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Influence of the Conditions for Coupling of the Shrouds on the Static Stress State of Blade Rings

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Abstract: The paper presents results of computational experiments on the determination of the influence of the contact surface orientation for two types of shrouds on the static stress state characteristics of the turbine rotor blades.

1. Introduction

Flange shrouding of rotor wheels, being an efficient design and manufacturing solution for reducing the level of resonant vibrations in rotor blades, is widely used in current turbomachinery structures to improve their reliability and serviceability. This is achieved by integration of blades into a system or packages that are closed to a circle.

The analysis of the investigations involving the determination of the influence of design and manufacturing, as well as operational, factors on the characteristics of the stress-strain state of turbine rotor blades with different types of shrouds shows that at present, there are no generalizing regularities in the influence of their parameter, such as the orientation of the contact surfaces, that is defined by the angle of their inclination α to the rotor wheel plane of rotation, as illustrated in Fig. 1 where N is the resultant of the normal forces acting on the contact surfaces.

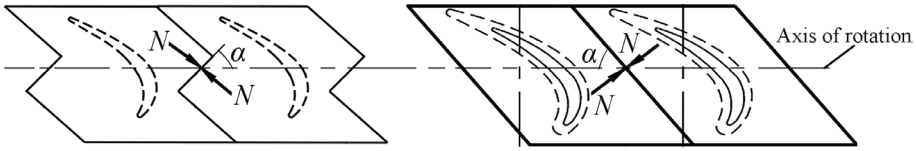

Fig. 1: Schematic of the interaction of Z-shaped (a) and straight (b) shrouds

In view of the above, the aim of the present work is the computational determination of the influence of the angle of inclination α of the contact surfaces of specific types of shrouds on the static stress state of rotor blades.

2. Object of investigation and its simulation

Two blade rings, the blades of which have Z-shaped and straight shrouds, were selected to perform the computational experiments.

The considered blade rings are the systems with a cyclic symmetry, in which the coupling of blades is due to their contact interaction along the shrouds. In this case, in performing the computational experiments, we can confine ourselves to the consideration of one cycle of the blade row with the appropriate boundary conditions [1].

To generate the finite element (FE) model of the blade, the 8-node finite element SOLID 45 was used exhibiting a satisfactory accuracy and high calculation speed [2].

The simulation of the contact interaction along the shrouds was carried out using the procedure the main provisions of which are described in [2]. The rigid attachment of the blade root in the disk groove was taken as the boundary conditions.

3. Results of the computational experiments

A comprehensive set of computational experiments has been performed involving the determination of the influence of the angle of inclination α (in the range of its variation from 45 to 60°) of the shroud contact surfaces on the static stress state characteristics, for which the contact pressure P_{max} along the shrouds and the stress intensity σ_i in the shroud and blade airfoil portion determined using the below formula were selected:

$$\sigma_i = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2 - \sigma_1\sigma_2 - \sigma_2\sigma_3 - \sigma_3\sigma_1}\,, \tag{1}$$

where σ_i (i = 1, 2, 3) are the principal stresses.

Based on the obtained results of calculations, the diagram of the maximum values of the selected characteristics *vs*. the value of the angle of inclination α of contact surfaces was plotted as illustrated in Fig. 2.

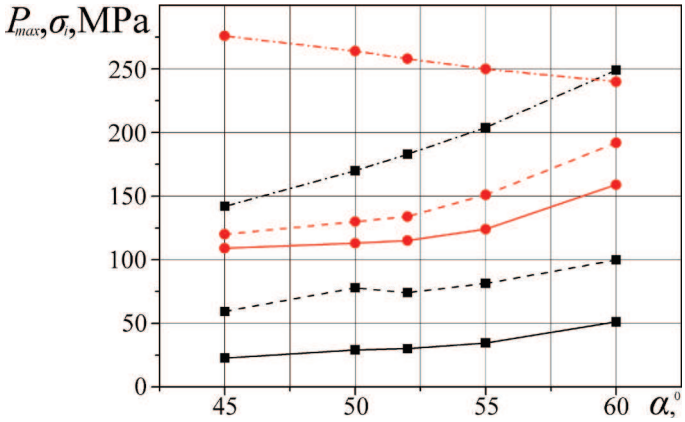

Fig. 2: Diagram of the maximum values of the contact pressures (solid line) and the stress intensity in the shroud (dashed line) and the blade airfoil portion (dot-and-dashed line) versus the value of the angle of inclination α of the contact surfaces to the rotor wheel plane of rotation for blade rings with a Z-shaped (•) and a straight (■) shrouds

Based on the analysis of the presented results of calculations, the following conclusions can be drawn:

1. Irrespective of the type of the shroud coupling, the values of the contact pressure and the stress intensity in the shroud increase in the whole range of variation of the angle of inclination α of the contact surfaces.

2. In the blade airfoil portion with a straight shroud, the values of the stress intensity increase, whereas in that with a Z-shaped shroud, they decrease with increasing angle of inclination of their contact surfaces.

3. As a whole, a Z-shaped shroud is responsible for the increase in the static intensity of blades as compared to that in the blades with a straight shroud.

References

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