

Fig. 1 Turbine rotor displacement (a, b) and dynamic stresses (c) fields. Harmonic index $k = 0$, vibration frequency $f = 537.06$ Hz

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THE MODERN SINGLE SHAFT MARINE GAS TURBINE ROTOR THERMAL STATE

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Abstract. The paper outlines a finite elements refined mathematical model of the thermal state of modern single shaft gas turbine engine that can be used in ground or floating power plants. The mathematical model is based on special finite elements of hexagonal type. On the base of the developed mathematical model the turbine rotor temperature field was found and experimentally verified. Using the results of temperature field calculation the rotor thermal deformations and stresses have been found too. The obtained results could be used in further studies of the turbine rotor stress-strain state and fatigue strength.

Key words: Gas turbine rotor, thermal stresses, temperature field, refined mathematical model, finite elements method.

The *research object* is the heat exchange between the turbulent working flow and the solid bodies, forming the turbine rotor. The whole rotor should be considered as an assembly of three impellers, connecting together by means of a shaft. Each impeller also is an assembly that consists of

the disk and working blades of the same shape and geometric characteristics. The *research subject* is thermal stresses and thermal deformations of the turbine rotor, caused by the heat flux from the turbulent working flow to the solid bodies.

Thus the aim of the research is to develop a refined mathematical model for calculating the temperature field of the gas turbine rotor and caused by it rotor thermal deformations and thermal stresses.

- To achieve this aim, the following tasks must be solved:
- Develop a refined mathematical model for determining the rotor field of temperature on the base of FEM and its experimental verification;
- Determine the temperature fields on the surface of the impellers and the whole rotor;
- Determine the rotor thermal stresses.

As the stationary coordinate system, the Cartesian right-handed xyz coordinate system with the center at point O located on the gas turbine engine axis is taken. The x axis is perpendicular to the turbine axis, and the z axis coincides with this axis (Fig. 1). The coordinate system rotates together with the rotor at constant angular velocity Ω .



Fig. 1. Gas turbine rotor in the Cartesian right-handed coordinate system.

The field of the designed gas turbine rotor thermal stresses can be represented by the following matrix equation [1]:

$$\{\sigma_T\} = \begin{Bmatrix} \sigma_{xT} \\ \sigma_{yT} \\ \sigma_{zT} \end{Bmatrix} = [D]\{\varepsilon_T\} \quad (1)$$

where $\{\sigma_0\}$ – the thermal stresses matrix-vector; σ_{x0} , σ_{y0} , σ_{z0} – the thermal stresses vector projections on the x , y , z coordinate axis; $[D]$ – elasticity matrix of the turbine rotor material; $\{\varepsilon_0\}$ – thermal deformation vector.

The vector of the rotor thermal deformation is represented by the eq. (2) [2, 3]:

$$\{\varepsilon_T\} = \begin{Bmatrix} \alpha T_x \\ \alpha T_y \\ \alpha T_z \end{Bmatrix} \quad (2)$$

where α – thermal extension coefficient of the rotor material; T_x , T_y , T_z – the rotor temperature field projections on the x , y , z coordinate axis.

Components of the matrix $[D]$ as well as the coefficient α should be taken for the specially developed high-temperature nickel-titanium alloy.

Thus on the base of eq. (1) and eq. (2) we see that solution to the turbine rotor stress-strain state problem depends on the correct finding of the rotor temperature field.

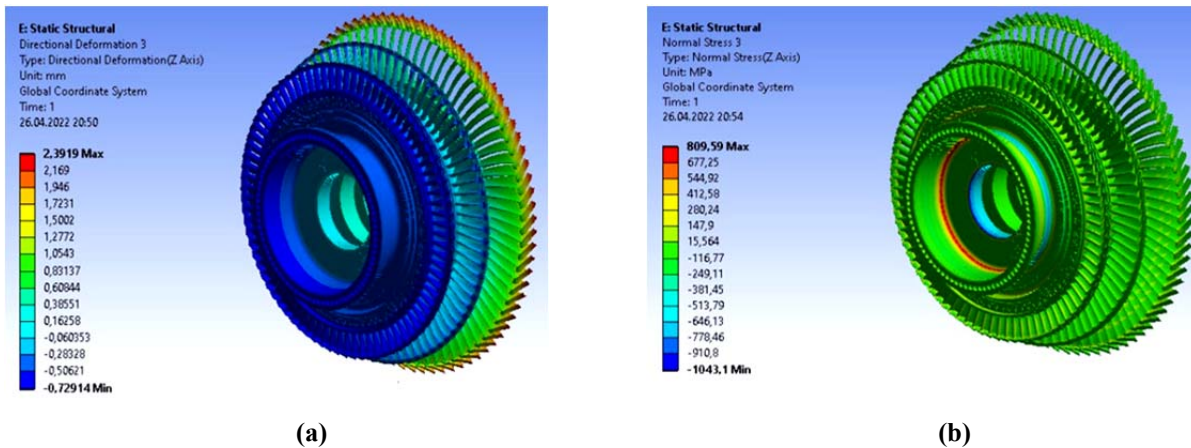


Fig. 2. Turbine rotor thermal deformations (a) and thermal stresses (b) of turbine rotor

Analyzing data represented on the fig 2 we can see that the highest thermal deformations are in the x and y coordinate axis directions. Deformation in z axis direction is much less in comparison with x direction and increases from the first impeller to the third. It can be explained by taking in consideration the rotor rotation that causes centrifugal force. Thus the third impeller blades according to their geometric characteristics are more malleable than the first impeller blades.

Normal stresses, caused by the influence of heat flux and centrifugal force are much bigger in the xy plane than in z axis direction. They are caused by a sharp temperature gradients between the blade and the disk for each impeller. Further more the drop of thermal stresses is present even between the different parts of the blade, because the blade feather peripheral part is hot up more than the blade root part.

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ДИЗАЙН ПРОПУЛЬСИВНОГО КОМПЛЕКСУ В АВТОНОМНИХ ПІДВОДНИХ АПАРАТАХ

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Анотація. Незважаючи на те, що океани покривають дві третини світу, інтерес до морських технологій, пов'язаних з їх вивченням відставав у порівнянні з дослідженням іншого середовища, від того, який виявлений до технологій, але останнім часом почав проявлятися