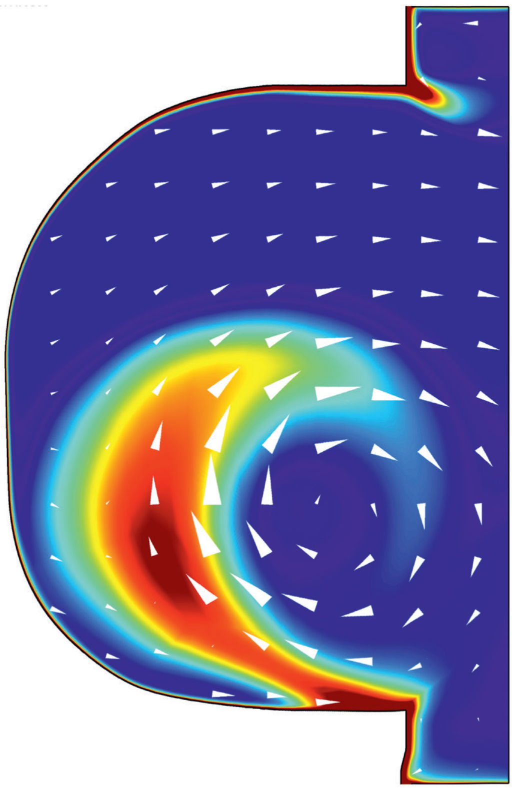
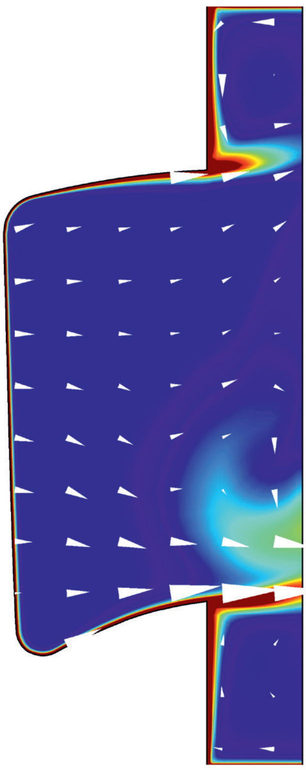
Experimental Investigations and 3D Flow Simulations of a Single-Blade and a Two-Blade Pump for the Analysis of Unsteady Characteristics and Local Losses

Steffen Melzer





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Steffen Melzer

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Berichte aus der Strömungstechnik

Steffen Melzer

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I dedicate this thesis to my parents Doris and Karl-Heinz.

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Abstract

The unsteady characteristics and local loss mechanisms of a single-blade and a two-blade pump are investigated by a combined experimental and numerical study. These pumps are designed for solid-laden fluids and clogging-prevention and thus have particular large flow channels with a weak flow guidance, which cause highly three-dimensional fluctuating flow fields and low efficiencies, so that their operation cannot be adequately described by stationary characteristics only. Thus, additional unsteady characteristics in terms of time-resolved pressure, impeller deflection and flow rate are analyzed. For evaluating the flow rate fluctuations, a new measurement method is presented based on an electromagnetic flow meter. With ensemble-averaging, interfering signals acting on the time-resolved measurement signals are filtered out. The validity of the new measurement technique is assessed by accompanied 1D circuit simulations. The two-blade pump shows a higher efficiency as well as lower pressure and flow rate fluctuations compared to the single-blade pump, which results in a significantly lower impeller deflection magnitude. For both pumps, the flow rate fluctuation amplitude is an order of magnitude smaller than the pressure amplitude. Fundamentally different unsteady characteristics are observed due to a different phasing of impeller and volute fluctuations with a local minimum at moderate part load for the single-blade pump and continuously decreasing values towards overload for the two-blade pump. No immediate correlation between time-averaged losses in terms of efficiency and the magnitude of pressure and flow-rate fluctuations is identified.

Due to the clogging-resistant impeller design, common design concepts for centrifugal pumps cannot simply be adopted and the sole evaluation of the efficiency is not sufficient for few-blade pump optimizations. Thus, a local loss analysis based on local entropy production is presented and applied to the single-blade and two-blade as well as a conventional multi-blade pump. A finite volume method and a statistical turbulence model are employed for the 3D simulations. The simulation results are validated by time-resolved measured characteristics of the pumps. A wall function for entropy production in isothermal flow is derived, implemented in the flow solver ANSYS-CFX and validated on standardized turbulence model test cases. The local loss analysis revealed distinctive pump type specific loss mechanisms in all three pumps. Due to the weaker flow guidance, characteristic loss mechanisms in the impeller have a major share in the total losses of both few-blade pumps. In contrast, the impeller losses are much less pronounced in the multi-blade pump, where volute and side-chamber losses are dominating.

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