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Valve exploiting the principle of a side channel turbine

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Valve exploiting the principle of a side channel turbine

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Abstract. The presented article deals with a side channel turbine, which can be used as a suitable substitute for a pressure reducing valve. Pressure reducing valves are a source of high hydraulic losses. The aim is to replace them by a side channel turbine. With that in mind, hydraulic losses can be replaced by a production of electrical energy at comparable characteristics of the reducing valve and the side channel turbine. The basis for the design is the loss characteristics of the pressure reducing valve. Thereby create a new kind of turbine valve with speed-controlled flow in dependence of the runner revolution. It is technical innovation and new renewable source of energy, which can be in future used in rehabilitation or projecting of pumped-storage power plants. It also increases the power of the power plant.

1. Introduction

At the pumped-storage power plant Dalešice the water for cooling is taken directly from the penstock, see 'Figure 2'. Pressure of the water is reduced in pressure reduction valve. The water taken for cooling is not used to produce electrical energy. During throttling in the valve, part of the energy is transferred in the form of heat to the cooling water and warms it up. The water pressure is throttled from 8.5 to 4 bars. With this comes the potential of energetic utilization. The flow is 0.145 m^3s^{-1} and the possibility of regulation of the flow to 0.08 m^3s^{-1} is required. Another utilization can be in the water mains, energetics, chemical processes or in the place where the conversion of energy into heat occurs due to throttling.

Figure 1. Pumped-storage power plant Dalešice (Czech Republic) (http://www.cez.cz)

Figure 2. Pressure reducing valve in a cooling system [1]

Pressure reducing valves are a source of high hydraulic losses and their replacement is possible thanks to the comparable resistance characteristics with the side channel turbine. Characteristics of the valve flow coefficient K_v on the relative opening of the valve, see 'Figure 4', is analogous to the turbine characteristic of unit flow Q_{11} on unit speed n_{11}, see 'Figure 6'. A medium pressure drop across the valve is needed for energy recuperation.

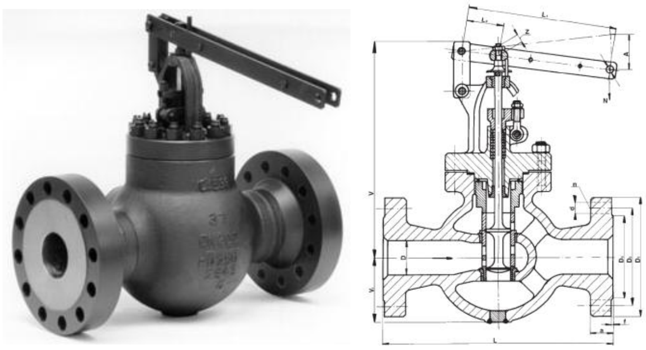

Figure 3. Pressure reducing valve (http://www.ldmvalves.com)

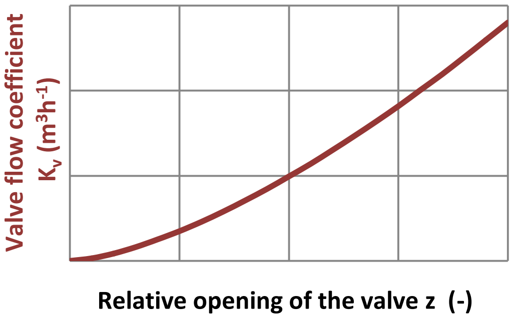

Figure 4. Flow characteristic of a pressure reducing valve

2. Side channel turbines

The side channel turbine falls into the category of reaction turbines and is intended for small discharges and medium heads. The working area is within the specific speed $n_s = 2 \div 30$ min^{-1}. The turbine can only process a part of the head. The main disadvantage is low efficiency, which is usually within the range of 20 to 50%. These machines find their use due to the fact that reaching specific speed $n_s < 35$ min^{-1} with classical turbines (Francis' turbine or multistage pump in turbine mode) at high efficiency is quite problematic. Under these circumstances, a counteracting vortex starts to occur in the channels between the blades of the impeller. This causes the decrease of efficiency which can even get below 30%. In a situation like this, it might be worth using side channel turbines as they have higher efficiency, than the low specific speed turbines.

Side channel turbines are useful for regulation due to their flat curve of efficiency in the area of optimum point and linear dependency of flow on revolutions. Theoretical energy efficiency characteristics η, unit flow Q_{11}, power P_{11} and torque M_{11} are plotted in dependence on unit speed n_{11} in 'Figure 6' [2].

Figure 5. Side channel machine (http://www.delavanagpumps.com)

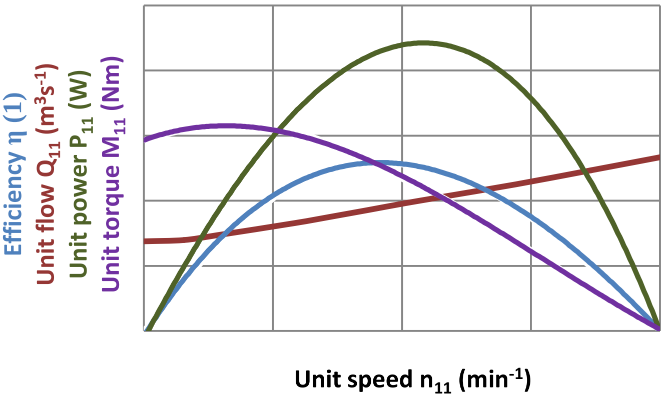

Figure 6. The course of the energy characteristics of side channel turbines

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3. Measurement of the side channel turbine

3.1. The pump in turbine mode

It is further examined, whether it is possible to use the side channel pump as a turbine for energy recovery in the piping system. For this experiment, a commercially produced side channel pump was

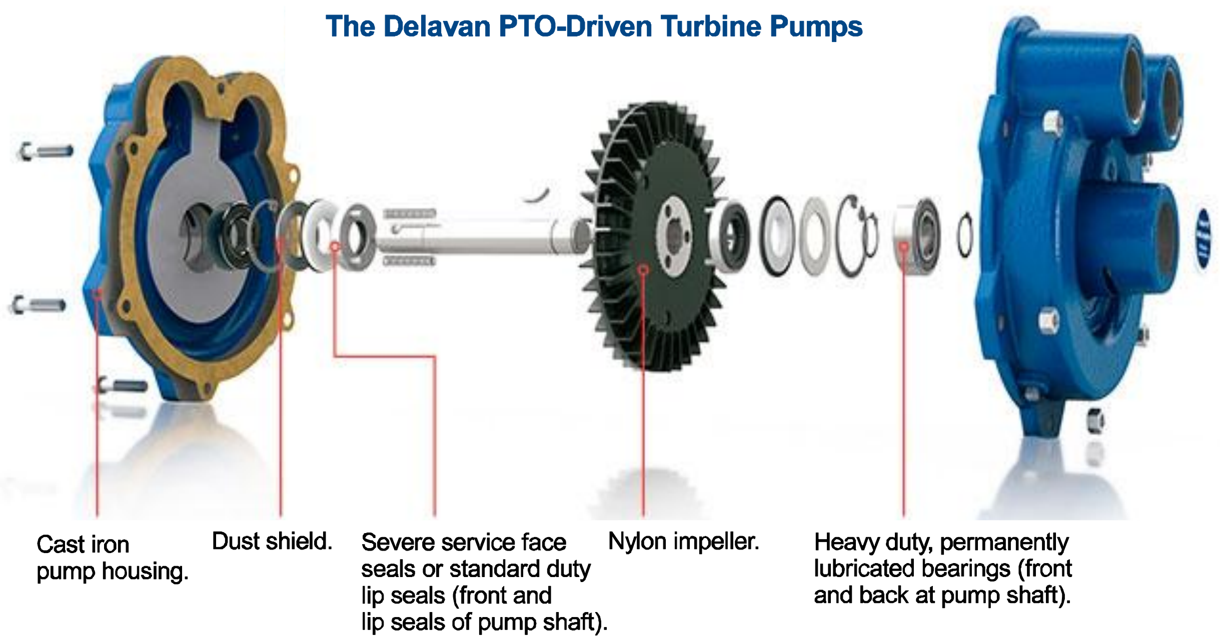

Figure 7. Assembly of side channel machine (http://www.delavanagpumps.com)

purchased from the American company Delavan, labeled Turbo 90, see 'Figure 7'. The pump has a closed type impeller. This means that the water enters and leaks directly into the channel. The impeller is symmetrical and has 36 blades on each side. The opposing blades are rotated by half the angular pitch. The side channel is part of the iron casting cabinet, which according to the manufacturer should endure 7 bar overpressure. The size of the connecting pipe is 3/2 inch. The shaft is sealed with ceramic - carbon mechanical seals. The maximum speed of the wheel is 1200 min^{-1}. The width of the side gap δ is approximately 0.1 mm. The dimensions of the hydraulic parts are shown in 'Figure 8'. The impeller is made from nylon. It is connected with the hub straight-sided splines and can move in the axial direction. It is self-centered during operation.

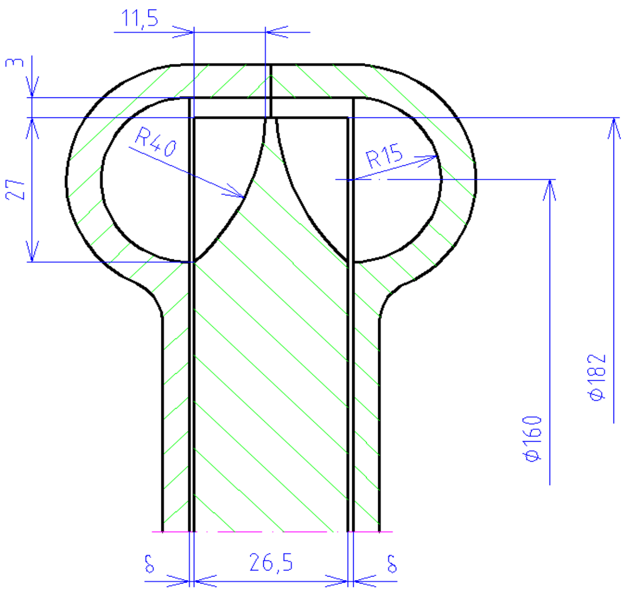

Figure 8. Dimensions of the hydraulic shape

3.2. Measurement of the characteristics of the side channel turbine

The side channel pump is measured in turbine mode. A test rig for the measurement of the energy characteristics of the side channel turbine is located in the laboratory of Victor Kaplan dept. of fluid engineering 'Figure 9 and 10'. Frequency converters are used for change of speed frequency of the turbine runner and feed pump impeller. Values of inlet and outlet pressure, torque, speed and flow rate are recorded by an industrial computer and our program, which is written in Labview.

Figure 9. Test rig

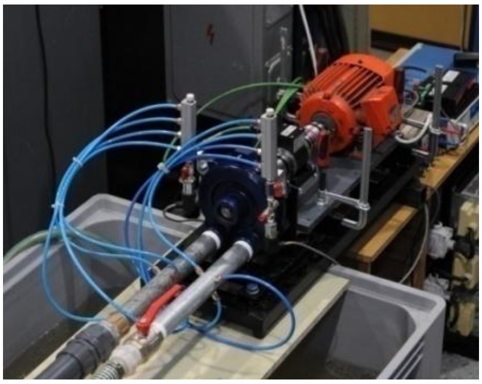

Figure 10. Turbine in the test rig

3.3. Characteristics of the turbine at constant heads with back-pressure

This section investigates the change of the characteristics of the turbine interposed in the piping system as a replacement of a pressure reducing valve. Turbine works only with a part of the pressure energy from the system. The characteristics of the turbine are measured at a constant head 15 meters and a changing speed of the runner. The change in the absolute values of the back-pressure in the suction line during the measurement is shown in the graph 'Figure 11' - $p_b = f(n_{11})$. The back pressure is not constant, but rather depends on the flow rate. Maximal reached value of efficiency under backpressure is 18,9% and 21,5% with the atmospheric pressure on the suction. Flow is maintained.

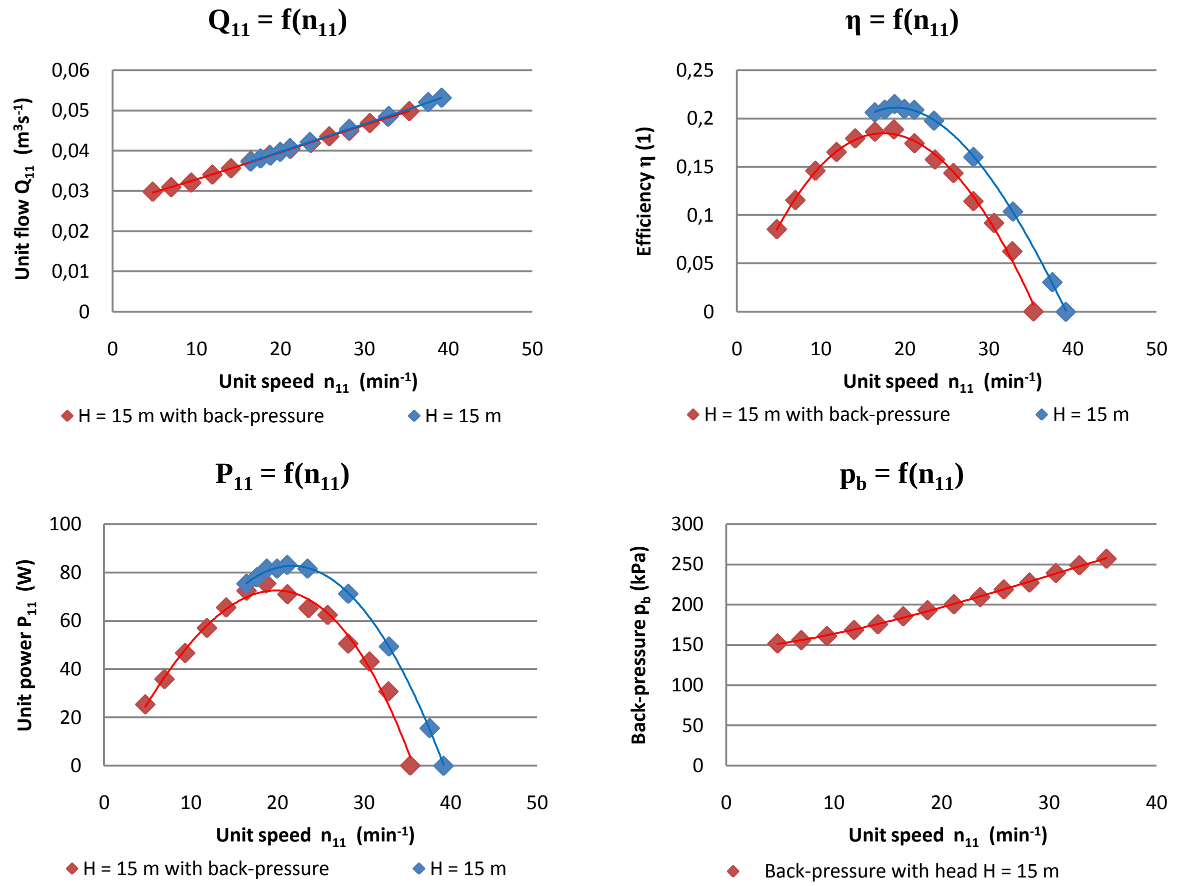

Figure 11. Turbine graphs measured with constant heads and back-pressure in suction

Characteristics of the turbine valve - during operation of the side channel turbine in the capacity of the pressure regulator is expected that only part of the pressure energy in the piping system will be used. Losses-making and flow characteristics of the side channel turbine Delavan Turbo 90 are shown in

'Figure 7'. The characteristic curve of the turbine is comparable as the curve of the pressure reducing valve.

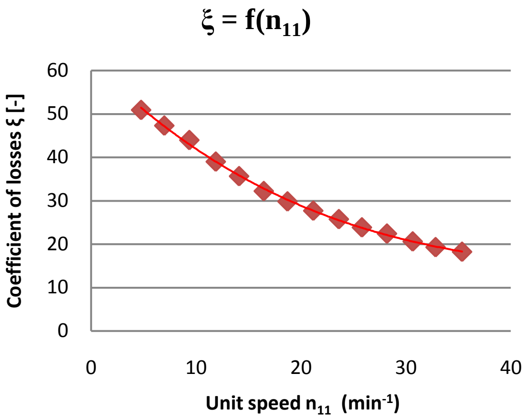

Figure 12. Loss-making characteristic of the turbine

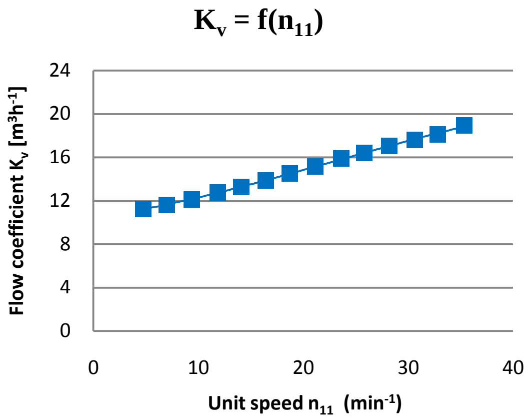

Figure 13. Flow characteristic of the turbine

4. Conclusion

In many technical solutions, it is necessary to decrease the pressure of liquids. Pressure reducing valves are normally used for this pressure reduction. However, it utilizes a considerable part of the pressure energy, which is not used, could be transformed just into electric energy. The pumping technique uses side channel pumps for pumping small quantities of liquids to large transport heights. These pumps are characterized by low-specific speed $n_s = 4 \div 40$ min^{-1} and after a small reconstruction they can be used in a turbine mode. It is possible to replace pressure reducing valves with side channel turbines. Thereby create a new kind of turbine valve with speed-controlled flow dependent on the revolution of the runner.

In order to verify the theory, a commercially produced side channel pump was purchased and used to measure turbine characteristics and verify the function of the partial recovery of energy. The efficiency of recovery is about 19% which opens a space for optimization of the hydraulic design of the turbine valve.

Replacement of the pressure reduction valve by side channel turbine is possible. Turbine valve works on swirl principle. Function of new turbine valve is verified on purchased pump measured in turbine mode. But is necessary to improve hydraulic design and increase hydraulic efficiency. According to the research is expected that custom design can reach efficiency of recovery energy about 50%. It is interesting challenge for future R&D investigation.

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