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EXPERIMENTAL VERIFICATION OF GEAR-BOX BODY DISCRETE FEM MODEL – STATIC PROBLEM

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Abstract: *In the paper an example of gear-box body stresses numerical analysis is presented. The body is a simplified welded structure and its discrete model is verified experimentally. The finite element system ALGOR is used to numerical solution of the static problem. The numerical results of calculations are verified by tensiometer measuring method. Measurements are done in several points of the body wall.*

Key words: gear-box body, stresses, finite element method, numerical calculations, tensiometer measuring method.

Introduction

Casting and welding are basic technologies commonly used in machine body manufacturing. Minimum thickness of a casted body wall is limited because of the casting technology. Result of this limitation is fact that casted bodies are heavy usually. Welded bodies have no such limitation and the technology of welding give us more possibilities to design light thin-walled corps. It leads that the structures in the static as well as the dynamic analysies ought to be tested. Especially in large structures design process the verifications are necessary.

The most popular methods of the structure testing are the numerical and the experimental methods. The numerical methods may be applied in the design process before the structure will be made in its real shape. It is very convenient for designer becouse he can correct the structure before it is completed. The experimental method may only be used when the structure is made completely. It allows us to verify assumptions that were considered in the numerical analysis. The both methods are used for investigations of the gear-box body behaviour that are presented in this paper.

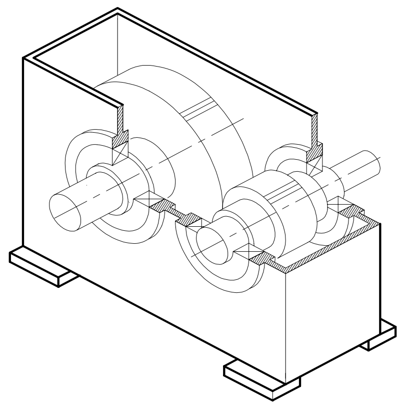

Fig. 1. The model of the considered gear box

Description of the model

To ilustrate the problem clearly the simplified thin-walled welded gear-box body model is presenteded. The gear-box is shown in Fig. 1. It consists of two wheels, two shafts, bearings

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and steel body. Input and output shafts transmit power by elastic couplings. Basic dimensions of the body are: 440 x 320 x 240 [mm] and the thickness of the walls and bottom is 5 [mm]. Dimensions, as well as stiffness and mass of the shafts and the wheels are great when compared them to thickness and stiffness of the body walls. It permits us to investigate the problems of the thin-walled body better.

The two methods are used to solve the problem:

- numerical method (FEM Systems – ALGOR and ABAQUS/Standard),
- experimental method (tensiometer measuring method).

The results provided by the finite element method are compared to the results of the experiment.

Table 1 Geometry of the model (Fig. 1.) and material properties

- dimensions of box	420x320x240 [mm]
- thickness of walls and bottom	5 [mm]
- material - steel	E = 2.1e5 [N/mm2], ν = 0.3,
- type of elements – 4 & 8node shell elements	S 8R5
- mass of shafts, wheels, bearings (15.4 and 24.6 kg),	32 x (m2= 0.48 [kg]) - input 32 x (m1= 0.77 [kg]) - output
- stiffness of elastic couplings is represented by elastic elements in 32 nodes at bearing sets	32 x (k= 10^4 [N/m]) - input 32 x (k= 10^4 [N/m]) - output
- distance between bearing sets = const.	**EQUATION*
- support of body	constrained (mainly)

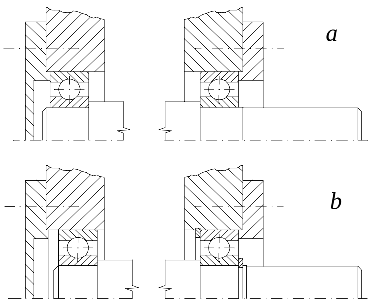

Fig. 2. Examples of locking shaft in axis direction

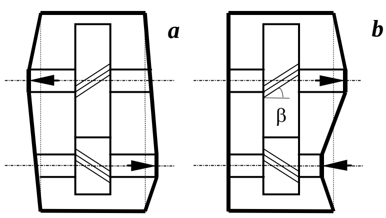

Fig. 3. Displacement and loads of the box body walls as the results of the cases of the shafts locking in axis direction

Static problem of the gear box body

The basic aim of investigations in the static problem of gear-box bodies is to search the displacements and stresses distributions. The knowledge of the stresses and displacements distributions allows us to correct and to improve the structure before the design process is completed.

To denote the distributions of displacements and stresses the finite element method system (ALGOR) is used.

Boundary conditions

The parts of the boundary conditions that are assumed in the problem are described in Table 1. The shafts are supported and locked in the bearing sets of the gear box body. Two variations of locking the shafts (Fig. 2.) are considered.

Loading

The body-box is loaded by the bearings in the bearing sets. According to the value of β angle (Fig. 3.) bearing forces act in the axial directions as well as in the plane of the walls direction. The values of β angle decide about proportions between the magnitudes of the both direction forces. In the paper the value of $\beta=0^0$ is considered only. Fig. 4. shows two variations of load distribution: uniform load distribution (a) and cosinus function load distribution (b). The both variations are considered in numerical analysis and the results of calculations are compared to the results of experiment. In the load for the value $\beta = 0^0$ (Fig. 3.), the forces act on the body in the planes of the walls only, but the bending effect cannot be neglected according to unsymmetry of welded wall, especially if bearings are situated out of the planes of walls. Magnitude of force that acts on bearing (see Fig. 4. „P") is: P = 6533 [N]. Discrete model of the structure is shown in Fig. 5. Half of the structure is considered only because of symmetry of the model. Four node shell-plate elements are used to build the discrete model. The model have 4241 nodes and 4084 shell elements.

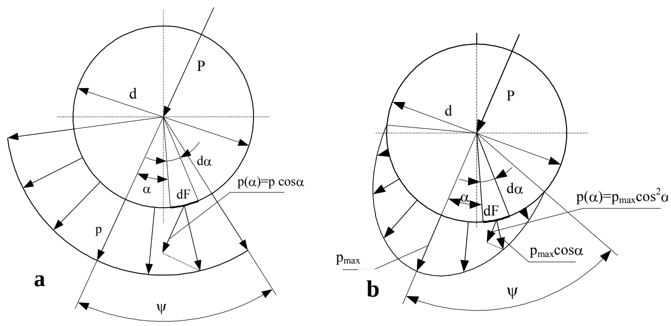

Fig. 4. Two variations of load distribution

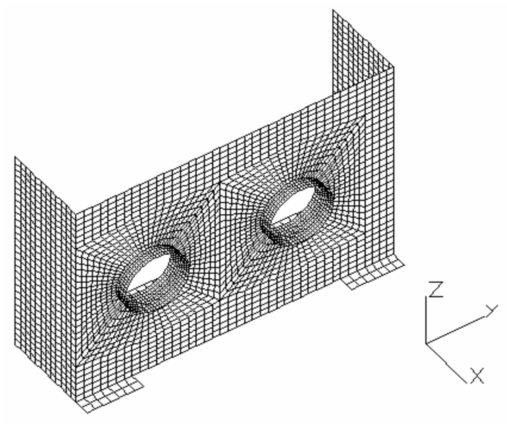

Fig. 5. Discrete model of the structure

Regular mesh of the discrete model is modified according to location of measuring points. Two variations are considered:

- nodes of the mesh are situated in the center of tensiometers,
- nodes of the mesh are situated in the corners of tensiometers.

Results of numerical calculations

Displacements and stresses distributions are investigated in numerical analysis. Two variations of load are considered. Displacements of the discrete model are shown in Fig. 6.

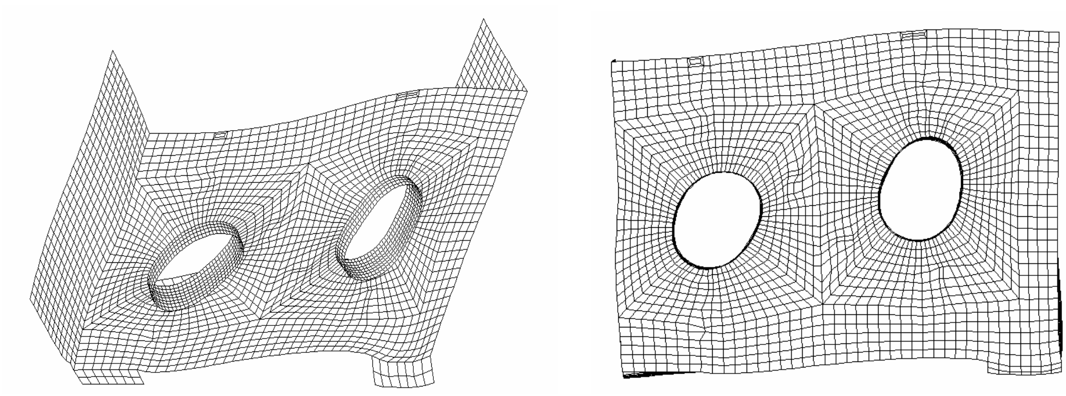

Fig. 6. Displacements of the discrete model of the structure

Distribution of v.Mises stresses is shown in Fig. 7. The maximum stress appears in the walls near the bearing sets for the cosinus function load distribution denoted in Fig. 4b. Fig. 7. shows outer surface of the wall only but in full stress analysis average values of the stresses on outer and inner surface are calculated in the measuring points. It allows us to consider wall bending effect and to verify FEM discrete model better.

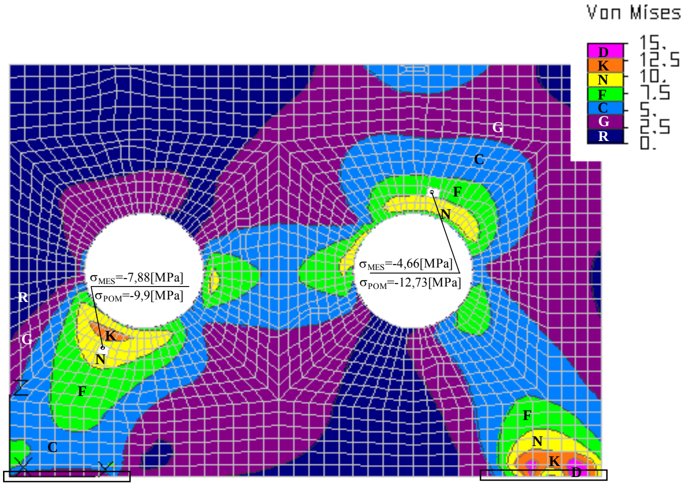

Fig. 7.
Results of the uniform load distribution - von Mises stresses distribution in the body wall outer surface [Mpa]

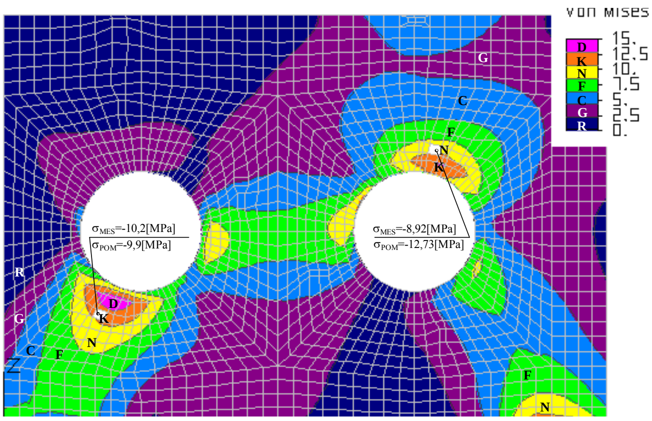

Fig. 8.
Results of the cosinus function load distribution - von Mises stresses distribution in the body wall outer surface [Mpa]

Experimental verification of the numerical results

The tensiometer method is used to verify the results of numerical calculations. Only the load value of $\beta = 0^0$ (forces act perpendicularly to the shaft axis) is considered in the experimental investigation. The locations of measuring points at the main wall of the box are shown in Fig. 10. The points are situated at the both surfaces (inner and outer) of the main wall.

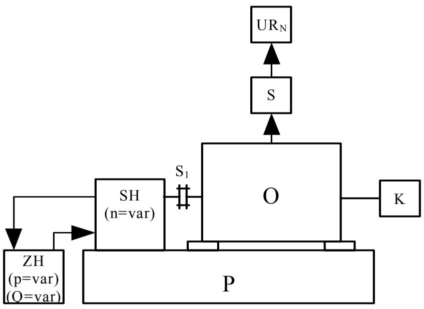

Fig. 9. Scheme of measuring stand

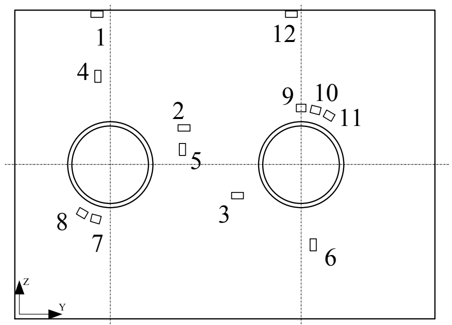

Fig. 10. Location of measuring points

The measuring stand that is shown in Fig. 9. consists of the following units: hydraulic motor unit (SH + ZH), measuring unit (S + UR), gear-box O, elastic coupling S1, base P, locking arm K.

Results of experiment and numerical analysis

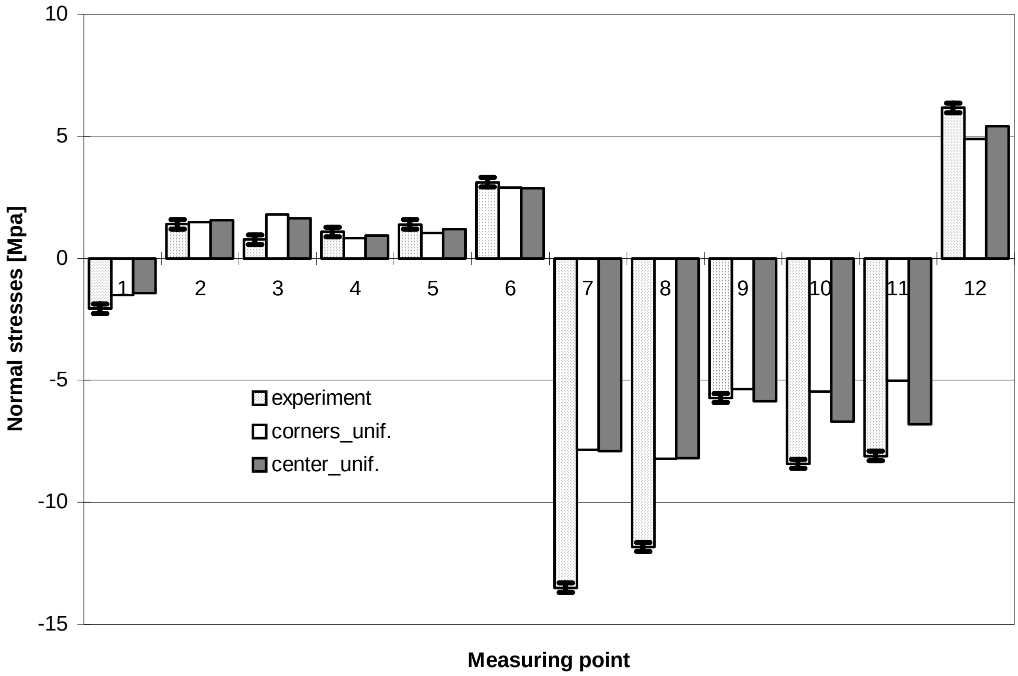

Fig. 11. Comparison of numerical and experimental results - normal stresses
Uniform load distribution in discrete FEM model

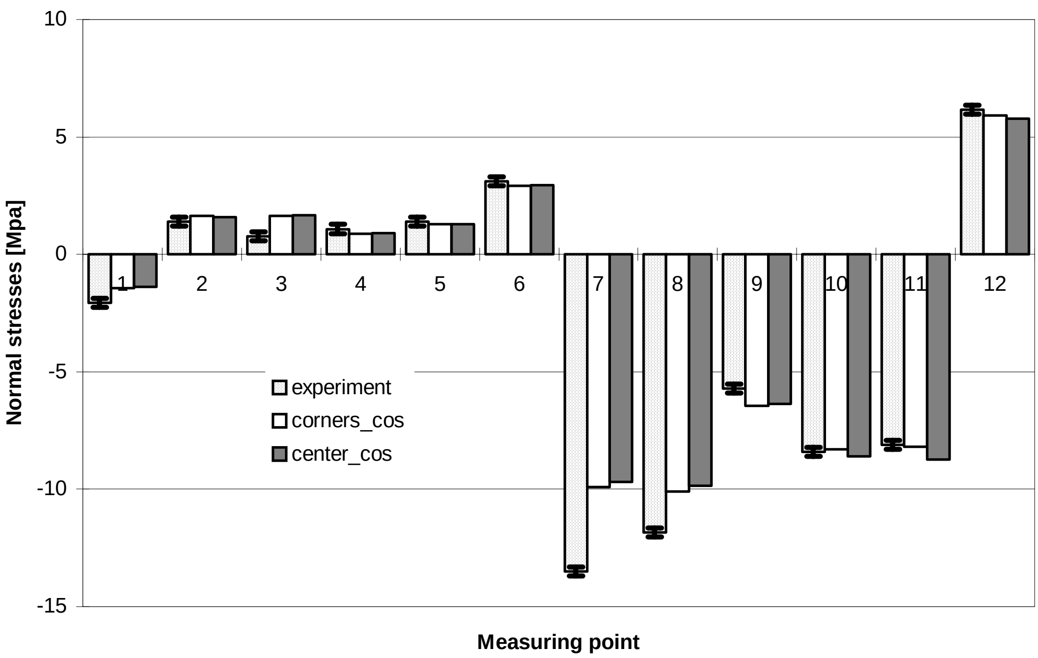

Fig. 12. Comparison of numerical and experimental results - normal stresses
Cosinus function load distribution in discrete FEM model

Results of measurements are shown in Fig. 11. and Fig. 12. The stress values that are presented in the figures are average stress values of of the measuring points in outer and inner wall surfaces. The figures ilustrate normal stresses comparison of the experimental and numerical calculations according to the measuring point locations. Two approaches are done in average stress value numerical calculations:

- the discrete model mesh nodes are located in **corners** of the tensiometer and average stress value is calculated from the corners values and input to the center of the tensiometer (measuring point) - it is denoted by „corners_...” in the figures,
- the discrete model mesh nodes are located in **center** of the tensiometer and average stress value is calculated for the center (measuring point) - it is denoted by „center_...” in the figures.

In the both cases average normal stresses values are considered for measuring points in outer as well as in inner wall surfaces.

Fig. 11. ilustrates comparison of numerical and experimental stress analysis for the uniform load distribution case. It is denoted as:

- „corners_unif.” – discrete mesh nodes are located in the tensiometer corners and uniform load distribution is considered,
- „center_unif.” – discrete mesh nodes are situated in center of the tensiometer and uniform load distribution is considered.

In Fig. 12. the same principle of notation is used. For example, notation of „corners_cos” means that discrete mesh nodes are located in the tensiometer corners and cosinus funcion load distribution is considered.

Conclusions

- Experimental verification of of the investigated gear-box body discrete model gives us good results.
- In the final numerical stress analysis of gear-box body model bending effect ought to be considered – it means that shell or solid 3D FEM elements must be used to construct FEM discrete model.
- Cosinus function load distribution approach gives better verification results especially close to bearing sets load region.

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