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SINGLE SHAFT GAS TURBINE ENGINE ROTOR DYNAMIC STRESSES DETERMINATION

Abstract. The problem of the gas turbine rotor dynamic stresses determination has been studied. The developed mathematical model takes into account the curvilinear finite elements of hexagonal type. The turbine rotor dynamic stresses fields were found for several most dangerous forced vibration modes and proved experimentally.

Key words: gas turbine rotor, dynamic stresses, forced vibration.

Introduction. For the different types of modern ground or even floating power plants, it is rather necessary to increase the engine's capacity along with the high level of engine's durability and reliability. To achieve these goals, the researchers are forced to solve a number of problems in different areas, such as fluid flow dynamics, heat transfer, mechanics of solid deformable body etc. Furthermore, all of these problems are closely interconnected and the appropriate mathematical models should be designed to take into account all the aspects of the gas turbine rotor working process.

Problem Solution and Results. As the stationary coordinate system, the Cartesian right-handed xyz coordinate system with the center at point O is taken (Fig. 1). This coordinate system rotates together with the turbine rotor at a constant angular velocity Ω equal to the angular velocity of rotor.

According to the generalized Hooke's law [1] the solid body stress-strain state can be described by the next matrix dependence:

$$\{\sigma\} = [D](\{\varepsilon\} - \{\varepsilon_T\}),$$

where $\{\sigma\}$ is stress matrix-vector; $\{\varepsilon\}$ is elasticity deformation vector; $\{\varepsilon_T\}$ is thermal elasticity vector; $[D]$ is elasticity matrix of the turbine rotor material.





Figure 1 – The 3D model of the gas turbine rotor as a solid body

The power of the investigated gas turbine is 25 MW. The gas temperature at the entrance to the turbine rotor is 1583 K; total pressure at the stage inlet 0.7578 MPa; rotor speed 9390 rev/min.

As it is obvious the increase of the turbine rotor dynamic stresses is caused by the growth of the rotor forced vibration frequency [2]. The most dangerous are the low vibration frequencies, because they can cause the resonance state with the rotor rotation frequency. Thus, it is obligatory to obtain the distribution of dynamic stresses for the first four harmonic indexes. The results of such calculations in comparison with experimental data [3] are given below in Table 1.

Table 1 – Maximum dynamic stresses in the blades of the first rotor impeller

Forced vibration mode harmonic index, k	Forced vibration frequency f , Hz	Maximum dynamic stresses σ_{\max} , MPa		Divergence, %
		Numerical data	Experimental data	
1	868,27	397,53	373,21	6,2
2	1876,70	431,71	419,90	2,6
3	2090,82	481,96	455,9	5,4
4	3175,40	514,20	489,8	4,9

Conclusion. The study of the modern gas turbine engine rotor stress-strain state has been held. For this problem a refined mathematical model using the curvilinear hexagonal finite elements with eight nodes was developed. The level of the rotor dynamic stresses and its forced



vibration frequencies for different harmonic indexes are connected directly proportional. The main factors of such dynamic stresses fields are the non-stationary gas flow, causing the irregular pressure field and heat exchange on the rotor surfaces. gas flow pressure. The sharp temperature gradient between the peripheral part of the blade, its root part and the disk is also should be taken into account. Such negative factors with the high level of dynamic stresses demand the new studies of the turbine rotor creep and fatigue strength.

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