Journal of the Technical University of Gabrovo

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MODELING THE AERODYNAMICS OF THE BLADES OF ENERGY STEAM TURBINES

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ARTICLE INFO

Article history:
Received 30 August 2019
Accepted 20 November 2019

Keywords:
steam turbines, steam turbine blades, solid-state turbine models, aerodynamics at supersonic speeds

ABSTRACT

In this paper, a research was conducted of experimental studies for real blades and CFD modeling of the blades of low pressure steam turbines. To model CFD, developed by solid-state models of blades of a special design are used (with a "back" profile curved against the flow and a thickened outlet edge). The CFD model includes a package of three blades which are similar real blades. Studies are conducted for three gas inlet angles 26°, 41°, 61°. An analysis of the experimental data and the results of CFD modeling of gas flow shows that gratings of a special design have small energy losses at high supersonic speeds. In terms of efficiency, these gratings are superior to traditional gratings by providing continuous flow by large Mach numbers. The use of special grids is rational in the case of turbine operation under variable operating conditions. The developed CFD model can be used as an element in larger models of energy steam turbines.

INTRODUCTION

In powerful energy steam turbine units, the operation of low pressure turbines largely determines the efficiency of the entire installation.

A special place in the design of low-pressure turbines is occupied by the last levels. When creating them, it is necessary to solve a complex set of problems. These problems include: the maximum dimensions of the blades; the complex nature of the flow at high supersonic speeds; variable mode of operation. This implies the need to address the inextricable unity, of both special structural and technological issues and aerodynamic problems.

The difficulty in solving aerodynamic problems in this regard is determined by the need to create economical last-stage blades, streamlined with Mach numbers of 2.0 or more, which is typical for modern conditions and is especially important for creating powerful steam turbines in the future.

Improving the design of profile blades for the last levels can lead to the achievement of goals on the basis of a detailed analysis of the flow structure during the flow around the blades.

A number of studies have been devoted to studying the influence of various geometric and regime parameters of gratings on the nature of the flow in them [1].

Nevertheless, further, more in-depth studies are needed. For example, the flow around the profiles of the blades at large angles of rotation of the flow in the lattice at supersonic speeds needs further detailed study.

The profiles of such gratings, as a rule, are characterized by a large curvature of the rarefaction side in the «throat» region (minimum passage section between the profiles in the channel).

When designing new gratings, all aspects related to the two-dimensional character of the passages in the «throat» region are not taken into account.

For research in the channels of the grid, a special aerodynamic bench is used, in which the speed and pressure of the gas passing through the channels of the gratings are recorded [1].

Modern software systems allow you to create three-dimensional solid-state models of turbines and fluid flows models using computer simulation [2].

To verify the adequacy of the results obtained in computer modeling, it is rational to bring the results in line with the results obtained on computer models and an aerodynamic bench [3].

EXPOSITION

For computer simulation of gas flows during the flow around gratings, forms are used in which three-dimensional models of gratings of two types are used: with a straight back (Fig. 1) and with a curved back (Fig. 2).

The results of experimental studies in the aerodynamic bench, speed and pressures in the channels of the coupled and working gratings of steam turbines showed a significant effect on the energy loss during their flow around (Fig. 3 and Fig. 4) [4].

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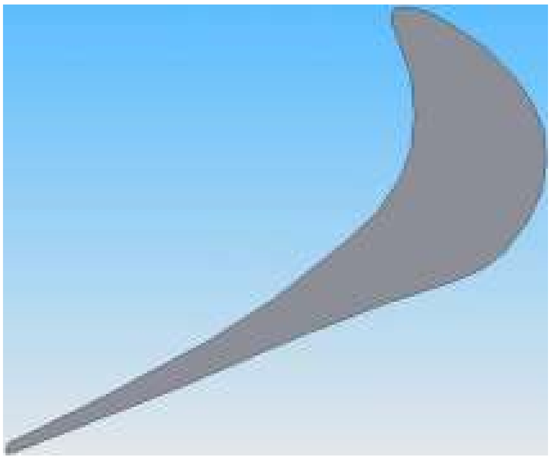

Fig. 1. Straight-back blade profile

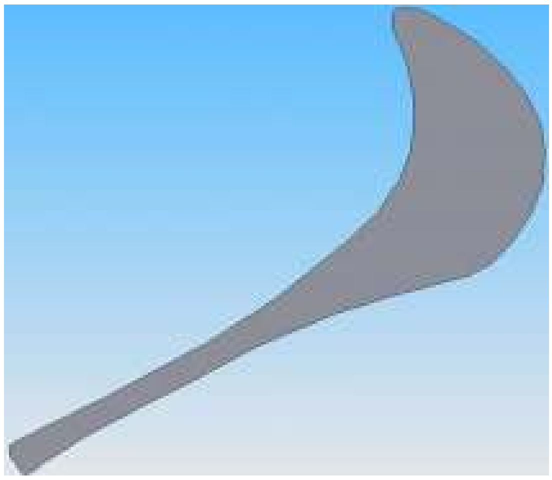

Fig. 2. Back concave blade profile

Fig. 3. The fluid flows blade profile with a straight back on the aerodynamic stand at M = 1.32

Fig. 4. The fluid flows in back concave blade profile on the aerodynamic stand at M = 1.32

An analysis of the flow pattern (Fig. 3, Fig. 4) shows that the critical point on the convex side of the blade (rarefaction side) at supersonic speeds extremely offset in depth into the channel, and towards flow. This phenomenon, with a significant curvature of the rarefaction side in the "throat" region characteristic of the working blades of the last stages, should be taken into account when profiling.

The jump in the flow compaction resulting from the summation of compression waves and reflections from the profile adversely affects the boundary layer, causing an increase in energy losses due to friction [4].

Thus, we can conclude that in the gas passages (Fig. 3) on the blade profile with a straight «back» there are increased energy losses, which is associated with the presence of gaps in the "back" of the profile.

The efficiency of blade profile using for supersonic speeds fluid flow can be enhanced by special profiling.

This profiling involves a smooth deviation of the rarefaction side of the profile against the flow and the formation for this reason of a relatively thicker output edge (Fig. 4).

Such blade profile smoothly fluid flow at high supersonic speeds, are much less sensitive to variable modes of the last stages of the turbine and to changes in the shape of the grating and profiles, compared with expanding blade profile.

For plates with such a profile, the flow occurs without separation of the flow from the “back” of the profile at high supersonic speeds. They are much less sensitive to variable operating modes of the last stages of the turbine and to changes in the shape of the lattice and profiles, compared with expanding blade profile.

Computer modeling of the air flow on the blades with a “straight back” and a “convex back” was carried out by simulating the movement of air with a speed of M = 1.32 – the rate of exit of the flow from the lattice profiles (as in a full-scale experiment).

Flow modeling was carried out as an external hydrodynamic problem. The blades model was placed in a virtual experimental stand with a limited computational domain.

Visualization of computer simulation of air flows for both blade designs at an inlet speed of M = 1,32 is shown in

Fig. 5 («straight back» blade) and Fig. 6 (scapula with a "concave back").

An analysis of the computer simulation of the flow around at supersonic speeds of entry into the virtual stand showed that at the surface of the scapula the speed is significantly reduced due to the interactions of the scapular wall and flow. Under the scapula, a swirling flow forms in both structures (Fig. 5, Fig. 6).

To study the gas velocities at the cut of the blade, patterns of the distribution of velocities in the sections of the blades at the cut were formed (Fig. 7 and Fig. 8).

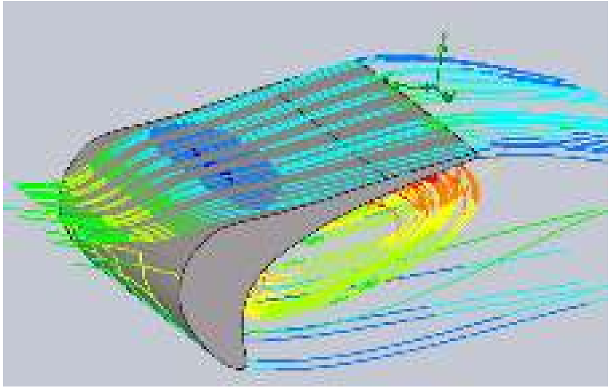

Fig. 5. Modeling the velocity flow for blade with a blade with a "straight back"

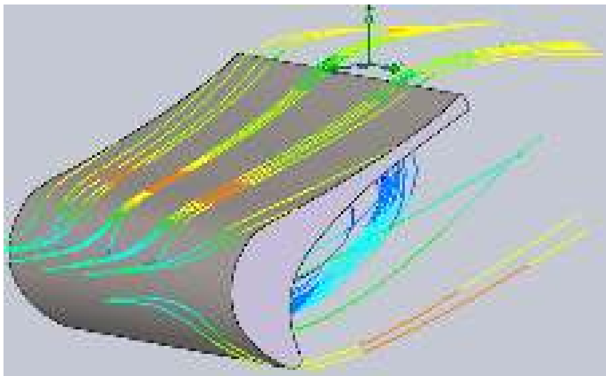

Fig. 6. Modeling the velocity flow for blade with a "concave back"

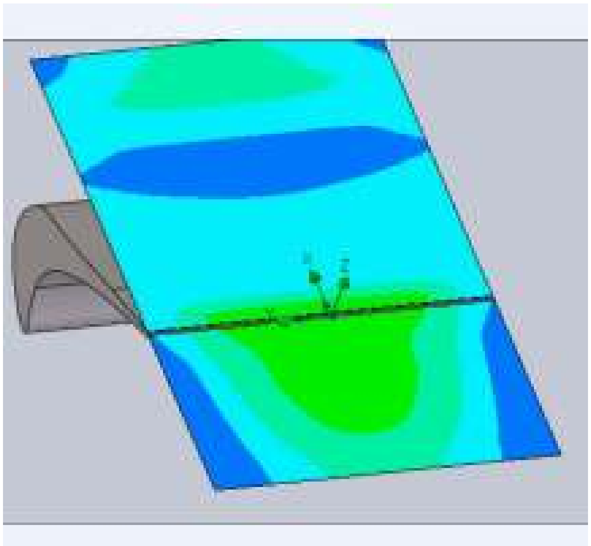

Fig. 7. Pictures of the distribution of speed in cross section on a slice for a blade with a "straight back"

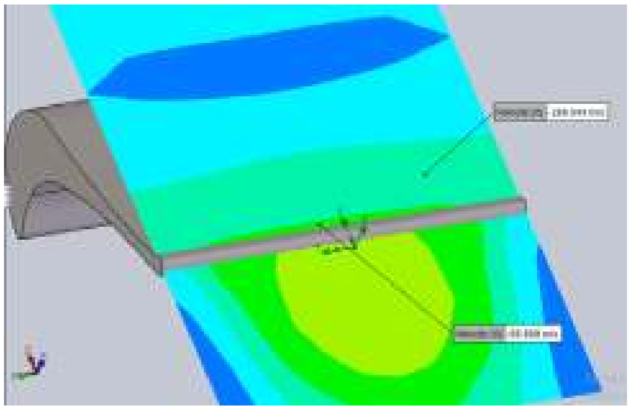

Fig. 8. Pictures of the distribution of speed in cross section on a slice for a blade with a "concave back"

Analysis of the patterns of velocity distribution allows us to determine the zone of increased velocity, the zone of separation of the flow from the "back" of the scapula.

CONCLUSION

Summing up, we note that the performed studies of blades with a "concave back" profile bent against the flow in an oblique section and a thickened outlet edge show that this type of lattice is characterized by a moderate level of energy loss at high supersonic speeds.

In terms of economy, these blades are superior to blades with a tapering channel between the profiles of the usual type (Fig. 9).

If we take into account that in this case the blades with a "concave back" flow around without separation at large values of the Mach number, then their use can be considered rational in those cases when it is impossible to use gratings with an expanding channel between the profiles.

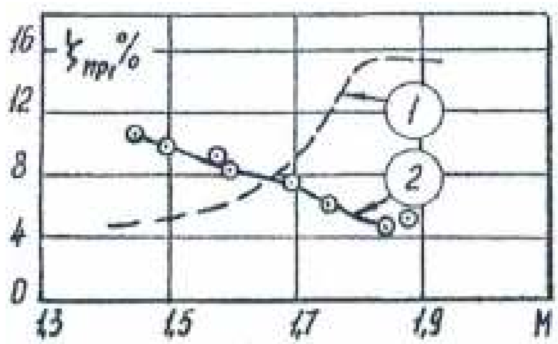

Fig. 9. Dependence ξnp=f(M) for blades with a "straight back" (1), and a "concave back" (2)

A numerical study of the distribution of gas velocities on turbine blades of different designs will allow us to analyze the flow process in order to reduce energy consumption.

The model helps to quickly and clearly simulate the movement of air flow at various speeds. Thus, the model can be used to optimize the design of the blades of energy turbines.

The developed model can be used as a separate modeling block in larger models of energy turbines.

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