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NUMERICAL SIMULATION OF TWO-PHASE FLOW IN A LOW PRESSURE STEAM TURBINE STAGE

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Abstract: *The paper deals with the numerical solution of two phase unsteady flow in a steam turbine stage performed by in-house numerical code. The main issues related to the flow model, numerical method and problem formulation are presented. The effect of droplet size of incoming wet steam is discussed.*

Keywords: ***Finite volume method, turbine, nucleation, wet steam, CFD.***

We consider the flow of steam with velocity, pressure and temperature corresponding to the conditions within the low pressure part of a steam turbine. The rapid expansion of steam leads to non-equilibrium phase change, i.e. the condensation appears when the steam temperature drops sufficiently below the saturation temperature (typically $30 - 40\ K$). We consider the liquid phase in the form of high amount of small spherical droplets dispersed in vapor and having the same velocity as the vapor. The flow model is based on the conservation of mass, momentum and energy for the mixture and the transport equation for the mass fraction of liquid phase. Such kind of model, known also as 'mixture model', is commonly used, e.g. Dykas et al (2003), Young (1992) or Šejna and Lain (1994). In reality there is a whole spectra of droplet sizes in the elemental volume of mixture. Flow models are mostly based on the average radius approximation, e.g. Dykas et al (2003). We consider three additional transport equations for the moments according to Hill (1966) to obtain higher precision of average droplet size prediction.

The flow model includes convection, nucleation and droplet growth phenomena, which have very different time scales. Current numerical method is based on the splitting method of Strang (1968), where each phenomena is treated by individual numerical method. Current numerical method has been verified for the case of steam flow in the Barschdorff nozzle, for details see Halama et al (2011). All cases have been chosen to have steam temperature slightly below saturation temperature and zero wetness at the inlet, nucleation then appeared inside the domain. Recent work has been aimed at the case of flow with nonzero wetness at the inlet. Since it is practically impossible to get reliable information about the droplet size structure of incoming steam, some basic numerical study for case of flow in a nozzle has been performed. The test have shown, that too small (under-predicted) size of droplets at the inlet means that secondary nucleation is hardly noticeable, since the inflow vapor contains too many droplets. The droplet growth is negligible, if the size of droplets approaches the critical radius. If we consider bigger droplets at the nozzle inlet, then droplets gradually grow and the sub-cooling is small, so there is no secondary nucleation. The big droplets (over-predicted size) at the inlet have relatively small total surface of droplets, so the droplet growth is small. Secondary nucleation generates the group of small droplets, which are then averaged with big droplets from the inlet and resulting average size is no more able to represent the droplet size spectra. Studied cases have referred to the considerable sensitivity of condensing steam flow model on the structure of liquid phase at the inlet. Therefore one has to be very careful with the estimation of inlet boundary conditions as well as with conclusions about results of numerical simulation.

Last part of the paper presents the first results of unsteady stator-rotor interaction with the non-zero wetness at the inlet. Initial computations have been performed for inlet boundary conditions with under-predicted size of droplets. This case yielded solution with strong oscillations. The oscillations have been

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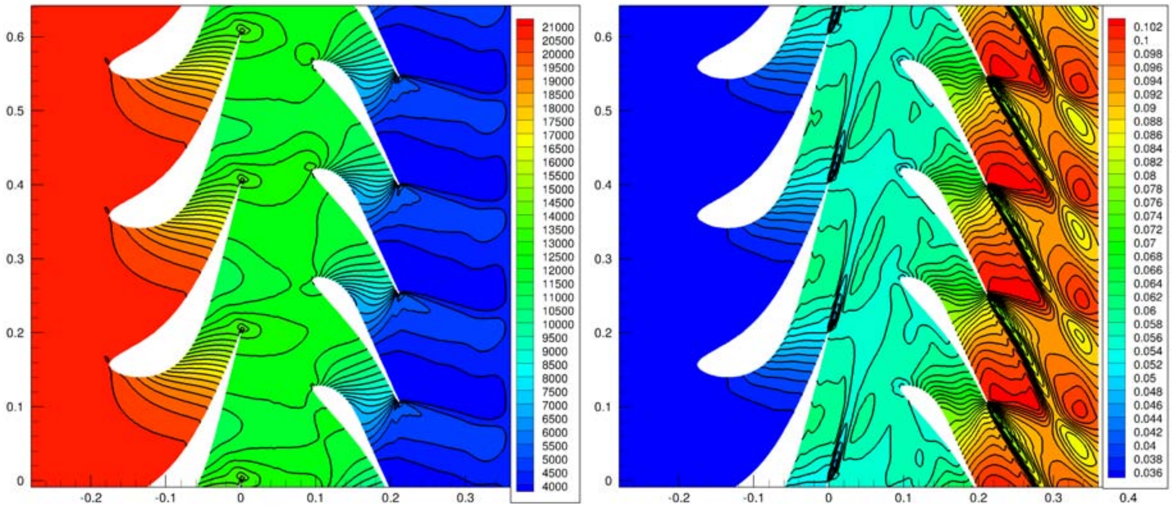
partly removed by the regularization of droplet growth model. It was finally found, that oscillations are forced also by 'too small' size of incoming droplets. Therefore we have modified the inlet boundary condition to have 'bigger' droplets. The Fig. 1 shows the example of instantaneous contours of pressure and wetness for the later case.



(a) pressure (b) wetness

Fig. 1: Instantaneous contours of flow field.

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