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Pressure loss reduction of pipe elements

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Abstract

A theoretical research was conducted from 2016 to 2018 which aimed to reduce the head loss of pipe networks in the pump stations. The results were promising and predicted an average head loss reduction by 30%. Afterwards, physical experiments were carried out to test the effectiveness of the new pipe designs. Two new prototype pipe sections were installed into one of our pump stations. The experiment was successful as two unique pipe sections installed in the discharge pipe reduced the head loss of the pump station by 25–26%. According to these results, we can set a target value of 30% head loss reduction at full pump station pipe reconstruction.

Key words: energy consumption reduction, pressure loss, turbulent flow

INTRODUCTION

One of the main focuses of water utility companies is the energy-efficient supply of drinking water. Pump stations are key locations in energy efficiency. They have the highest velocity values in the water network system and the highest pressure loss values are also present here. Reduction of pressure loss at these facilities is the most feasible and most advantageous solution.

METHODOLOGY & RESEARCH

A theoretical research was conducted from 2016 to 2018 that aimed to reduce the head loss of pipe networks in the pump stations. The analysis used a new method to reduce pressure loss. Numerical calculations were carried out on the original standard pipe elements to determine the problematic fluid dynamic zones where pressure loss occurs. The two indicator quantities of these zones are turbulence kinetic energy and streamlines of the section (Tu *et al.* 2008). The problematic zones have a high turbulence kinetic energy value and the streamlines in and near these zones are not parallel to each other. After the problematic zones are identified, geometry changes aiming to reduce these zones can be made and tested numerically.

RESULTS

The research first concentrated on single pipe elements like pipe elbows or T-junctions. After promising results, complete pump house pump networks were analyzed.

Standard 90° pipe elbow with R1,5 radius

This is one of the most common pipe elements used in pump houses. The flow dynamics of the standard 90° pipe elbow are extensively researched and documented (Hiliding Beij 1938). It is known that

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the main reason for pressure loss is the formation of two secondary counter rotating vortexes after the elbow (György 1995), as seen in Figure 1. This phenomenon is caused by the forced direction change of the water molecules. The starting point of the vortex is located at the beginning of the longer arc of the elbow.

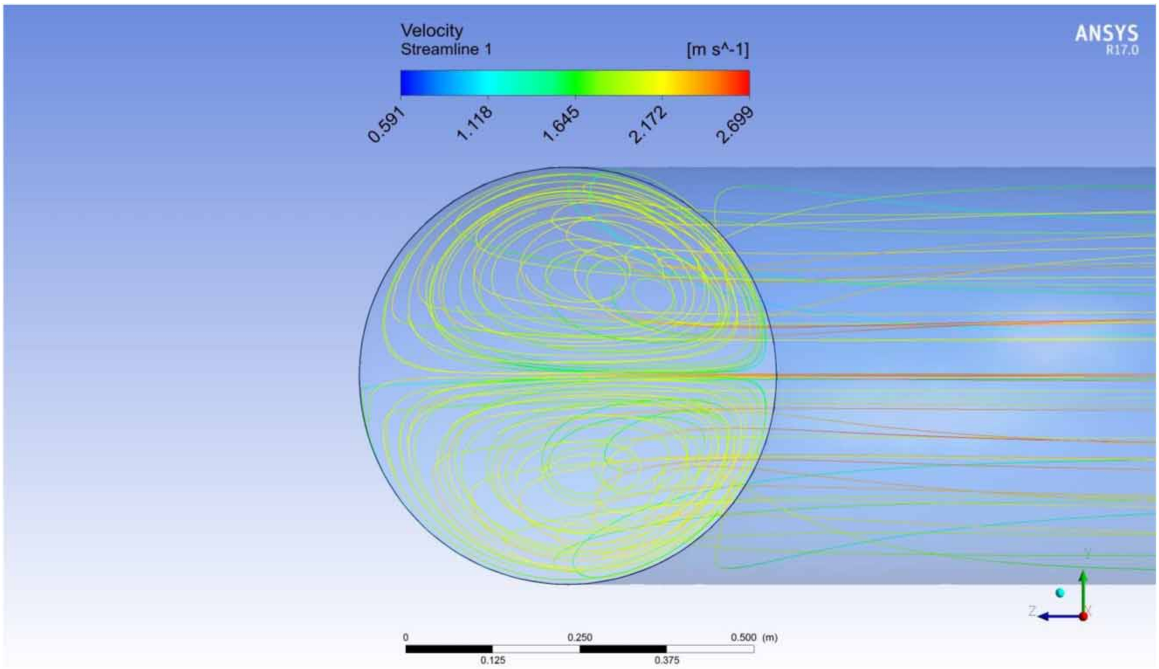

Figure 1 | Counter rotating vortexes at the standard 90° pipe elbow.

The other cause of pressure loss at high Reynolds number is backflow after the short arc of the elbow. The back flow and the vortex formation can be decreased by increasing the radius of the elbow, but this is not feasible when the installation space is limited. The new geometry reduces the secondary vortex formations via vanes installed at key areas on the inner surface of the pipe, as seen in Figure 2. This reduces and delays the formation of the counter-rotating vortexes.

The space requirement for the pipe section remains the same for the new geometry, only the inside of the pipe is altered. This geometrical change is simple, yet cost effective and also can be easily manufactured. The new geometry reduces the secondary vortex formations via vanes installed at key areas on the inner surface of the pipe, which also reduces pressure loss.

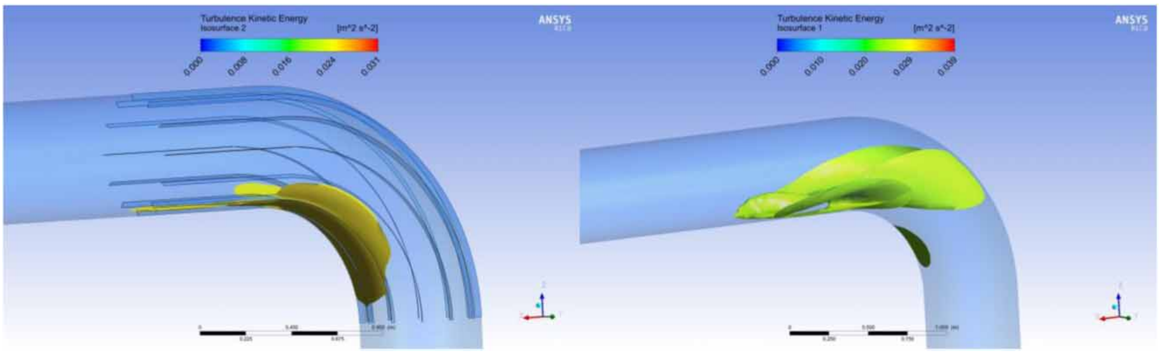

Figure 2 | Turbulence kinetic energy zones of 0,025 [m^2/s^2] (left: new geometry, right: old geometry).

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With modifying the internal geometry, depending on the flow velocity and surface roughness, a pressure loss reduction from 6 to 15% percent is achievable (Figure 3).

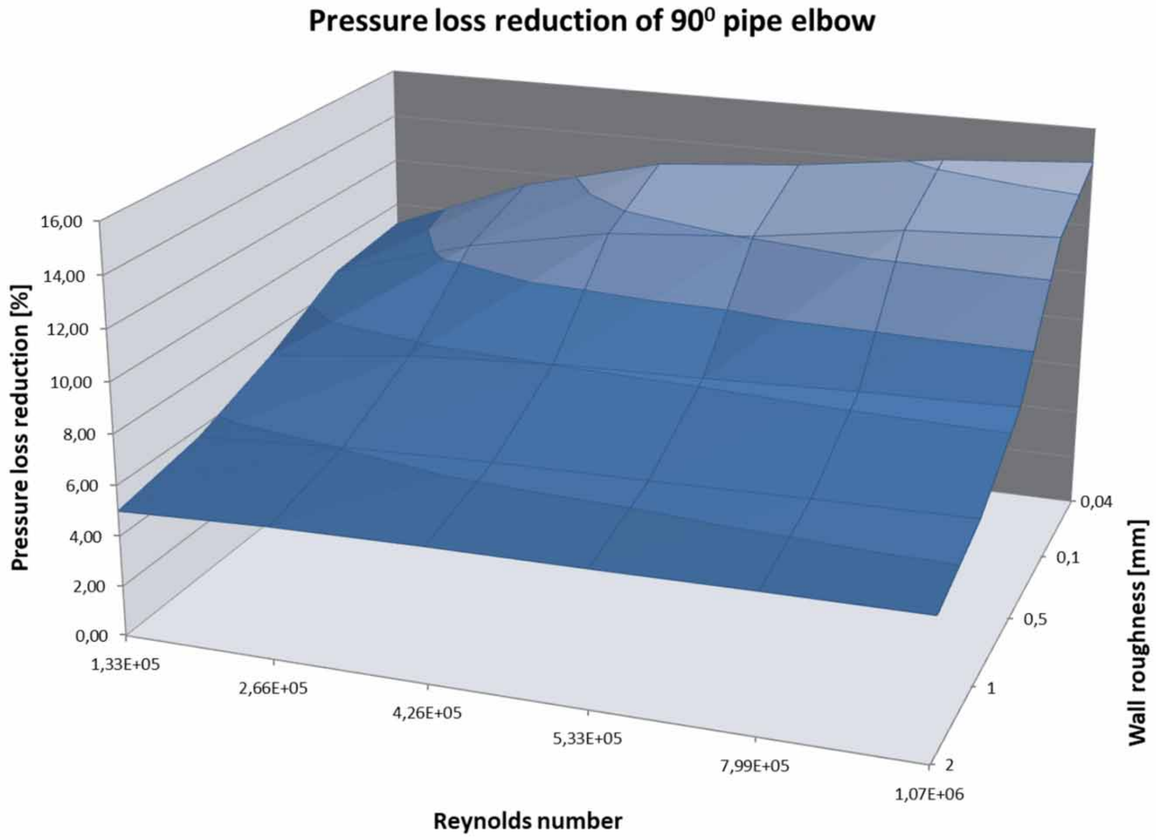

Figure 3 | Pressure loss reduction of 90° degree pipe elbow.

Pump house pipe systems

The theoretical research continued on pump house pipe systems; in this approach, the whole pump house pipe system was analyzed and geometrical changes were carried out on the whole length of the pipe system taking into account how the flow of the individual elements affect each other. The pressure loss reduction is above 30% and can even reach 60%. The geometry can be optimized for multiple operation state, as seen in Figure 4.

There are no two identical pump houses; a unique design is necessary at each location. The pipe geometry also reduces the harmful forces on pipe fittings caused by turbulence.

Physical experiments on new prototype pipe elements

Afterwards physical experiments were carried out to test the effectiveness of the new pipe design methodology. Two new prototype pipe elements were installed into one of our pump stations, during an R&D project. A conventional T pipe junction was replaced by a modified pipe junction geometry and a pipe elbow was also replaced with modified geometry with inner vanes just after the pump (Figure 5).

The experiment was successful as two unique pipe elements installed in the discharge pipe section reduced the head loss of the pump station by 25–26% (Figure 6).

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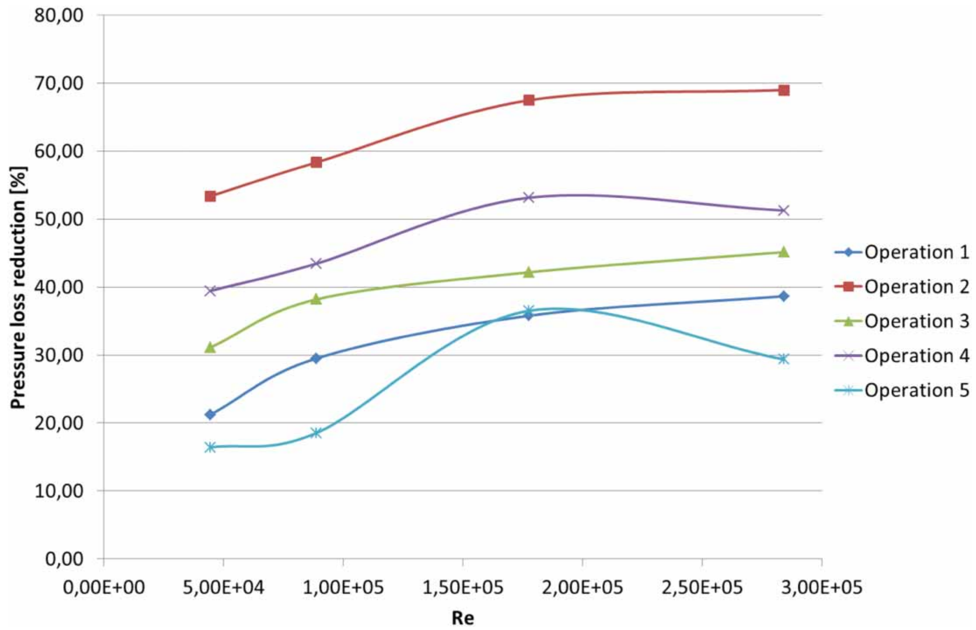

Figure 4 | Optimization for multiple operation state.

Figure 5 | New pipe elements in the discharge pipe of the pump house.

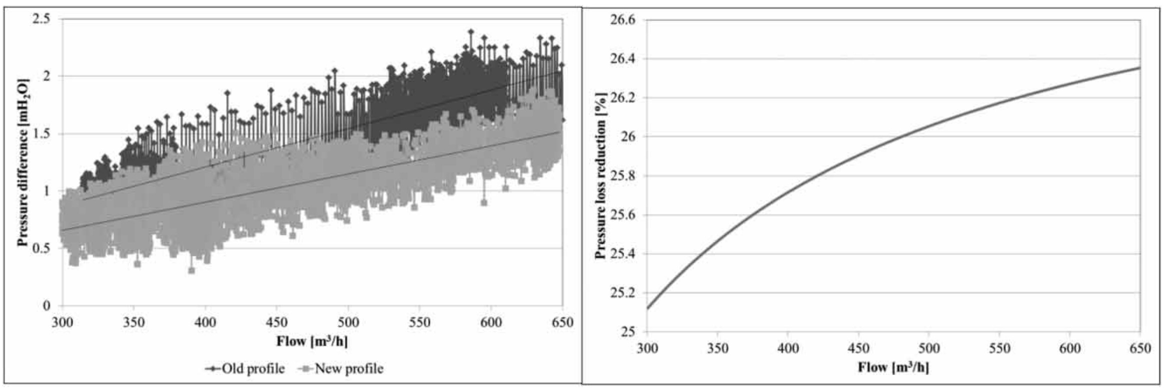

Figure 6 | Result of the two prototype pipe sections.

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Integrating new pipe design methodology into pump house reconstruction

The developed pipe design technology can be applied at pump house reconstruction where old pipes need to be changed. To prove that this methodology of pipe design is better than a conventional method we compared an existing reconstruction pipe geometry plan with a geometry designed by the new methodology (Figure 7, Table 1).

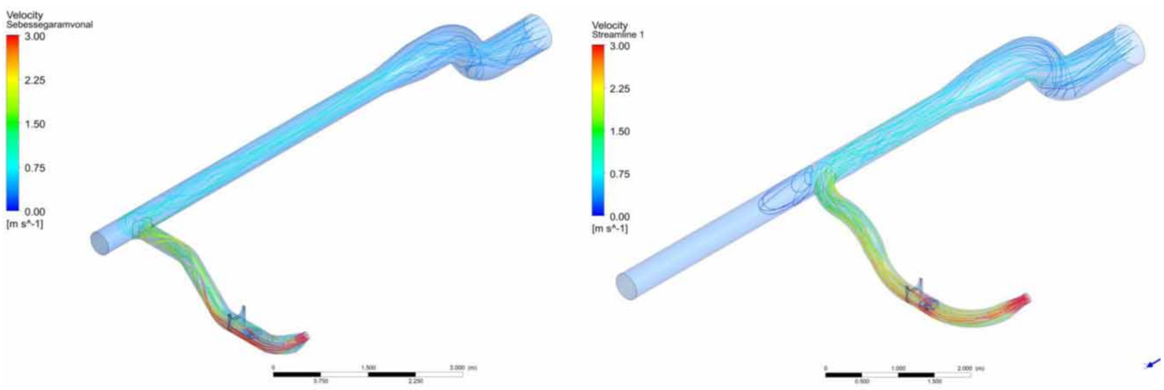

Figure 7 | Left: Pipe geometry with conventional design method. Right: Pipe geometry with new design methodology.

Table 1 | Comparing the pressure loss of the two pipe designs

	[Pa]	[mH2o]	Pressure loss reduction [%]
Pressure loss in the original pipe design	5663.4	0.58	
Pressure loss reduction in the new design	3611.5	0.37	**36.21**

CONCLUSION

Energy consumption reduction in pump houses is possible via the new methodology of pipe design. According to these results, we can set a target value of 30% head loss reduction at full pump station pipe reconstruction, this makes the technology financially recoverable. The electrical costs of the pump station operation can be reduced by 1% with the reduction of pressure loss. Furthermore, the new pipe elements reduce the chance of impeller damage caused by unstable flow and it also reduces the damage caused by highly turbulent flow on valves and check valves.

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