New modeling approaches for the interaction between drops and blades in a compressor cascade

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Long Abstract

Introduction

The injection of water sprays into the compressor inlet of stationary gas turbines, also called high-fogging technique is used to rapidly increase the gas turbine's power output. This effect can for example be used to overcome fluctuations appearing in power supply systems, caused by today's increased use of wind and solar energy. The water injection results in an evaporative cooling before and within the compressor, hence the compression work is reduced and the mass flow is increased. A significant portion of the water droplets can pass into the cascade and leads to interactions between droplets and blades, depending on the operating conditions and fineness of the spray. For the application smaller droplets are favorable. Reasons are the faster evaporation and the better follow-up behavior in the accelerated flow. Nevertheless larger droplets (~D > 20 μm) appear with higher injected mass flows due to droplet dynamics. These droplets do not follow the accelerated gas flow leading to erosion problems and the formation of a fine spray at the leading edge of the blades. Beyond that a distinct part remains on the blades' surface and forms thin films or streaks which propagate along the blade surface to the trailing edge. In the shear layer disintegration takes place and forms drops that are injected into the flow field. The significance and the interest in this process becomes reasonable in the knowledge of the possible formation of larger droplets that could enter the following stage leading to the mentioned problems again. The important parameters for the modeling of the disintegration process are the film thickness and its velocity.

1. Methods

Numerical investigations on the subject are essential because it is extremely difficult to measure the wall film properties at real flow conditions. Using an Euler-Lagrange approach also the small scale processes of single droplets are accessible within the numerical study of the whole cascade flow. The behavior of the droplets is computed in a Lagrangian framework, solving the equations of motion and the resulting trajectories. The flow field of the cascade is computed by solving the Navier Stokes Equations. If a droplet trajectory hits a blade the developed splashing model [2] is used to predict the ejected secondary droplet diameter. The droplet diameter spectrum in front of the blades' leading edge, that strongly influences the flow field close to the blade can be evaluated by applying this to a large amount of droplets. Furthermore, the model facilitates the quantification of the specified film properties.

In [3] a model for the droplet wall interaction was developed for a simple flat plate test case that was refined in [2] and applied for a compressor blading. The wall interaction model describes the necessary boundary conditions for the transition from the Lagrangian to the Eulerian method. These boundary conditions are the key point of the model and reasonably an accurate modeling is essential. The presented model in [2] describes one approach to model the occurring parameters, which have a strong influence to the solution. In the current work a parameter study has been executed to evaluate the influence of the single parameters.

Another possible improvement to the prediction of the wall film is the further investigation of the impacting droplet diameter spectrum. Until now the critical diameter of these larger droplets is associated with about D > 20 μm. This estimate follows from dimensional considerations and the solution of the equation of motion and is reasonable if the relaxation over an entire stage is regarded. Local velocity gradients immensely reduce the diameter of droplets which are able to fully adapt to the flow.

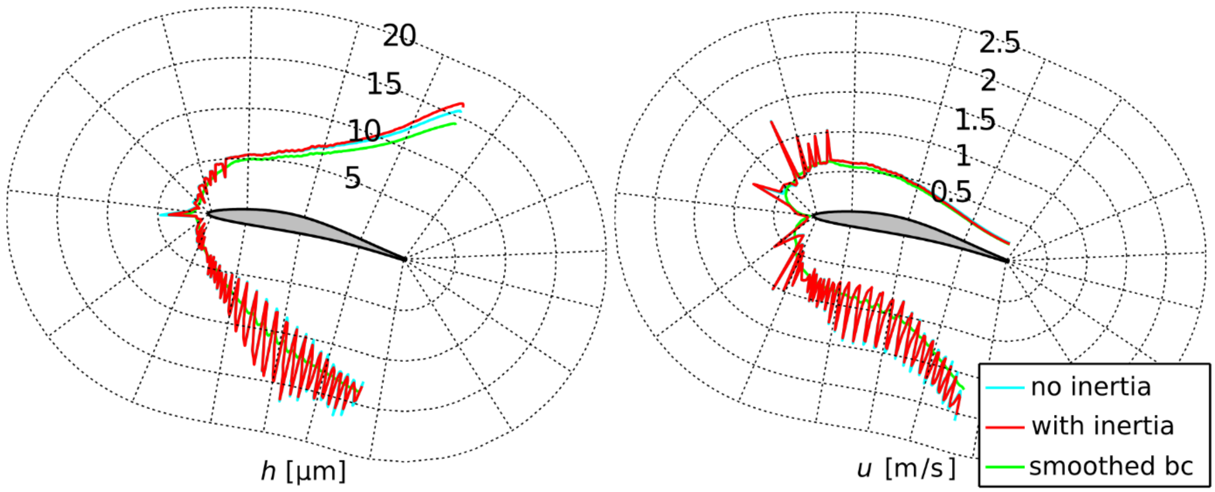

Figure 1. Wall film properties for different modelling approaches [2]

Within the parameter study the model is applied to the blade geometry of a transonic cascade flow field that was measured by Eisfeld and Joos [1]. With the wall interaction model the wall film thickness as well as the wall film velocity can be computed depending on the inflow conditions and the incoming droplet diameters. Preliminary results for three different modeling schemes are shown in figure 1. Further possible modeling approaches are considered and are validated with experimental data in the full paper.

The full paper comprises the results for the critical droplet diameter and describes in detail the significance of each single parameter of the wall film model including an elaborate comparison. Additionally the application to the mentioned compressor blade geometry [1] is presented together with the resulting wall film properties in dependence of the inflowing conditions.

References

[1] T. Eisfeld, F. Joos, Two Phase Flow Phenomena in a Transonic Compressor Cascade, *ASME,* GT-2009-59365.

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