

MODAL AND FREQUENCY ANALYSIS FOR ROTOR BLADES OF TURBO-JET ENGINE TJ 100

Ján VAVRO^{1*} - Marta KIANICOVÁ¹ - Ján VAVRO jr.¹ - Alena VAVROVÁ¹

¹Alexander Dubček University of Trenčín in Trenčín, Faculty of Industrial Technologies Puchov, Slovakia

*Corresponding author: jan.vavro@fpt.tnuni.sk

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Abstract

The paper presents modal and frequency analysis for the blades of the turbojet engine TJ 100 with the help of the mathematic modelling of finite element method with utilization of Pro-Engineer and ANSYS. The paper also presents results of the stress analysis of the turbine blades.

Keywords: Modal analysis, frequency analysis, finite elements method, ANSYS

1 Introduction

The turbo-jet engine TJ 100 is normally used as a small power driving unit which can be installed as auxiliary engine into light and ultralight planes, sailplanes as well as gliders. The design of this small auxiliary turbine engine TJ 100 can be seen hereinafter (Fig. 1).



Fig. 1 Image of turbojet engine TJ 100

TJ 100 is single-shaft engine with single-stage radial compressor, annular combustion chamber and single-stage axial turbine which consists of rotating integral guide (distribution) and turbine blade wheel (it is starter-generator) together with output nozzle.

The intake air is compressed in the radial compressor wheel and then it pass through the radial and axial diffuser into the annular combustion chamber where it is mixed together with the fuel. The mentioned fuel is sprayed by the fuel nozzles. The residue gases of combstion which occurs during the burning process of fuel in the combustion chamber expand through the single-stage axial turbine and they get out through the output nozzle at the high speed into the atmosphere and this is the way for creation of motor thrust. The compressor running is provided by axial turbine.

Rotor is placed on ball bearings which must be lubricated with pressure oil.

The basic operating parametres for turbojet engine TJ 100:

Operating engine speed (revolutions per minute):

- idle engine speed 30 000 rpm,
- maximum output engine speed (100%) 60 000 rpm.

Maximum fuel consumption is 60 litres per hour. Temperature of gass in front of turbine is about 890°C.

Stator as well as rotor turbine blades are made of nickel superalloy Inocel 713 LC. The chemical composition of this nickel superalloy is shown in table below:

Chemical element	C	Cr	Ti	Al	B	Zr	Nb	Mo	Ni
wt. %	0.05	12.08	0.75	5.91	0.01	0.1	2.02	4.58	bal.

1.1 The computational model

The computational model of rotating turbine blade wheel is shown in Fig. 2.

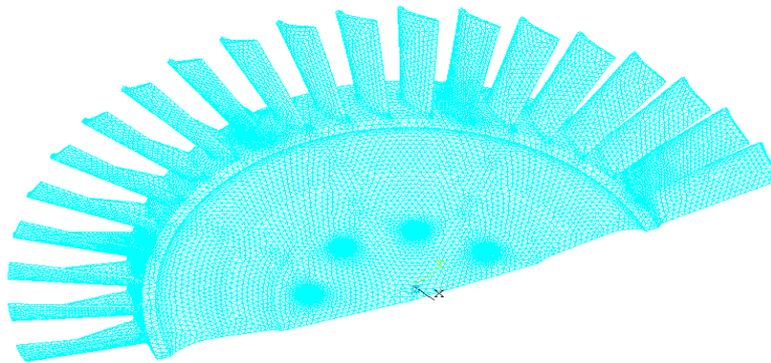


Fig. 2 Model of rotating blade wheel

1.2 The calculation of the eigenfrequencies and eigenshapes for turbine blades

Mathematical model can be expressed in form (1)

$$[\mathbf{M}]\{\ddot{\mathbf{u}}\} + [\mathbf{C}]\{\dot{\mathbf{u}}\} + [\mathbf{K}]\{\mathbf{u}\} = \{\mathbf{f}(t)\} \quad (1)$$

where \mathbf{M} is the mass matrix, \mathbf{C} is the damping matrix, \mathbf{K} is the stiffness matrix, $\{\mathbf{f}(t)\}$ is the time varying load

vector and $\{\mathbf{u}\}$, $\{\dot{\mathbf{u}}\}$, $\{\ddot{\mathbf{u}}\}$ are the displacement, velocity and acceleration vectors, respectively. Modal and frequency analysis were done according to known equation in the form

$$(-\omega_i^2[\mathbf{M}] + [\mathbf{K}]) \cdot \{\Phi_i\} = \{0\} \quad (2)$$

where ω_i is i-th eigenfrequency, $\{\Phi_i\}$ is the eigenvector representing the nodal shape of i-th eigenfrequency. We calculated eigenfrequencies and from the eigenfrequencies, there were calculated frequency characteristics with the modal damping $\xi = 0,001$.

The motion equation for i-th eigenshape is in accordance with:

$$\ddot{x}_i + 2\xi_i\omega_i\dot{x}_i + \omega_i^2x_i = \{\Phi_i\}^T\{f\} \quad (3)$$

This relationship is generalized problem of the eigenvalues where solution is made by the semi-automatic-space iterative method. This method is based on the idea of the inverse iteration conversion with several vectors at the same time.

At Fig. 3 we can see the first four eigenfrequencies calculated by the help of the underspace method. There are described the first four eigenshapes of vibrations, in the Fig. 3.

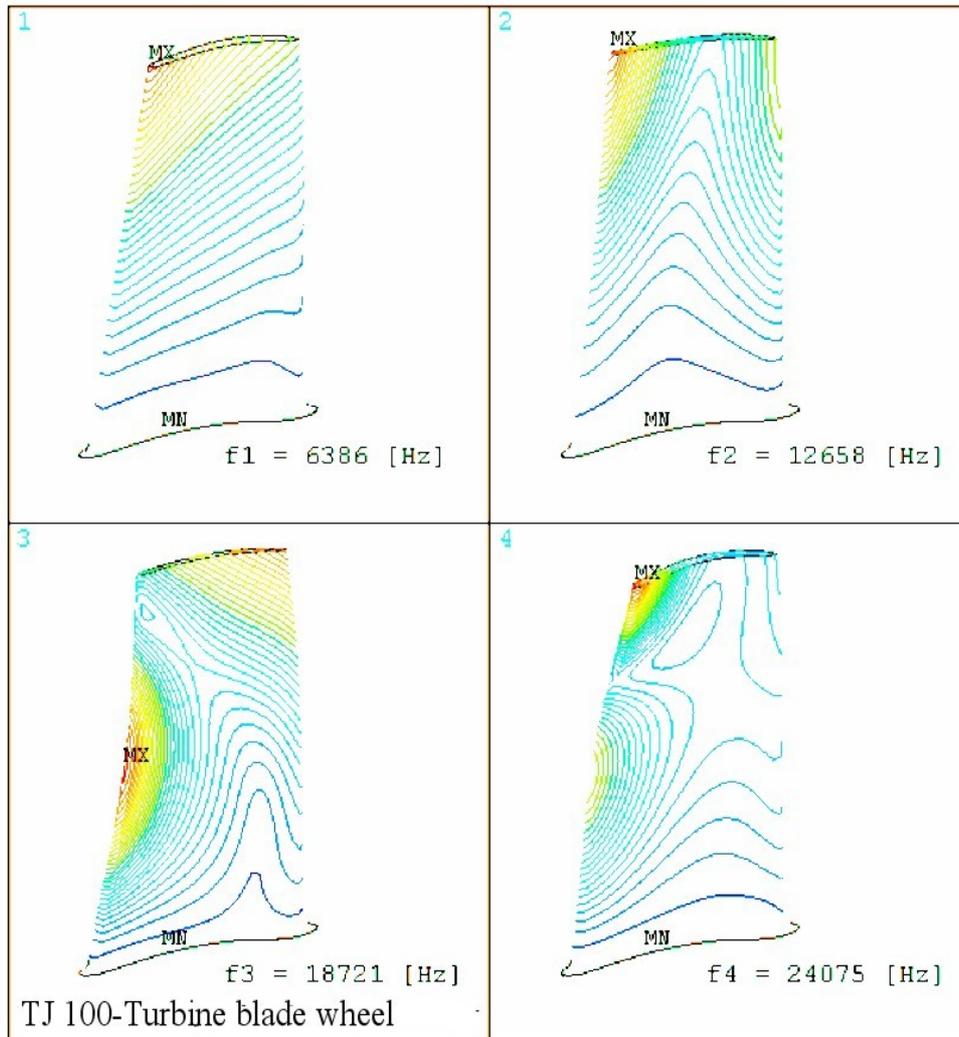


Fig. 3 First four eigenshapes of vibrations

1.3 Calculation of the blade construction loaded by the dynamic loading

The mathematical model for turbine blades was created with eightnodal volume elements. Stability equations were solved using (4):

$$[\mathbf{K}]\{\mathbf{u}\} = \{\mathbf{f}(t)\} \quad (4)$$

Dynamic analysis of the blade construction includes solution of the stability equations (4). Tenseness distribution is presented in [Pa] and it can be seen in the Fig. 4

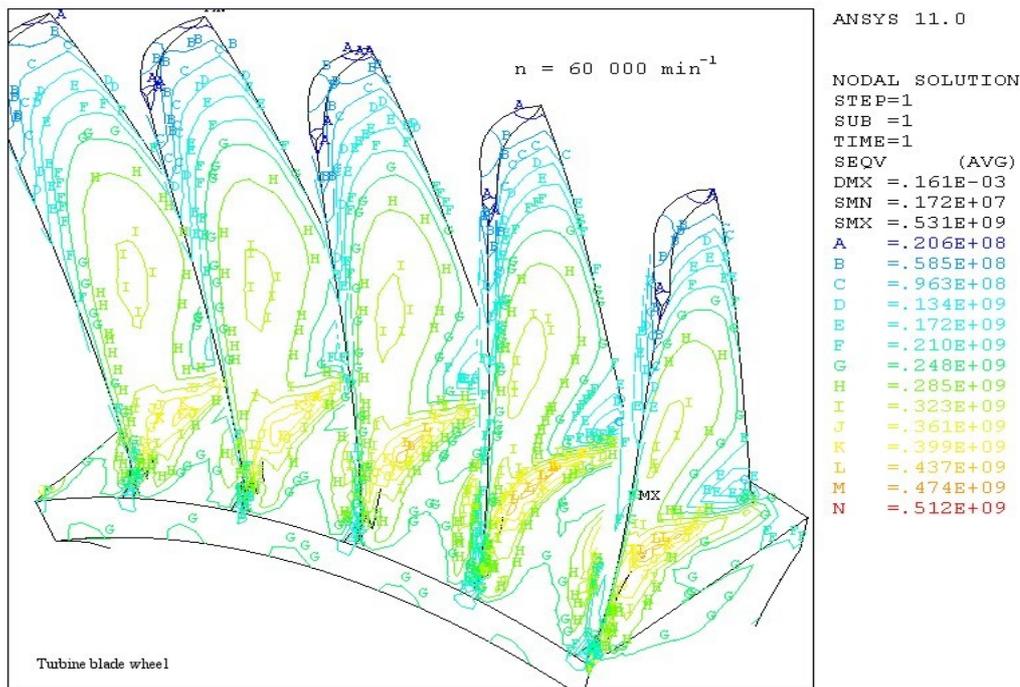


Fig. 4 Tenseness distribution [Pa]

2 Conclusion

The results obtained on the base of frequency analysis, thermal loading of turbine blades as well as distribution of main stresses pointed out the areas for which the loading of turbine wheel and blades is the highest. The given results can help us to specify the areas representing the possible initiation and distribution of crack relating to turbine blades. Figure 5 represents such crack of turbine wheel.



Fig.5 The turbine wheel with the crack of blade

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