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ARTICLE

ANALYSIS OF NATURAL FREQUENCIES OF OSCILLATIONS OF THE BALANCING MACHINE AND ROTOR GTE-16M

Sergey A Nazarychev[1], Sergey O Gaponenko[2*], Aleksandr E Kondratiev[2], Andrey V Busarov[3]

[1]*The Alexander Butlerov Institute of Chemistry, Kazan Federal University, Kazan, RUSSIA*

[2]*Kazan State Power Engineering University, Kazan, RUSSIA*

[3]*Center of Expertise of Industrial Safety, Kazan, RUSSIA*

ABSTRACT

Descriptions of the general structure of the ANSYS program using the finite element method are given. The basic structures of the modal analysis and the position of the finite element method are studied. For reliable calculation, accuracy and suitability for elemental applications, equations in the form of matrix systems are described. A modal analysis is performed that characterizes the frequency and nature of the natural oscillations of a given structure. The calculation of natural frequencies of oscillations of the main elements of the balancing machine and the turbocharger rotor is performed. Presented is the imported GTD-16M rotor model, finite element mesh on the GTD-16M rotor model. The calculation of the natural frequencies of the bed and the support assembly of the balancing machine is performed. To calculate the natural frequencies and modes of natural oscillations of the machine bed, the bed model is loaded into the ANSYSWB environment. The first 24 modes of oscillations of the examined support assembly of the balancing machine are determined. The results are shown in the table. The calculation of natural frequencies and modes of natural oscillations of the support assembly of the balancing machine is carried out. The reference node model is loaded into the ANSYSWB environment. An informative frequency range has been obtained that allows balancing rotors in the pre-resonance mode of operation. The results of experimental studies are presented and presented graphically.

KEY WORDS
ANSYS, finite element method, vibration modes, pre-resonance regime, balancing.

INTRODUCTION

Such automated production and design systems such as AutoCAD, Pro / Engineer, Uni graphics, DUCT and Solids Works are widely used in computer prediction of unusual form standards, creation of control systems for CNC machines and production of techniques, however such group numerical prediction packages do not have developed methods analysis. Concepts of this kind, such as ABAQUS, ANSYS, COSMOS, I-DEAS, NASTRAN, which are mechanisms of automatic engineering analysis, allow performing high-quality forecasting of projects of different physical nature, and studying the response of such programs to external influences in the form of temperature, velocity, stress distribution, electromagnetic fields and other factors.

MATERIALS AND METHODS

Application of ANSYS

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The ANSYS system is a convenient, reliable resource for design and research. The specificity of ANSYS is that all the incoming resources of this program are compatible and defined for all platforms used. This program operates in a group of operating systems often used by hardware. The multi functionality of this program allows the possibility of applying the same model for solving such intertwining problems as the influence of magnetic fields on the strength of a structure, the action of heat and mass transfer in an electromagnetic field, and stability under thermal loading. All this provides the subscribers of the program with reliable methods and options for solving a vast field of engineering issues [1-2].

Carrying out calculations by the ANSYS system, possibly thanks to basic engineering concepts and rules. With the help of proven numerical methods, these concepts can be expressed in the form of matrix equations that are maximally suitable for finite-element equations. In the mathematical model of the system, which consists of the integrity of the final branches (elements), interconnected at a finite number of points (nodes), it is necessary to evaluate its order and analyze the changes. The degrees of freedom of the nodes of the elemental finite model are key unknowns, namely, displacements, magnetic or electric field potentials, pressures, temperatures, velocities and rotations. The exact content of degrees of freedom is established with the type of element that is conjugated to this node. According to the degrees of freedom, for each component of the model, the mass, rigidity (or thermal conductivity) and resistance (or specific heat) matrices are determined.

Basic concepts of the finite element method and modal analysis

***Corresponding Author**
Email:
sogaponenko@yandex.ru
Tel.: 89874170041

To date, widely used numerical methods, preferably the finite element method (FEM), to evaluate the dynamic parts of structural elements [3].

The decisive dynamic tasks are: the dynamic effect on the load, due to the duration; calculation of free design vibrations; propagation of waves [5].

In this work the ANSYS software complex was applied, which allows to perform the modal analysis (an important part of any dynamic analysis, since it allows estimating the dynamic behavior of the object) to determine the forms and frequencies of the object's own vibrations.

Own (free) oscillations are a necessary characteristic of linear systems. They manifest themselves in the absence of external forces, natural movements.

Modal analysis of the ANSYS system has solvers, it makes it possible to find the own values of the task. The Block Lanczos module is such a solver. It is used when a large sample contains elements of incorrect form 2- and 3-dimensional, for calculating a large number of modes. When a model consists of shell parts or their combinations and solidities, the Block Lanczos module works well. In comparison with the method of iteration in the subspace, the performance is faster, and the memory requirements are higher by 50% [6].

Applying the method of finite elements, the discrete equations of motion of the construction can be represented in the form of equations, presented in the educational material, Leontiev N.V. "Application of the ANSYS system to solving modal and harmonic analysis problems" [7].

The most important problem of finite element analysis is the justification of the uniqueness of the size of the computational grid. At the heart of the order, the ANSYS system is a means of estimating the calculation error used in performing linear strength and thermal analysis of elements due to the grid-based sampling, there is also a choice of rejecting it [7-8].

Calculation of the natural vibration frequencies of the basic elements of the balancing machine and rotor design

Modal analysis consists of the following basic steps: creating a geometric model of the object of control; setting properties of materials; creation of contact conditions; determination of calculation methodology; the creation of a finite element grid (CE); course of calculation; view calculated results and create a report. The geometric characteristic of the object forms the basis for the analysis. There are two ways to create a model of the object under study in ANSYSWB-importing a model from an external CAD and creating geometry with internal tools. For this reason, Autodesk Inventor 2016 CAD software imports the geometry of the rotor into the ANSYSWB environment [Fig. 1].

The properties of the materials are specified:

- density: kg / m3;
- modulus of elasticity: N / m2;
- Poisson's ratio: $\nu = 0{,}3$.

The contact conditions are established: fixed fixation along the lateral faces of the model along the axis of rotation of the rotor and cylindrical fastening in the places of support of the rotor shaft. Due to the fact that the modal analysis is linear, the inclusion of contacts in this calculation can be neglected.

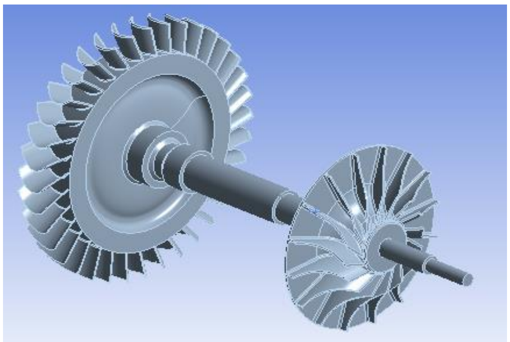

Fig. 1: Imported rotor model GTD-16M.

Execution of the finite element grid. When determining the calculation options, note, for modal analysis, the main assumptions and limitations: the absence of damping; the stiffness matrix [K] and masses [M] are constant; fluctuations are free; the behavior of the system is linear; the form of free oscillations is calculated in relative units and does not allow to determine absolute displacements [9].

To create the CE grid [Fig. 2], the following parameters are selected:

- grid on a solid body (grid type):
- standard grid (used splitting);

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- high (quality of the grid);
- 44015 (number of nodes);
- 23219 (number of items).

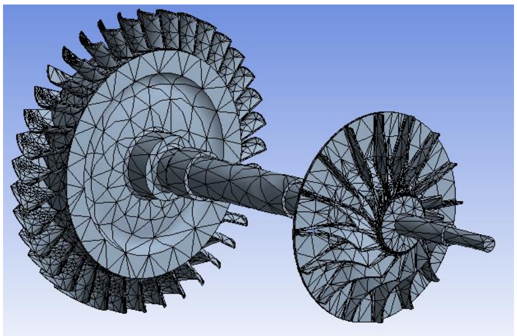

Fig. 2: The finite element mesh created on the GTD-16M rotor model.

As a result of the study, 24 first modes of oscillations of the calculated rotor are determined. When analyzing the results of the modal calculation, it is necessary to take into account that the form of free oscillations is calculated in relative units and does not allow determining absolute displacements.

The vibration shape of the first mode of the balancing rotor at a frequency of 269.67 Hz is shown in [Fig. 3].

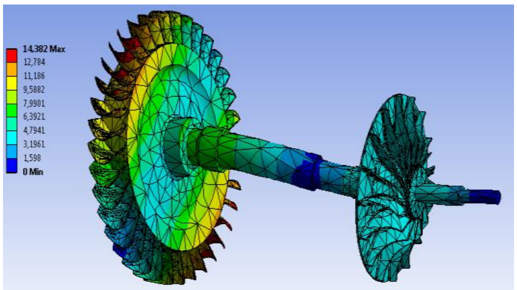

Fig. 3: Shape of vibration of the first mode of the rotor of the turbocharger.

The results are summarized in [Table 1].

Table 1: Modes of vibrations of the rotor in question

Mode of oscillation	Frequency, Hz	Mode of oscillation	Frequency, Hz	Mode of oscillation	Frequency, Hz
1	269,67	9	1594,7	17	3190,8
2	394,52	10	1597	18	3227,2
3	395,1	11	1947,4	19	3550,9
4	428,13	12	2463,5	20	3564,6
5	703,52	13	2475,4	21	4022,3
6	704,88	14	2931,6	22	4147,5
7	1309,6	15	2936	23	4263,2
8	1313,1	16	3086,5	24	4267,8

Using the obtained frequency range of the natural oscillations of the rotor, it is necessary to determine the natural frequencies of the balancing machine base in order to subtract these frequencies from the frequency modes of the rotor under investigation [10].

Calculation of the natural frequencies of the bed and support assembly of the balancing machine
To calculate the natural frequencies and modes of natural oscillations of the machine bed, the bed model is loaded into the ANSYSWB environment [Fig. 4].

The frame is made of polymer granite and this material has the following properties:
- density: kg / m3;
- modulus of elasticity: N / m2;
- Poisson's ratio: $\nu = 0{,}25$.

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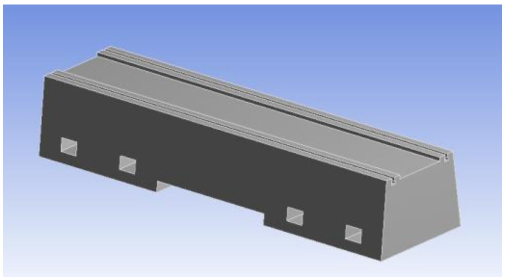

Fig. 4: Loaded geometry model of the frame in ANSYSWB.

When creating a finite element grid [Fig. 5], select:

- grid type: grid on a solid body;
- used partitioning: standard grid;
- grid quality: high;
- number of nodes: 9817;
- number of elements: 5471.

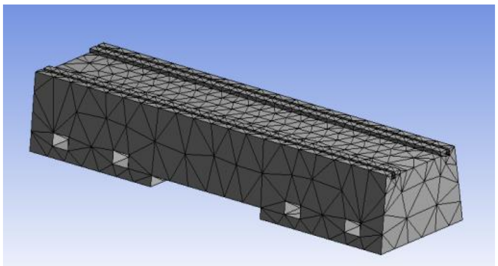

Fig. 5: The finite element grid on the bed model.

As a result of the modal examination of the frame, 24 first modes of oscillation are determined.

The results are summarized in [Table 2]

Table 2: Modes of oscillations of the examined bed of the balancing machine

Mode of oscillation	Frequency, Hz	Mode of oscillation	Frequency, Hz	Mode of oscillation	Frequency, Hz
1	1015,5	9	2288,1	17	3144,5
2	1083,4	10	2290	18	3229,8
3	1339,7	11	2404,2	19	3231,1
4	1419,6	12	2620,7	20	3311
5	1603,6	13	2678,3	21	3389,9
6	1769,2	14	3003,8	22	3432,5
7	1927,8	15	3030,6	23	3515,8
8	2019,5	16	3112	24	3567,8

The shape of the oscillation of the first mode of the machine bed at a frequency of 1015.5 Hz is shown in [Fig. 6].

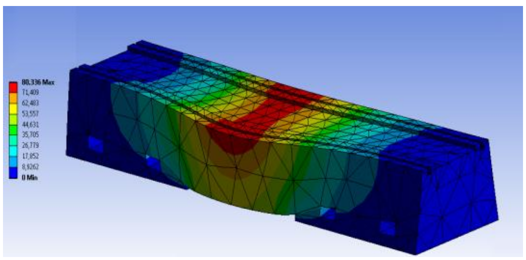

Fig. 6: The shape of the oscillation of the first mode of the machine bed of the balancing machine.

Similarly, the calculation of natural frequencies and modes of natural oscillations of the support assembly of the balancing machine is performed. The reference node model is loaded into the ANSYSWB environment [Fig. 7].

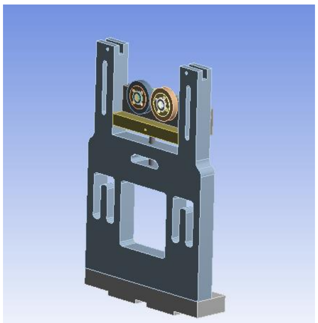

Fig. 7: Geometric model of the reference node in ANSYSWB.

The material properties are defined and a finite element grid is created [Fig. 8].

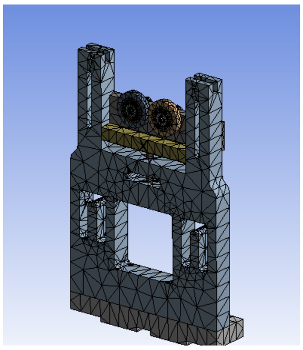

Fig. 8: The finite element grid on the model of the reference node.

As a result of the modal examination of the reference node, 24 first modes of oscillation are determined.

The shape of the oscillation of the first mode of the machine bed at a frequency of 1015.5 Hz is shown in [Fig. 9].

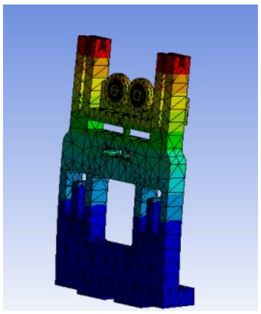

Fig. 9: Shape of oscillation of the first mode of the balancing machine support assembly.

The results are summarized in [Table 3].

Table 3: Modes of oscillations of the examined support unit of the balancing machine

Mode of oscillation	Frequency, Hz	Mode of oscillation	Frequency, Hz	Mode of oscillation	Frequency, Hz
1	2	3	4	5	6
2	714,75	9	1478,3	17	2369,5
3	920,95	10	1501,3	18	2380,7
4	1135,6	11	1697	19	2517,7
5	1170,1	12	1703,8	20	2691,4
6	1184,1	13	1760,2	21	2703,5
7	1247,9	14	1984,7	22	2728,1
8	1304,3	15	2159,2	23	2817,8
9	1440,7	16	2219,6	24	2839,1

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RESULTS AND DISCUSSION

As a result of this calculation, the range of the natural frequencies of the oscillations of the reference assembly of the balancing machine is determined.

When comparing [Tables 1- 3], it can be seen that the frequencies of the first 6 modes of the natural frequencies of the rotor oscillations lie below the natural oscillation frequencies of the frame and the supporting unit of the machine. Frequency range 0-705 Hz is the most informative frequency range on which it is necessary to carry out pre-resonance balancing of the rotor.

As a result of the modal analysis of the rotor, the bed and the support assembly of the balancing machine, an informative frequency range was obtained which allows balancing the rotors in the pre-resonance mode of operation. The balancing machine of the pre-resonance type is more efficient, because on this machine balancing is performed without calibration starts, high balancing accuracy is achieved and balancing of any rotor types corresponding to the overall dimensions of the machine is possible.

CONCLUSION

In this work, a modal analysis (one of the methods for determining the forms and frequencies of natural oscillations) was performed using the ANSYS software and results were obtained. As a result of the studies, the goal and objectives were fully met. The general structure of the ANSYS program using the finite element method was considered, the natural vibration frequencies of the basic elements of the balancing machine and the turbocharger rotor were calculated.

CONFLICT OF INTEREST

There is no conflict of interest.

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FINANCIAL DISCLOSURE

None

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