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MODAL AND FREQUENCY ANALYSIS OF THE ULTRASONIC MACHINING SYSTEM OF THE BALL-BEARING

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ABSTRACT: The paper presents the investigation of the dynamic characteristic of the ultrasonic machining of the ball-bearing. The advantages of this method are shown in the introduction part of the paper. The authors explain the description of the lapping. The dynamic characteristics of the system disc-buster-UZ converter were modelled by the help of the twenty and eight nodal elements. The solution of the problem had two parts.

1) the solution of the modal and frequency characteristics
2) the solution of the amplitude-frequency characteristic by the help of the modal decomposition.

KEY WORDS: Modal analysis, frequency analysis, finite elements method

1. INTRODUCTION

The technical progress provokes the growth of the requirement of the high quality bearings with the long working life, high operational preciseness, low noise working and the ability to work with the high revolution and in aggressive environments.

The special technologies of the world-known producers contribute to the high bearing balls quality too, mainly at the final operation. This paper deals with the problems of the bearing ball surface adjustment by lapping with the help of the super sound exited disc.

From the introduced method is obvious that:

1. The working (lapping) productivity will be increased up to 25 – 30 %.
2. Geometric parameters of the balls will be improved, which has influence for the bearing vibration level decreasing.
3. The ball working life will be increased up to 200 %.
4. This technology may be used for the ball grind operation.

1.1 Description of the operation - Lapping

The lapping is a precise work operation based on the friction among a cutting tool, a work and lapping medium. The tools supersonic vibration is expressed in the final increased homogeneity of the mechanical properties across the ball cross section and in overall improvement thanks to structural changes.

The lapping work ball principle with the using of the intensive supersonic is shown in the Fig. 1. The balls (1) are rolled between rotating cast iron disc (2) and supporting cast iron disc (3) in the ring grooves, with the press force F, acting on the rotating disc. The supporting disc (3) is vibrationally excited with the piezoelectric ceramic converter (4), which feeds the ultrasonic generator (5). The vibrations from the piezoceramic converter are transferred through a buster to the disc.

The lapping suspension (6) is led from the storage tank to the zone among vibrating disc (3), worked material balls (1) and rotating disc (2). The press force acting on rotating disc (2) and in the same time on working balls (1) is regulated with the help of the hydraulic mechanism. Under the influence of the press force F and double amplituded disc (3), the lapping comes dispersed in the lapping emulsion are pressed to the work material- the ball.

Lapping grain with their sharp edges brakes out small pieces from the balls surface. The pieces are together with the lapping suspension washed ashore to the level. This process repeats until the balls are worked down to the required parameters.

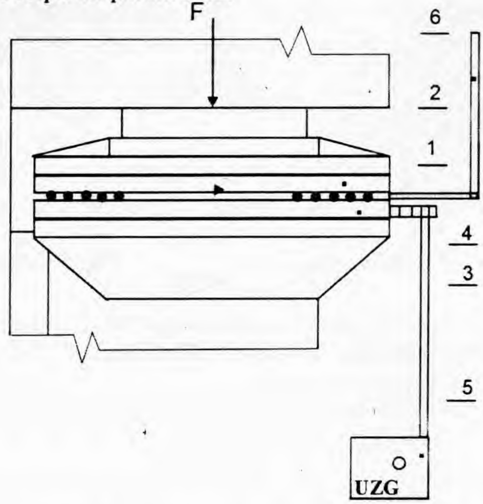

Fig. 1: Schematic layout of ultrasonic lapping.

The balls lapping process at the ultrasonic working is accompanied either with elastic or plastic deformations. It results into the strain hardening of the surfaces of the connecting parts.

1.2 Computational model

The computational model of all the construction set is shown on the Fig.2. It consists of three parts:

- disc (3), Fig. 3,
- piezoelectric converter (4), Fig. 4,
- buster Fig. 5.

The converter (4) is connected to the disc (3) with the buster (5).

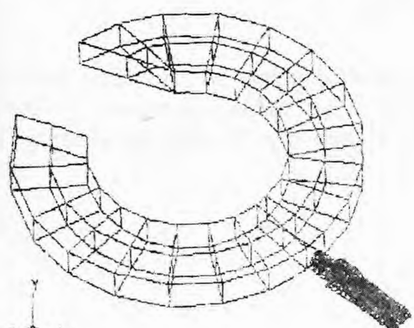

Fig. 2: Schematic layout of the computational model.

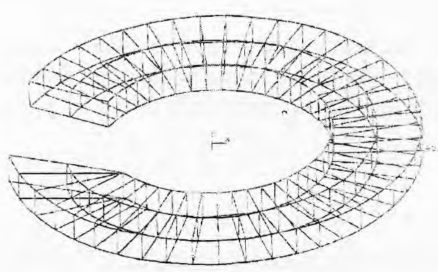

Fig. 3: Model of the disc.

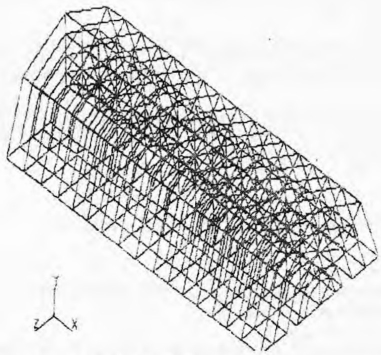

Fig. 4: Model of the UZ – converter.

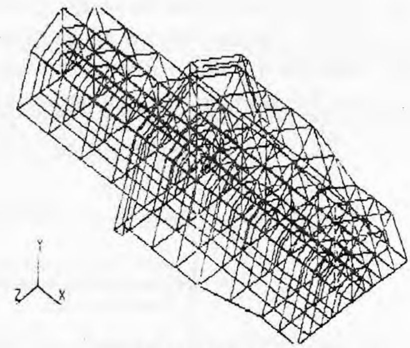

Fig. 5: Model of the buster.

The set disc- buster- UZ- converter was modelled by the help of the twenty nodal finite elements for the disc and eight nodal finite elements for buster and converter.

Mathematical model is in known form (1)

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

where **M** is the mass matrix, **C** is the damping matrix and **K** is the stiffness matrix.

Modal and frequency analysis were done according to known equation in the form

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

where ω_i is i-th natural frequency, $\{\Phi_i\}$ is the eigenvector representing the nodal shape of i-th natural frequency.

We calculated 150 natural frequencies and the highest was 15 830 Hz. From the natural frequencies were calculated frequency characteristics with the modal damping $\xi = 0{,}001$.

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

$$\ddot{x}_i + 2\xi_i\omega_i\dot{x}_i + \omega_i^2 x_i = \{\Phi\}_i^T\{f\} \tag{3}$$

The frequency characteristics were counted for the separate points with exciting force (with amplitude 1 N) loading in the nodal point number 463 (Fig. 3) in the "plane of symmetry" of the disc.

The frequency characteristic for nodal point No. 520 is on the Fig.6. For Rayleigh damping in the form

$$\mathbf{C} = \alpha\mathbf{M} \tag{4}$$

We consider the material damping of $\alpha = 0{,}001$.

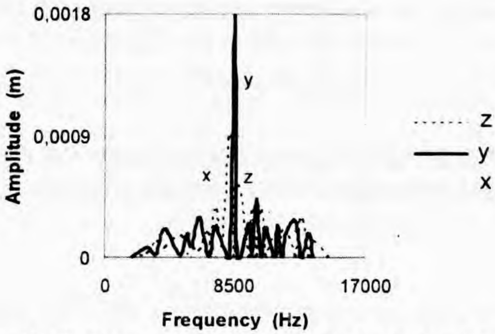

Fig. 6: Amplitude-frequency characteristic for the nodal point No. 52.

2. CONCLUSION

The results proved that expressive manifestation determinated oscilation shape in the frequency area of 8500-10000 Hz.

From the point of view of the balls lapping (grind) only the frequencies of value about 8500 Hz are significant. In conclusion it has to be pointed out that besides in an introduction mentioned advantages, another advantage appears and that is the low energetic requirement of the final working.

3. REFERENCES

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