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[Extended Abstract]

Investigation of different design methods of volutes with circular cross sections for a single-stage centrifugal pump

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Introduction

In the open literature different methods to design a volute geometry have been described well since several years, for example ECKERT [1], PFLEIDERER [2], STEPANOFF [3] or TROSKOLAŃSKI [4]. Nevertheless, there is no comparison of those design methods with respect to the pump performance known at the moment. In this paper, four different design methods of volute geometries with circular cross sections for a single-stage centrifugal pump are compared to each other according to the pump performance.

Methods

In a first step, four different volute geometries with circular cross sections have been designed by different design methods. The first volute geometry has been designed according to a given parabolic distribution of the entry flow angle α_4 at every cross section. The second one takes a given linear course of the relation A_z/R into account whereby A_z represents the area of every cross section and R represents the radius of the centre of every cross section. The third volute geometry has been calculated by design rule of PFLEIDERER [2] (constant swirl), whereas the fourth volute geometry has been calculated by design rule of STEPANOFF [3] (constant velocity). These four different volute geometries have been investigated numerically by means of 3D-CFD (Computational Fluid Dynamics) tools. For validation, the four different volute geometries have been investigated experimentally as well. To ensure the comparability of the four different design methods, every volute has circular cross sections, is used with the same impeller geometry and in addition the design of the tongue region is the same for every volute design. The design point of the impeller and the volutes is:

$$\text{flow rate } Q = 100\, m^3/h$$
$$\text{head } H = 30\, m$$
$$\text{rotational speed } n = 3000\, rpm$$

The experimental tests have been done at a new test facility at the Institute of Fluid Mechanics and Fluid Machinery (SAM) at the Technical University of Kaiserslautern. This test rig allows to perform experiments with a rotational speed up to 3000 rpm with water as working fluid. The test bench is equipped with pressure sensors to determine the pressures on the suction and the pressure side of the pump. The flow rate is determined by a magnetic-inductive flow meter which is installed at the ascending line. The torque to calculate the efficiency can be measured by means of a torque meter. Different operating points can be adjusted by means of a control valve to reduce the flow rate and a variable speed drive to vary the speed of the asynchronous motor. The volute casing of each design variant has been manufactured from polymethyl methacrylate (PMMA) and thus offers an optical access to the flow at the volute.

With these experiments the influence of different design methods of volutes on the performance of a single-stage centrifugal pump can be examined and the results of the CFD simulations can be validated as well.

The numerical model includes the inflow of the pump, the impeller with both impeller sidewall gaps and the volute with a cylindrical outflow. All meshes of the fluid regions are generated in ANSYS ICEM CFD. The numerical calculations have been done by means of ANSYS CFX using the SST (Shear Stress Transport) turbulence model and a sliding mesh at the impeller region. All fluid regions are connected via general connected interfaces. If a stationary region is connected with a rotating region, transient rotor stator is defined as frame change option. All numerical results have been averaged over 60° after two calculated revolutions of the impeller. To ensure the comparability between experimental and numerical results, the evaluation planes of the numerical model are placed just like at the test rig.

In this paper, the influence of the design methods on the performance of a single-stage centrifugal pump is shown for the nominal speed of $3000\,rpm$. Diagrams showing throttle curves and efficiency curves that have been evaluated numerically as well as experimentally are discussed. The results shown offer the opportunity to increase the efficiency of a single-stage centrifugal pump by varying the design method of the volute geometry.

References

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