of the invention of the stabiliser itself.

Many modellings were carried out, in which the system was subjected not to a static constant load, but to a dynamic short-term – but strong – load. With proper installation of the stabiliser as a system of passive protection of the pipeline, the designing organisation will receive a guarantee that the designed pipeline will operate for the entire planned period. This will prevent an environmental incident, and bring cost benefits, as it will make it possible to avoid emergency stops (the stop of only one unit at a nuclear power plant for one day causes losses of more than €3 million).

There are transients in each piping system. These processes at some point (it is impossible to predict at the exact point) undergo strong dynamic disturbances and pulsations, for which the system is not designed and which, in turn, lead to hydraulic impact. Only operating organisations know about these transients. Therefore, these experts are the most important apologists for the introduction of stabilisers. Only they can confirm that they may have such problems, and need to protect themselves from them. During the introduction, the stabiliser begins to 'take on' and dampen these dynamic disturbances, so nothing needs to be modelled.

The most obvious 'readings' for the installation of a stabiliser are compressor and reinforcement stations, places of terrain change, and sharp turns in laying the pipeline. For example, the flow of water is pumped up, at the time of the pump stop – and the water column falls down. For this, a return valve is usually installed, and it receives the impact. Sometimes it can be plain to see: the pipe is shaken by the impact. Sometimes the valve withstands, but sometimes it leads to its rupture. Direct water impact, which often leads to emergency situations, occurs if something stops or starts in the so-called 'zero seconds'. However, it happens very rarely – it is only in case of an accident. It lasts for seconds, or even a fraction of a second. In this case, the disturbances do not reach the maximum values of impact, but they have the accumulative character. All operating organisations know that two major problems for the pipeline are erosion and corrosion; they arise and become dangerous not immediately, but as time passes. This is the closest analogy to dynamic disturbances, as they also have temporary and accumulative character. They destroy the pipeline in certain places as time passes. To prevent this, the stake was put on the thickness of the pipeline metal. The installation of the stabiliser makes it possible to achieve substantial savings here too.

Figure 4. Please provide caption.

Example of stabiliser installation

At a mine, which was previously actively developed, and then stopped, there was a constant problem of it filling with water. There were two pumping stations, which pumped out this water. If this water was not pumped out, the mine could flood the entire nearby city. Water is pumped out of the mine for 3 km outside the settlement line, along the uphill terrain, where it drains. The pumps were located 100 m down in the depths of the mine. When the pumps were shut down, a 3 km-high column of water impacted the return valves. During this impact, the pipeline came into motion and visually 'jumped' by 1.5 m. This system 'survived' to the maximum for a month, before it was necessary to change the reinforcement. Two stabilisers were installed: one on the pumps, the other in front of return valves, and the system has been operating without shutdowns for approximately one year.