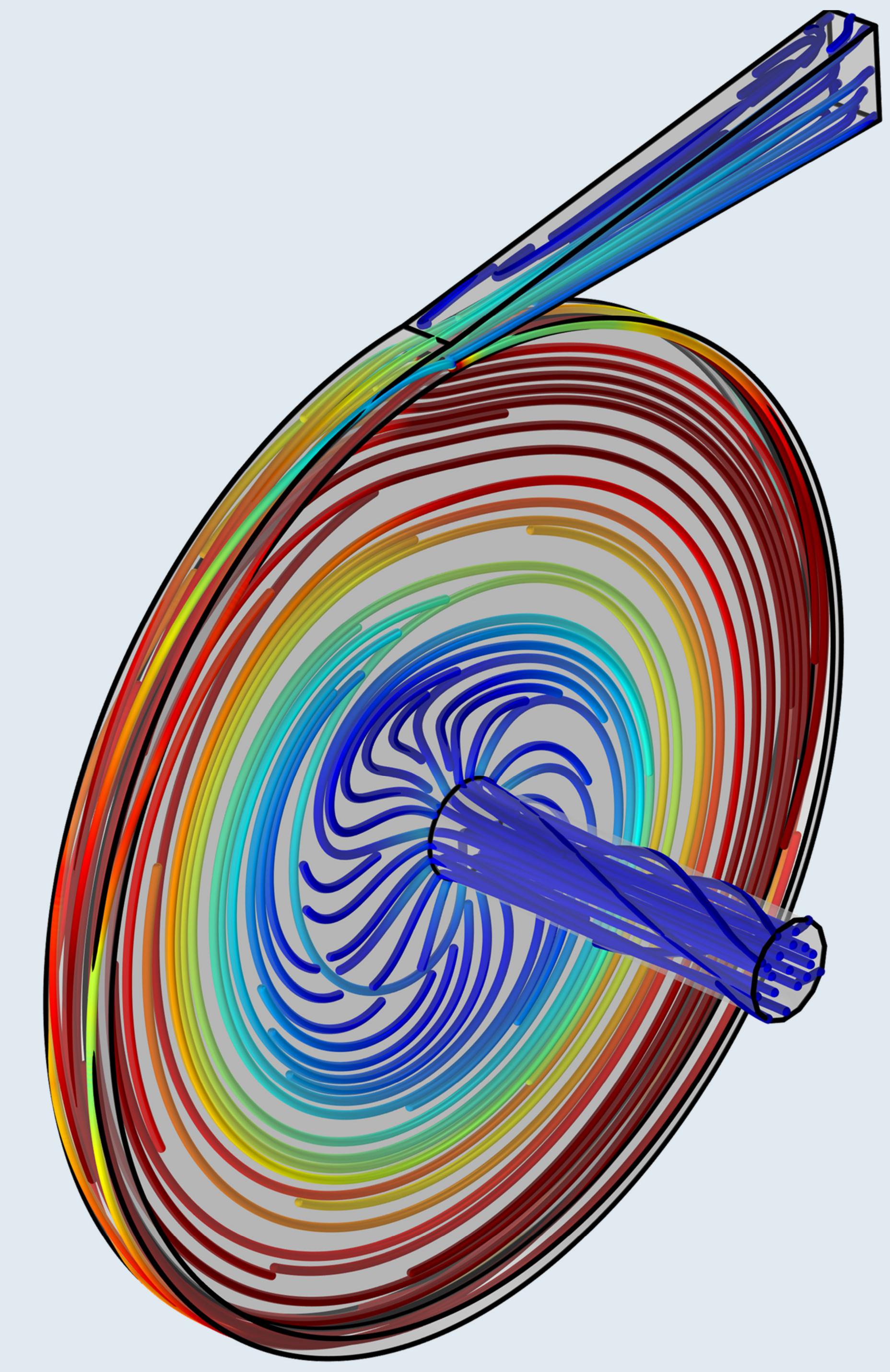

Simulation based design of a bladeless centrifugal flow compressor

A bladeless centripetal flow turbomachinery is a system with a large number of design parameters. A structural-mechanics and fluid dynamics simulation approach is utilized to model the gas flow in a principle model with the goal to determine the influence of the disc diameter and speed.

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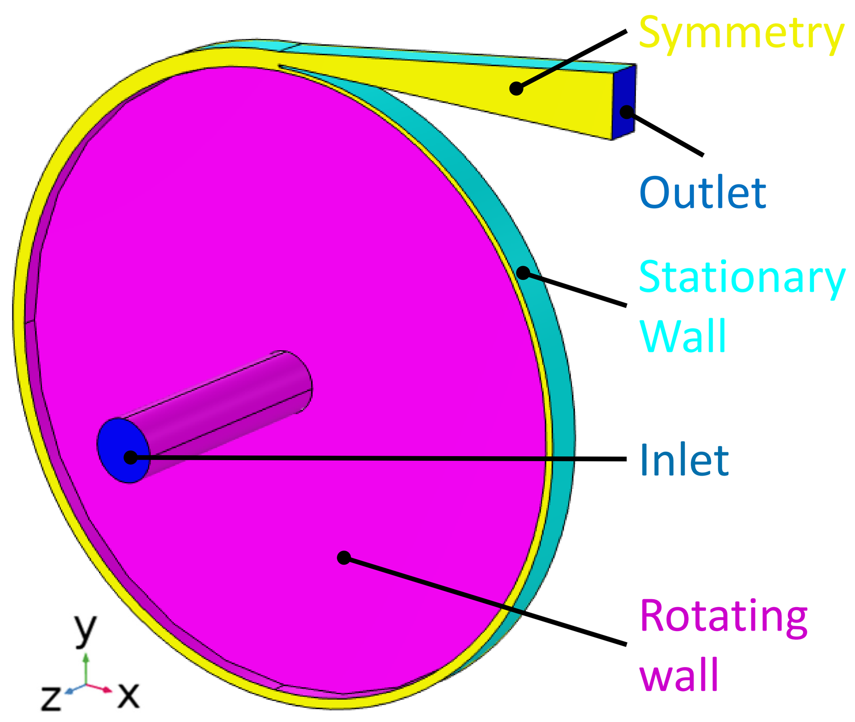
Introduction

The bladeless centripetal flow turbomachinery was invented with the aim to realize a turbine with higher efficiency and structural simplicity compared to the state of the art at that time. Unlike conventional turbines, the disc turbine does not use rotor blades. Instead, it consists of a series of thin discs arranged on a common shaft. By reversing the principle, a bladeless centrifugal flow compressor can be realized. The function of such a compressor is based on the friction between two rotating discs and the fluid (Ref. 1).

The rotation of the disc is realized by applying an electric drive and the working fluid is accelerated towards the outer edge in a narrow gap between the discs, resulting in a compression effect. An advantage is the great simplicity and versatility, which allows to transport a wide range of fluids such as gases, liquids or slurries. The compact design and low peripheral speeds result in minimal mechanical stress. Only radial and tangential flow forces act on the rotating part, eliminating any axial load (Ref. 2).



Boundary	Definition
Inlet	Pressure inlet
Outlet	Normal outflow velocity, fixed
Rotating wall	No slip; Rotation
Stationary wall	No slip, fixed
Symmetry	Slip, fixed

FIGURE 1. Left: Model geometry of a bladeless centrifugal flow compressor. Right: Definition of the boundary conditions

Methodology

In this work, a simulation based concept design for a bladeless centrifugal flow compressor is presented. Based on two different promising materials, structural mechanics simulations using the "Structural Mechanics Module" were performed to derive the interactions between the rotational speed, the disc diameter and the mechanical loads. The objective is to determine the maximum possible speed of the discs. In a subsequent simulation model, fluid-dynamic parameters such as the pressure rise were calculated by using the "CFD Module" and evaluated on the basis of the maximum possible rotation speed while varying other relevant design parameters such as disc diameter. Finally, a basic functional design for a bladeless centrifugal flow compressor is derived based on the simulation results.

Results

The maximum possible rotational speed is a critical parameter and is heavily dependent on the material properties and the selected diameter. For instance, with a diameter of 60 mm, the maximum speed achievable is 90,000 min^{-1}, while for a larger diameter of 100 mm, the maximum speed is limited to 60,000 min^{-1}.

Within the system, air undergoes a significant acceleration between the two discs, with a specified gap width of 0.8 mm. Results show, that a larger diameter and rotational speed increase the pressure. A maximum pressure of 0.9 bar could be observed for a diameter of 100 mm and a speed of 60,000 min^{-1}. As a result, a larger pulley diameter rotating at a lower speed is preferred to increase air acceleration and pressure to improve efficiency.

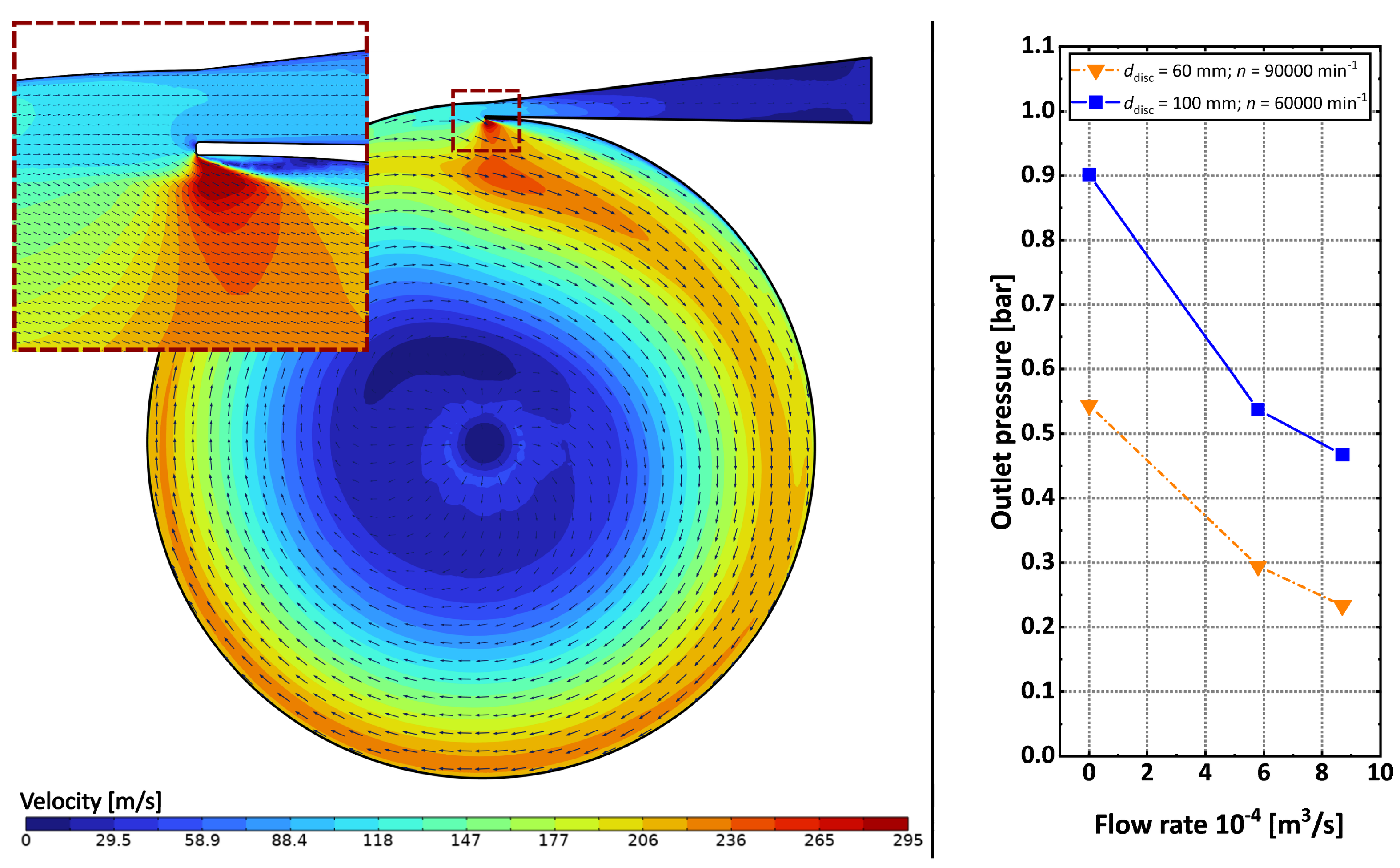


FIGURE 2. Left: Flow field between two discs (d = 100 mm; n = 60,000 min^{-1}; $\dot{V}$ = 8.7 · 10^{-4} m^3/s). Right: Pressure increase as function of the flow rate

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Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag