Increasing pump performance

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In systems like district heating or oil pipelines, centrifugal pumps often have to work in the low-flow rate mode due to seasonality or gradual volume increase. In such cases, an easy switch into nominal flow rate mode should be provided. But pump operation at flow-rates lower than nominal has known consequences, and less efficiency and increased noise and vibration level can make it unacceptable. Engineering a pump design for this condition is therefore quite a challenge. In this paper we present the results of our research studies, where numerical simulation with ANSYS CFX-12.0 was applied, with regard to different volute insert versions for double suction pumps with double volute casing. Numerical simulation results were then validated during full-scale field tests to allow us to select volute insert version in terms of the best pump performance.

In pipeline systems, there is often a need to operate in the low flow-rate mode due to seasonality or other reasons. When this mode lasts long enough, pipeline operators may suffer from significant losses due to low pump performance and less reliable service. In practice, replaceable low-capacity impellers are used to maintain higher performance at the required flow rate. However, use of low-capacity impellers in volute casing leads to additional hydraulic losses at the spiral volute entrance. To eliminate this drawback we found a solution in the use of diffusers for replaceable impellers, to provide flow harmonization between impeller and spiral volute in all modes, including nominal. Nevertheless, this solution leads to a considerable increase of the pump's main dimensions, because additional space (between impeller and single spiral volute) is required for installing the diffuser. For this pump type (with double volute casing) volute inserts allow high performance of a pump in the low flow-rate mode. The drawback to this solution is the use of welding during installation of volute inserts. Switching into the other flow-rate mode will necessarily mean substantial financial and time costs. Since their installation together with a rotor is preferred, these volute inserts should be easily replaceable. Presented here are the results of the research study for three different volute inserts designed for a double suction pump with double volute casing (single stage, double suction pump, double volute casing with semi-volute suction chamber). Volute insert No.2 (Fig. 1A) was made in the form of two spiral channels with the dimensions of the double spiral volute designed for nominal flow-rate and head. We assumed that this version would provide flow harmonization (between impeller and double spiral volute) and ensure minimal losses in the flow part, and their manufacturing would be much easier than conventional diffusers. We designed them according to the analysis results of the double spiral volute cross-section, cutwater location and distance from trailing edges to cutwaters.

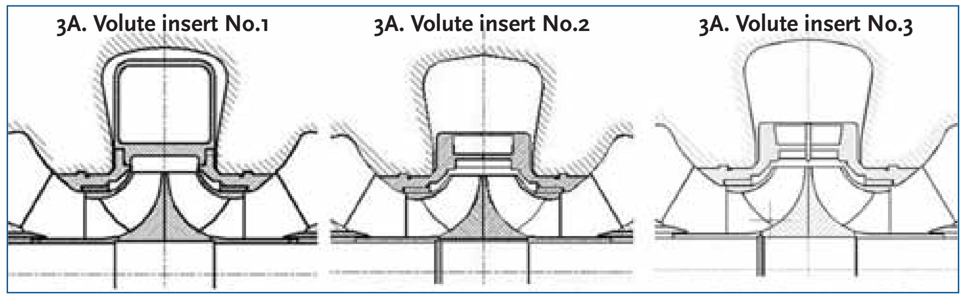

Figure 1: Pump cross-section for three volute insert versions.

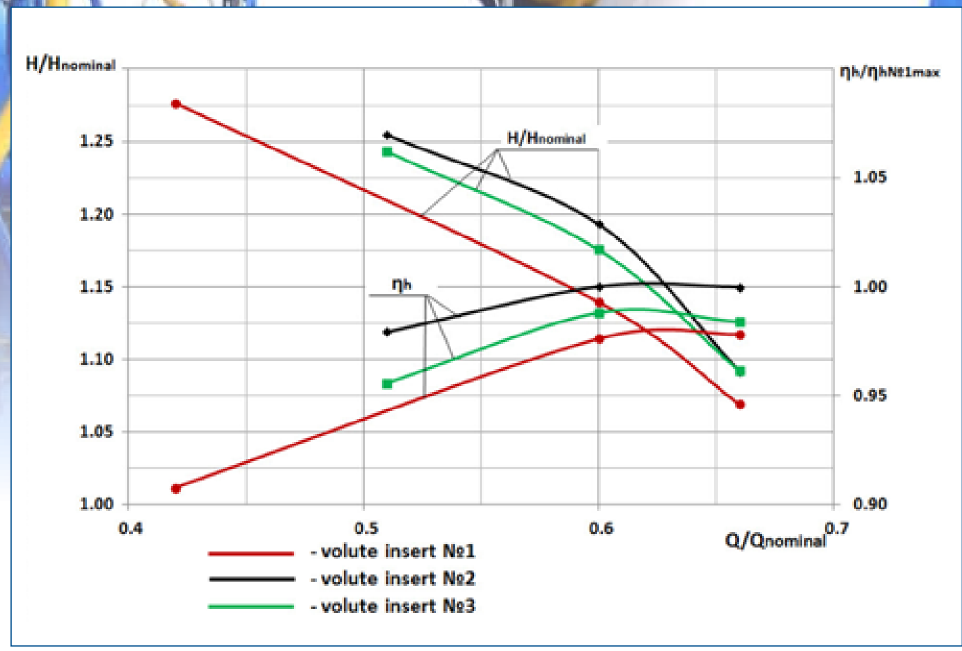

Figure 2: Pump parameters with volute insert versions.

Volute insert No.2 (Fig.1B) is made in the form of multi-channel insert. A distinctive feature is that much of it is placed in the spiral volute cavity [5]. Diffuser channel design was defined by the optimal opening angle. However, there is sudden enlargement due to the limited radial dimensions of the volute insert exit. To minimize energy loss caused by this sudden enlargement, we developed volute insert No3 with intermediate rib. Diffuser channels have been left the same as in No.2, the width in the exit being increased to ensure equivalent opening angle but this time for each half of volute insert (Fig.1C). For calculating projected main parameters (Q-H, performance) with described above flow parts we have used ANSYS CFX. Numerical grids of flow part elements have been received in ICEM CFD. The total number of nodes for a model amounted

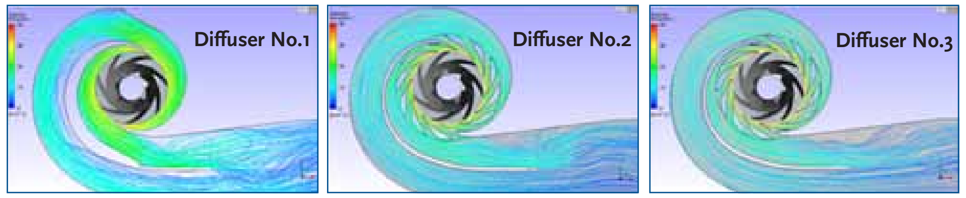

Figure 3:
Streamlines in flow parts according to numerical simulation results

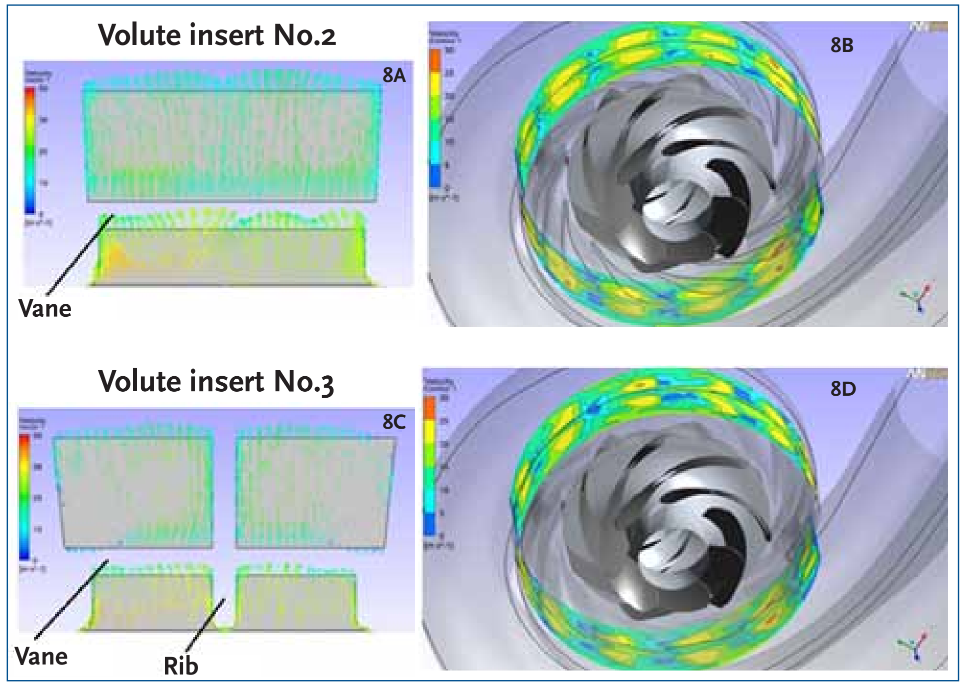

Figure 4:
Flow analysis in Volute insert No.1 and No.2 based on numerical simulation results (left – velocity vectors in the cross-section of volute insert, right - velocity distribution on the surface of diffuser channel exit)

to an average of 10,5 million. Numerical simulation was carried out in the transient type for the three modes, since state mode results were affected by the instantaneous interaction between impeller blades and stator. Numerical simulation results have shown that the above described volute insert versions ensure different levels of efficiency (Fig.2) and that volute insert No.2 is the most efficient.
Comparison of flow patterns has shown that the largest irregularity of velocities and vortex formation is observed in the case of volute insert No.1 (Fig.3). Analysis of velocity vectors distribution (volute inserts No.2 and No.3, Fig.4) showed that placing an intermediate rib made it possible to obtain a more even flow in the diffuser channels. Also, a decrease of high velocity areas can be observed at the diffuser channels exit (volute insert No3), which also ensured minimal losses at the sudden enlargement. However, the head and power of pump with volute insert No.3 remained the same as with No.2. This could be explained - the minimization of sudden enlargement loss was offset by friction losses on the walls of the intermediate rib. Numerical

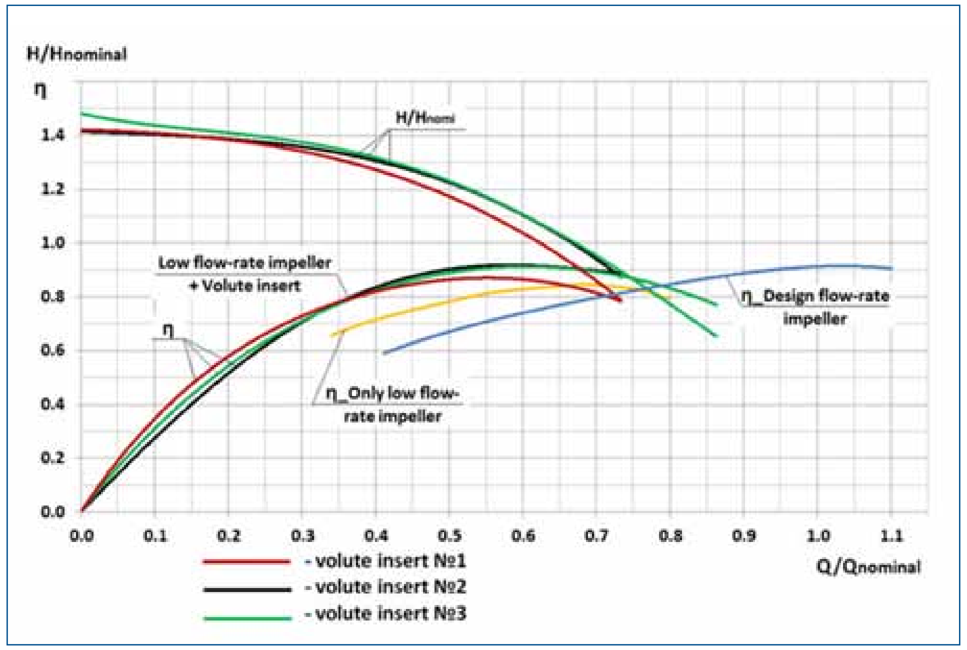

Figure 5:
Experimental performance curves.

simulation results have been verified on the testbed with all three volute insert versions (Fig. 5), and the above conclusions were confirmed.

Therefore, the results of our research study and tests have shown that the use of special volute inserts in combination with replaceable impellers ensure the high performance of a pump in a low flow-rate mode while retaining the same main dimensions (Fig. 5).

Conclusion

As the outcome of our research study, we could develop a design of volute insert to ensure the required energy efficiency and minimal occupied space for a given application and main dimension. It was clear that transient simulation (for simulating the mutual influence of impellers and diffusers) should be applied for precise prediction of main parameters (Q-H, performance) for sequentially arranged impellers and diffusers. Such a numerical experiment is effective for analyzing flow patterns, and makes it possible to optimize geometry and main dimensions in terms of providing the required performance.

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About the HMS Group

The HMS Group is a pump manufacturer and provider of flow control solutions to the oil and gas, nuclear and thermal power generation and water utilities sectors in Russia and the CIS. Their products are mission-critical elements of projects in industries and large-scale infrastructure projects in Russia, including the Vankor oil field and other pipelines projects linking Russia's core oil producing areas to export ports on the Pacific Ocean and Baltic Sea.