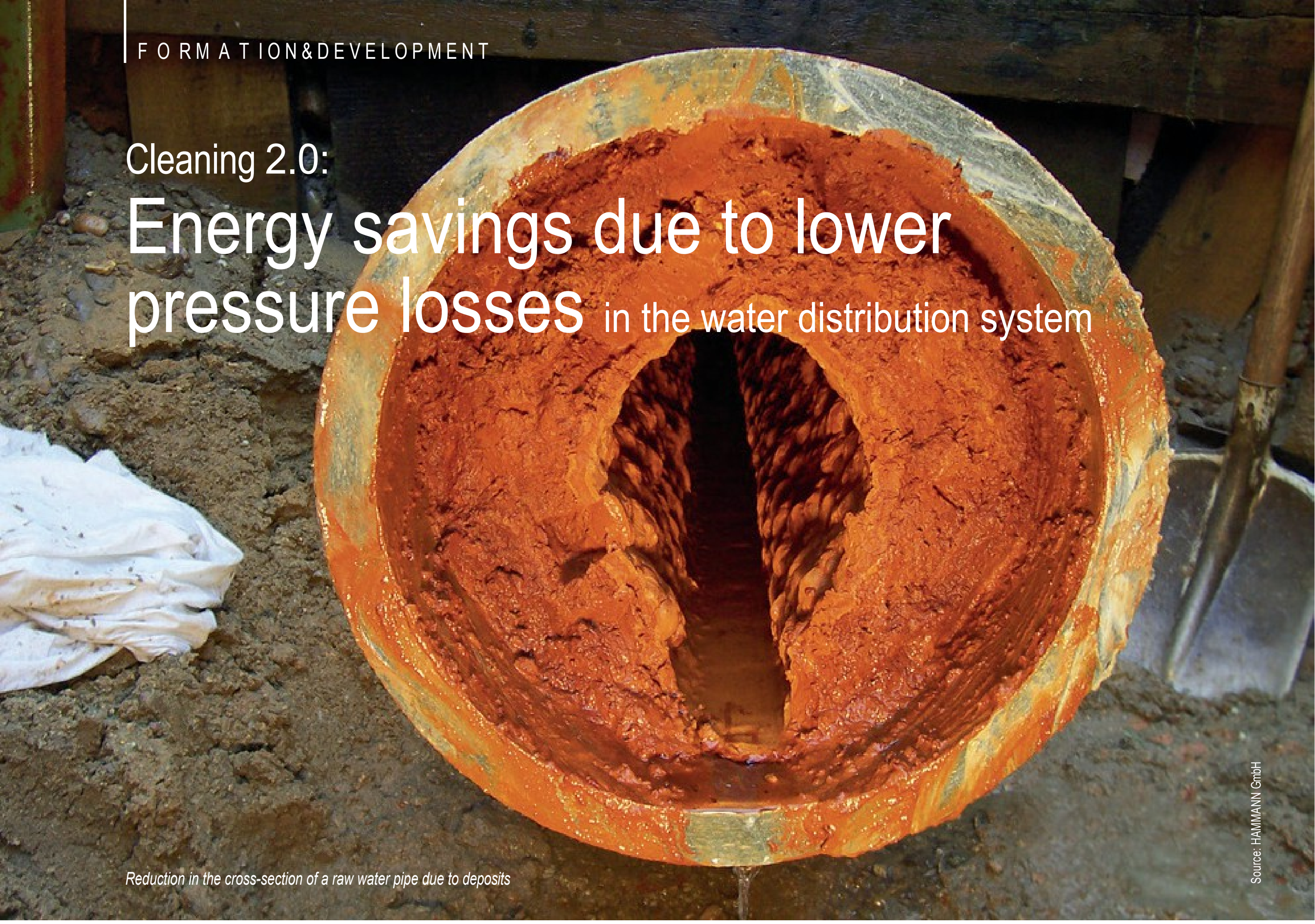
Cleaning 2.0:

Energy savings due to lower pressure losses in the water distribution system



Reduction in the cross-section of a raw water pipe due to deposits

Source: HAMMANN GmbH

Energy savings are often achieved by overhauling and replacing pumps. However, energy can also be saved by removing deposits from pipes. Deposits increase the roughness and reduce the pipe cross-section so that the pressure loss increases. The research and development project "REINER - Increasing energy efficiency in water networks through new assessment tools and optimized cleaning" aims to clarify how much energy can be saved by cleaning pipelines and thus removing deposits. The joint project, which started in mid-2015, is scheduled to run for two years and is being funded by the Federal Ministry of Education and Research (BMBF) as part of the BMBF funding measure "KMU-innovativ: Ressourcen- und Energieeffizienz" in the technology and application area "Nachhaltiges Wassermanagement (NaWaM)".

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Drinking water must meet the requirements of the German Drinking Water Ordinance (TrinkwV 2001) [1] and must not cause any adverse health effects for the consumer. In addition, drinking water should meet high aesthetic standards. The TrinkwV 2001 specifies all the necessary The test parameters for monitoring drinking water and the corresponding limit values are bundled. The requirements placed on drinking water apply not only when it is discharged into the supply network, but also up to the tap of a drinking water installation that is used to draw off the water. of drinking water. Until then, the quality of drinking water can be affected by a wide variety of influences, such as sediment, corrosion products and microorganisms. These influences should be minimized by purification processes.

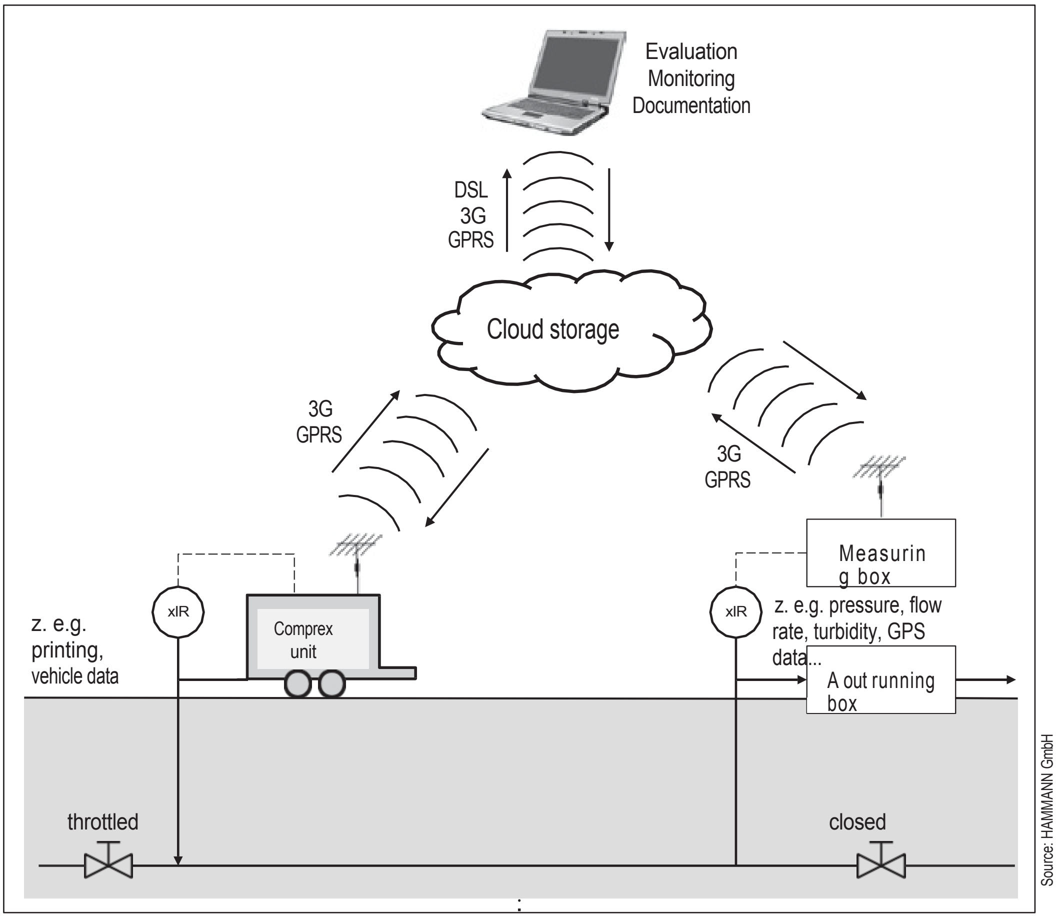


Fig. 1: Schematic representation of the COMPREX process

The cleaning and disinfection of pipelines are described in DVGW Code of Practice W 291 "Cleaning and disinfection of water distribution systems" [2]. The focus here is clearly on the hygienic aspect; energy efficiency in water distribution has not yet been taken into account. Information on this topic can be found in DVGW Water Information No. 77 [3] and in DVGW Code of Practice W 614 [4].

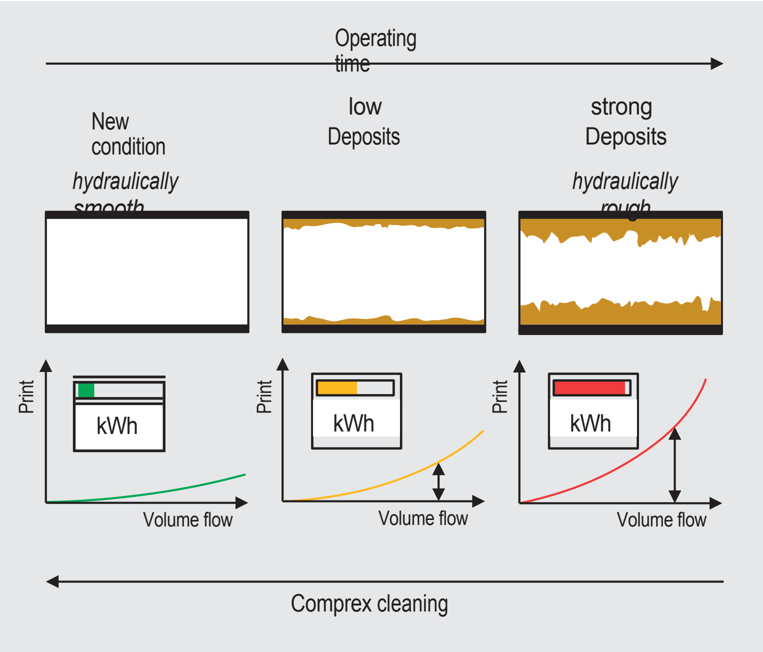
According to the latest findings, increasing the control speed in the pipe by 100 percent is sufficient to remove loose deposits. The cleaning effect can be increased by adding air at the same time.

The REINER joint project is coordinated by HAMMANN GmbH, which developed the patented COMPREX pulse flushing process **(Fig. 1)**. A cleaning section in the distribution network is defined by two valves and two hydrants. The first valve restricts the water flowing into the pipe section. The second gate valve remains closed and represents the end of the cleaning section. A hydrant in the front section

The water section of the cleaning section is used for the pulsed feed of treated compressed air. This causes air and water blocks to form in the cleaning section. These blocks reach speeds of over 20 m/s. The shear and drag forces generated in the process detach deposits from the inner surfaces of the pipe. The particles mobilized in this way are transported through the cleaning section and discharged at the outlet hydrant. The process is also suitable for pipelines made of fragile materials, as the net resting pressure is not exceeded during cleaning.

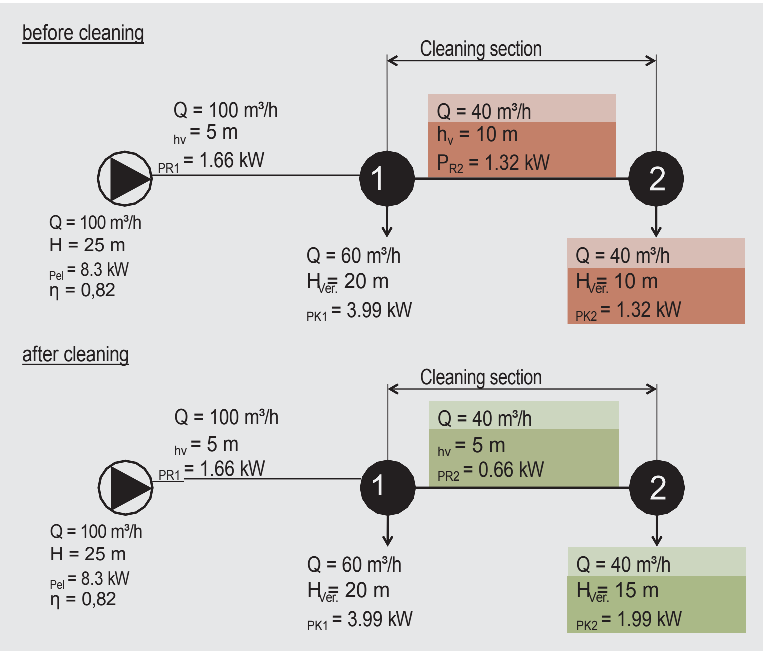
RWW network flushing

Due to demographic change and ever decreasing consumption volumes per capita, drinking water networks in Germany are now oversized. In order to meet the requirements of the TrinkwV 2001 and still keep the network in perfect condition, RWW systematically flushes the pipe network unidirectionally from the feed-in point to the consumer according to the "clear water front" principle. The aim of this type of network flushing is to minimize costs and benefits.



Source: HAMMANN GmbH

Fig. 2: Influence of deposits on pipe hydraulics and energy consumption



Source: RWW mbH

Fig. 3: Exemplary allocation of the required power to individual pipe sections, before and after cleaning

Legend:
$_{hv}$ = pressure loss [m]
$_{HVer.}$ = supply pressure [m]
$_{Pel}$ = electrical pump power [W]
$_{PK}$ = available power at the node [W]
$_{PR}$ = power required to transport water through the pipe [W]

are in an economical and sensible relationship. On the other hand, flushing end lines based on a time-based cycle and event-oriented "flushing on demand" are often not effective and efficient. This is due to the fact that a large proportion of the particulate load remains in the upstream pipe network. Deposits are mobilized and displaced instead of being effectively removed. Network flushing with a clear water front, on the other hand, is carried out systematically according to a flushing plan. The sequence of the individual flushing steps is defined and described in detail in this plan.

The main contents of the flushing plan are

- Subdivision of the supply area into individual flushing areas,
- Determination of all flushing hydrants,
- Determination of suitable flushing lines (starting from the waterworks/transport lines),
- Definition of direction and flush volume per flush line,
- Definition of the valve positions for each flushing section.

Such network flushing is an efficient and modern process to avoid turbidity in pipe networks. Frequent and costly end hydrant flushing can be largely omitted if the pipe networks are flushed with clear water at strategically sensible intervals (as rarely as possible, as often as necessary). Network flushing does not currently pursue the goal of saving energy.

Project idea REINER

The processes of water extraction, treatment and distribution require electrical energy. Around half a percent of primary energy in Germany is required for water supply [5]. Particularly in view of climate protection, it is necessary to increase energy efficiency through the continuous development of new technologies.

In most water supply companies, most of the electrical energy required for pumping water in the water distribution system is used for pumps. The necessary delivery head of the pumps, depending on the flow rate, is determined by the geographical conditions of the supply area. The pressure losses in the pipe network and the pressure required at the transfer point to the customer are determined by the height of the building. The pressure losses are caused by friction in pipes and by fittings and valves.

Age-related deposits in the pipe worsen the hydraulic conditions **(Fig. 2)**. As a result, the energy required to transport the drinking water increases. Cleaning measures can reduce pressure losses in the pipeline caused by deposits. Currently, the cleaning

Source: HAMMANN GmbH

Fig. 1: Pipe section with reproducible model deposits (top) and pipe section from practice with deposits (bottom)

mainly for hygienic reasons and mostly at the end strands of brown water and turbidity problems and for refurbishments. The REI- NER R&D project aims to quantify energy optimization through cleaning measures. REINER has two main focuses with regard to energy savings:

- Novel calculation approaches are to be used to make statements about the hydraulic condition of the pipe before and after COMPREX cleaning. These are intended to quantify the cleaning performance and the resulting energy savings.
- The control of the COMPREX process is to be optimized and the cleaning performance significantly increased. A newly developed mobile measuring box is to transmit measured variables from the outlet point of the cleaning section to the COMPREX unit in real time and serve to optimize the control of the cleaning process **(Fig. 1)**.

Allocation of the required energy to individual pipe sections

The energy required in the water distribution system is the sum of all the power-consuming units involved. Most water supply companies know the total energy demand of their water distribution system. For individual pipe sections, however, the corresponding share of the total energy requirement is only known to a limited extent.

The allocated energy demand of a pipeline section can be derived from an annual database. If this data is not available, a special funding situation can serve as a data basis. The energy demand of individual pipe sections is calculated from **equation 1**.

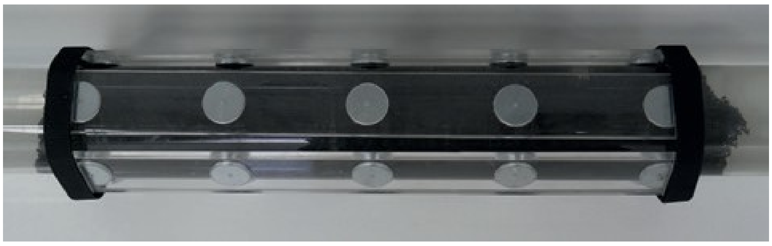
$$P = \frac{\rho \cdot g}{\eta} \cdot \Sigma H \cdot Q \qquad \text{Eq. 1}$$

P = Pump power [W]
ρ = Density of water [kg/m³] g = Acceleration due to gravity [m/s²] η = Efficiency of the Pump unit [-] H = Delivery head [m]
Q = Volume flow [m³/s]

Figure 3 shows an example of the power required for two network nodes 1 and 2 and for the pipe section between nodes 1 and 2 before and after cleaning.

Cleaning improves the hydraulic conditions in the pipe by reducing the pressure loss. This reduces the energy consumption for this pipe section. To simplify matters, all components in the example are at the same geodetic height.

Cleaning the pipe section between node 1 and node 2 reduces the pressure loss from ten to five meters. As a result, there is a residual pressure of 15 instead of ten meters at node 2. Before cleaning, 10,560 kWh per year are required to transport water between node 1 and node 2; after cleaning, only 5,280 kWh are required. To



Source: HAMMANN GmbH

Fig. 5: Pipe section with model deposits in the test facility

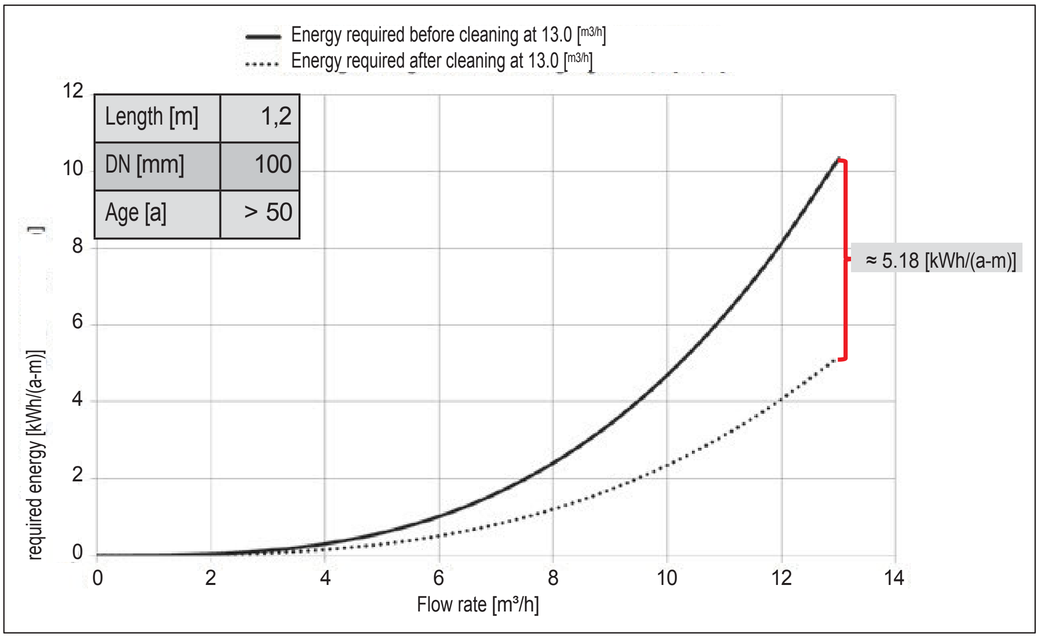
Node 2 has additional pressure energy available after cleaning. By reducing the power required for the cleaning section, the power return in the supply network increases. This is initially reflected in the provision of a higher static pressure. By controlling the pump with a frequency converter (FC) or by using a smaller pump, this power reserve can then mean a saving in electrical energy.

Investigations at the test facility

In order to understand the relationships between hydraulics and cleaning, a test facility on a semi-industrial scale is helpful. For this reason, HAMMANN GmbH expanded its existing test facility made of transparent pipes. Among other things, new fittings, sensors and MSR-components are installed. A mobile measuring box transmits various parameters wirelessly and in packets from the outlet point to the COMPREX unit at the inlet point. This data is a prerequisite for evaluating the pipe hydraulics and optimally controlling the cleaning process.

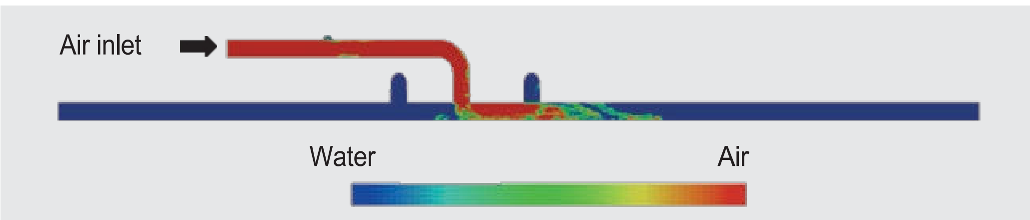
While only one-off tests of a cleaning section are possible in the drinking water network, the test facility allows repeated tests under reproducible conditions. Model deposits with defined adhesion, cohesion, thickness and geometry are used for this purpose. Various systems were compared as model deposits. Steel particles of a defined size that are held from the outside by magnets with specific adhesive forces are particularly suitable.

Abbildung 4 zeigt ein transparentes Kunststoffrohr mit Modellablagerungen aus Stahlpartikeln im Vergleich zu einer aus dem Trinkwassernetz entnommenen Gussrohrleitung. Die ablagerungsbedingte Querschnittsverengung lässt sich annähernd reproduzierbar durch die Stahlpartikel nachbilden.



Source: RWW mbH

Fig. 6: Energy required using the example of a pipe sample before and after cleaning



Source: University of Duisburg-Essen

Fig. 7: Phase distribution during the inflow of an air pulse (cross-sectional representation)

Figure 5 shows a partial section of a 1.2 meter long transparent pipe section with model deposits in the test facility. The steel sections are held in place by neodymium magnets with an adhesive force of 36 kilograms each. Despite the short length of the cleaning section with reduced cross-section, a corresponding pressure loss can be measured with the built-in pressure sensors. Cleaning reduces the pressure loss and therefore the energy required to overcome the pressure loss in the cleaning section.

Pipe samples from the RWW network are intended to establish a link between the model tests and practice. A pipe section from practice was installed in the test system and cleaned for investigation. **Figure 6** shows the energy required to overcome the pressure loss at a flow rate of approx. 13.0 m^3/h before and after cleaning. Due to the cleaning performance, the energy required to overcome the removed pipe section at a flow velocity of 0.5 m/s is reduced by approx. 5.18 kWh/(a-m).

Further cleaning tests with pipe samples from the RWW supply network should provide additional information on deposits in pipes. Different pipe materials and nominal width ranges can be examined.

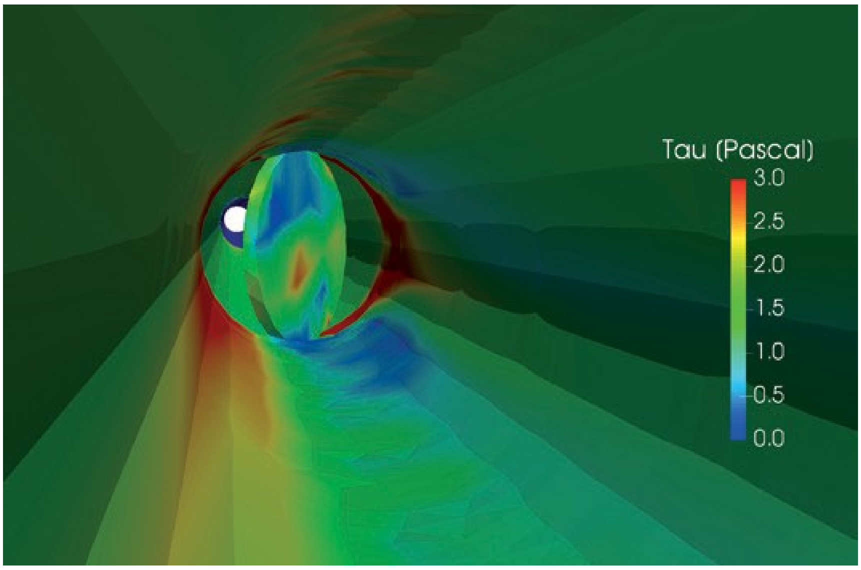
Numerical simulation of the cleaning processes (air/water phase)

The use of numerical simulation software enables a high-resolution representation of the cleaning processes within a pipeline. On the one hand, with regard to the highly dynamic cleaning processes, this offers the advantage of being able to analyze relevant parameters of the flow independently of location and time. Furthermore, in addition to the experiments at the test facility, it is also possible to carry out extensive parameter studies with regard to cleaning efficiency. By transferring some parameters of the simulation into a practical model, it is also possible to determine and evaluate data in real time during the cleaning process and convert it into appropriate technical measures.

A multiphase model designed for compressible media is used to simulate the feed of air pulses into a pipe. Optimum detachment of the deposits requires the highest possible wall shear stresses. This can be achieved by maximizing the flow velocities of the water blocks near the pipe wall. **Figure 7** shows an example of the progression of the phase boundaries of air and water during the inflow process.

The computer-aided calculations can also be used to characterize the influence of valves such as butterfly valves and gate valves in the cleaning section. Valves that are not fully open significantly change the multiphase flow and, in addition to pressure losses, lead to dead spaces and areas with increased wall shear stresses. The effects of a 30 degree closed butterfly valve on the shear stress distribution can be seen in **Figure 8.** The pressure losses of internals determined in this way also indicate a risk of cavitation in some cases, which could already be proven by a corresponding experiment on the test system.

The knowledge gained from the numerical simulation will then be incorporated into the developed measuring box for optimized control of the COM-PREX process. This is to be tested in the further course under laboratory conditions, at the test facility and under real conditions during cleaning measures in practice.



Source: University of Duisburg-Essen

Fig. 8: Wall shear stress distribution determined by simulation in a pipeline with a butterfly valve installed and rotated 30 degrees against the flow (looking in the opposite direction to the flow)

Summary

In order to quantify the cleaning result from an energy perspective, it is essential to allocate a specific energy requirement to individual pipes. It can be seen that reducing the pressure loss in individual pipe sections can have direct and indirect energy effects. The direct energy effect is the reduction in the energy requirement of the cleaned piping. The indirect effect of cleaning is a higher static pressure in the supply area with the same pump capacity.

The newly developed calculation tool makes it possible to describe the pipe to be cleaned using a hydraulic efficiency factor. Based on this, a specific energy requirement is calculated for the pipeline. The knowledge gained during the course of the project can be used to forecast the effects of cleaning.

The COMPREX control system is optimized with the help of a numerical simulation, among other things. This makes it possible to analyze the cleaning process in high resolution, to be displayed. This makes it possible to identify differences in cleaning intensity, which is mainly determined by the wall shear stress generated, at different air/water ratios. The findings on cleaning intensity obtained from the numerical simulation are incorporated into the development of the control system. This should make it possible to determine the cleaning success during cleaning and, based on this, to adjust the cleaning intensity in a targeted manner. This results in a dynamic cleaning process. ■

Literature

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