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Title: Numerical simulation of vortex structures in turbomachinery.

Abstract

The ability to study fluid motion by tracking the evolution of the vortex field is a very attractive and desirable research method. The fluid flowing past solid bodies such as turbomachinery stages causes rapid changes in the velocity field. This leads to the presence of transient phenomena. These non-stationary effects significantly impact the lift and drag forces of turbomachinery blades. These forces play a significant part in low-solidity turbines (conventional wind turbines and hydrokinetic tidal turbines). The lift to drag ratio is a crucial aerodynamic parameter of the turbine's kinematics. Appropriate control of vortex phenomena makes it possible to improve blading system performance. It translates directly into the change in the circumferential force acting on the rotor. The increase in the aerodynamic performance of an airfoil improves the power coefficient of the fluid and allows it to approach the Betz limit.

Non-stationary effects also play an essential part in classic multi-stage machines used in power plants and aviation. Today, the mutual interaction of blading system stages of rotating machines is an important area of interest for many researchers.

It was decided to investigate the possibility of the control and behavior of vortex structures around the profile of a turbine blade. For this purpose, an in-house code has been developed to solve the vorticity transport equation. This equation is solved using the vortex particle method, which due to the viscous splitting algorithm, allows solving advection and diffusion quationsion in two steps. The penalization method allowed to simulate the flow past a complex shape bodies. In this method, the solid and the liquid are treated as porous media with different permeabilities.

This work presents the implementation of the discrete vortex particle method, which, with the aid of parallel computations and the use of high-order compact schemes, is characterized by high robustness and improved accuracy. This allows for precise tracking of the vorticity field when flowing around bodies with a high Reynolds number. The code was used to determine the effect of the vortex trapping cavity on the pressure side of the airfoil on the behavior of the nearby flow field. The cavity is designed to reduce the recirculation zone's negative impact and limit the intensity of the vortex structures in this zone. Numerical investigations were supplemented with water tunnel flow visualization. For this task, fluorescent dyes were used. Additionally, the thesis included the periodic flow case of the T106A low-pressure, high-solidity turbine cascade.

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