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Influence of the Mesh Parameters on Stresses and Strains in FEM Analysis of a Gear Housing

The influence of the mesh parameters on the results of FEM simulations depends on the type of the study and the geometry of the system submitted to analyze. In this paper a gear housing was submitted to static analysis. Six studies with distinct values for the maximum dimensions of mesh elements were applied. The results show significant differences for the values of maximum stresses and relatively small differences for the maximum displacements and strains.

Keywords*: FEM simulation, mesh, stresses, strains, gear housing*

1. Introduction

Nowadays the optimal design of mechanical elements combines the classical empirical methods of design with finite element method (FEM) analysis. In the finite element analysis the process of meshing of the geometry have a high influence on the accuracy of the results [1, 2, 3]. For mesh with higher density the results are considered more accurate [4].

In this paper a gear housing was analyzed using a static FEM study, in order to determine the deviation caused by mesh density. The part analyzed represents the bottom half of the housing of two stage cylindrical gear speed reducer. The part has a complex geometry and significant differences between the overall dimensions (figure 1: 435x220x152 mm) and some local dimensions (thickness of the ribs – 8 mm, width of the circular channels – 5 mm).

The main conditions used for the analysis were:

- The material associated to the geometry was the cast iron G300 (1.0558);
- The fixtures (*fixed geometry* type) were applied on the bases of the housing and on the screw holes (figure 2);
- The loads were applied on the bearings (figure 2); the values of the three types of loads (axial forces, tangential forces and radial forces) were obtained from the torque transmitted by the shafts of the speed reducer.
- The mesh type: solid mesh with tetrahedral elements (4 Jacobian Points);

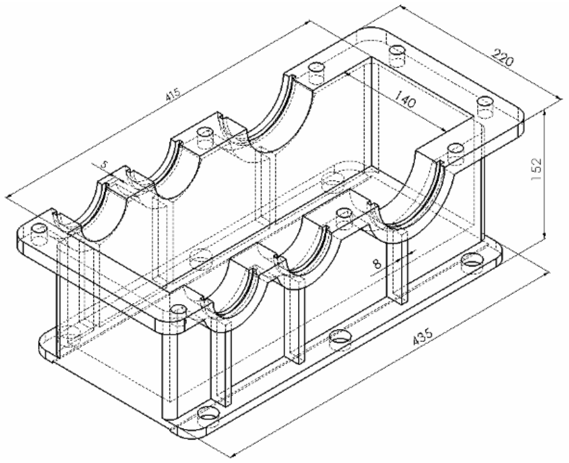

Figure 1. The overall dimensions of the gear housing

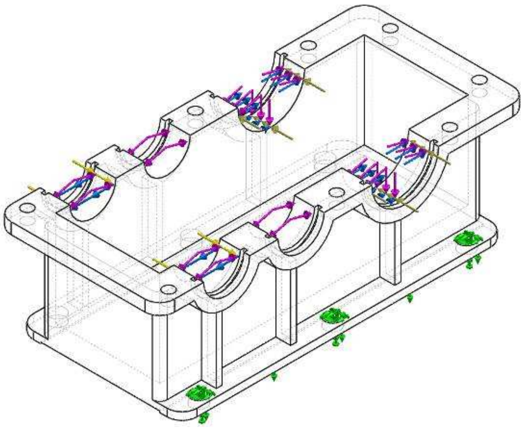

Figure 2. Loads and fixtures

2. FEM Simulation

The FEM simulations were performed in *SolidWorks Simulation* [5,6]. The gear housing was submitted to six different finite element studies. For each of this studies were used distinct values for the maximum size of mesh elements. This parameter was varied from 10 mm to 5 mm, values chosen considering the minimum dimensions of the housing (holes and ribs) and the limitations imposed by computing system. In table 1 can be observed the influence of the maximum element size on the total number of nodes and elements, on the maximum aspect ratio R (the ratio of distortion of the finite element relative to a regular tetrahedron) and on the percentage of the elements with aspect ratio $R<3$. The differences of mesh density between the studies 1 and 6 are shown graphically in figure 3.

Table 1. The mesh parameters for the six studies

Study no.	Element size [mm]		No. of nodes	No. of elements	Maximum Aspect Ratio *R*	Elements with *R*<3 [%]
	Maximum	Minimum				
1	10	1	77400	45192	7.8551	98.4
2	9	1	103769	62286	6.0939	98.6
3	8	1	136692	82926	6.1233	98.9
4	7	1	179146	110693	6.1233	99.2
5	6	1	261506	164987	9.3007	99.3
6	5	1	475459	309906	8.7358	99.4

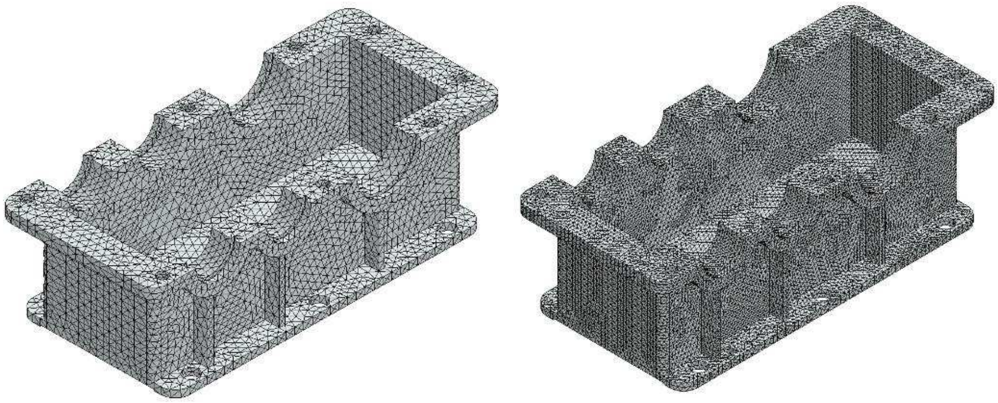

Figure 3. The meshes applied for study no. 1 (left) and study no. 6 (right)

All the assumptions used in the six simulations were identical, except the differences in meshing. The same computer was used for processing of studies.

Three types of results were analyzed: von Misses stresses, resultant displacement and equivalent strains. For each of this parameters were evaluated two aspects: the evolution of maximum values on the six studies and the differences between the distributions of values. The variation of resultant displacements was similar to the variation of equivalents strains. For this reason further will be discussed only the variation of resultant displacements and stresses.

The results show a significant difference on the maximum Von Mises stress that occurs in the six studies. The differences between the maximum values obtained for study 6 as compared to study 1 reach 20% (table 2).

Analyzing the coordinates of points where the maximum values of the stress occur (table 2), can be noticed that the maximum remains in the same area (the coordinates are measured related to the origin of the part: left down corner of the housing frame). The similarity between the distributions of stresses can be observed also by comparing the stress distribution for study 1 (figures 4) with the stress distributions for study 6 (figure 5).

Table 2. Maximum values for von Mises stress and resultant displacement

Study no.	Maximum von Mises stress		Maximum resultant displacement		Position of maximum von Mises stress		
	Value [MPA]	Variation [%]	Value [mm]	Variation [%]	X (mm)	Y (mm)	Z (mm)
1	114.60	0.00	0.336	0	-20	13.13	-304
2	114.46	-0.12	0.338	0.60	-20	10.56	-302
3	114.27	-0.29	0.339	0.89	-20	13.13	-304
4	131.82	15.03	0.340	1.19	-20	10.56	-304
5	135.41	18.15	0.342	1.79	-20	10.56	-304
6	138.24	20.63	0.343	2.08	-20	10.56	-304

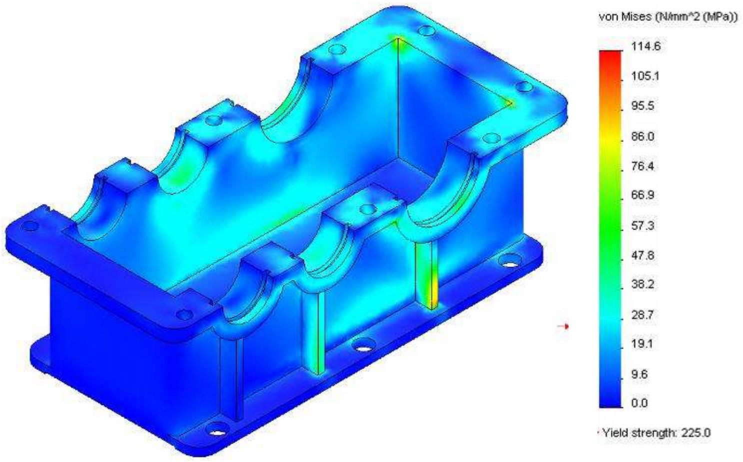

Figure 4. Von Mises stress variation for study no. 1

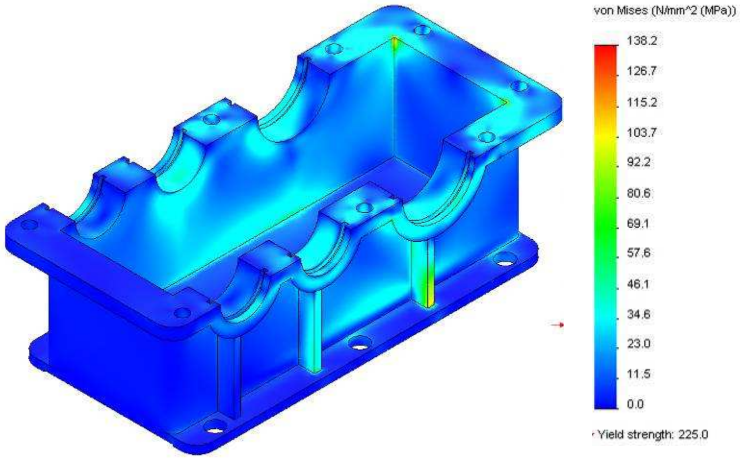

Figure 5. Von Mises stress variation for study no. 6

The differences between the maximum resultant displacements (U_{RES}) obtained for the six studies are smaller than the differences of the maximum stresses (table 2). The maximum deviation is 2.08% (study 6 relative to study 1). The distributions of displacements for study 1 (figure 6) and study 6 (figure 7) are similar.

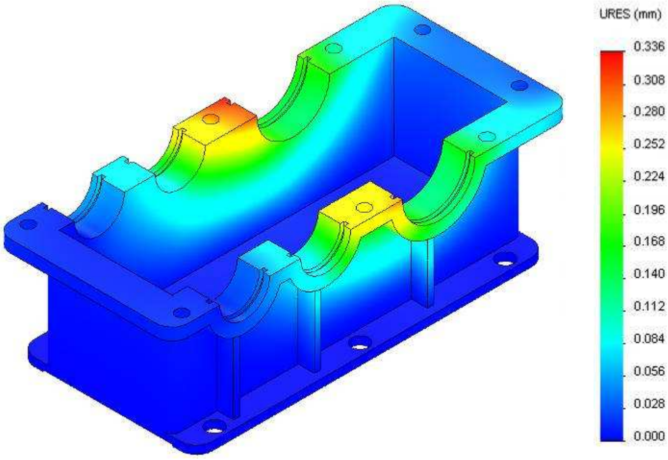

Figure 6. Resultant displacement variation for study no. 1

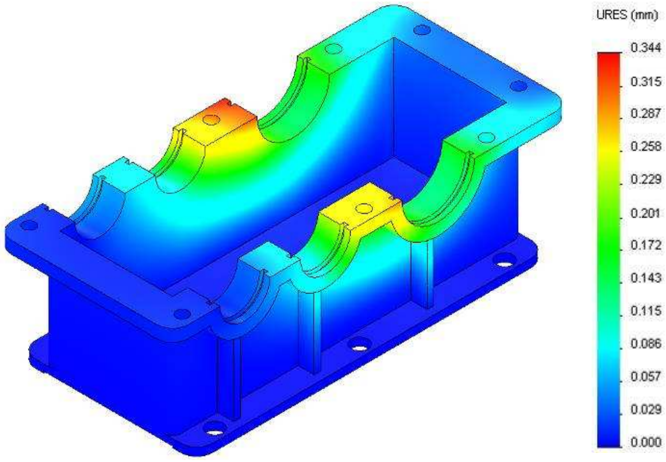

Figure 7. Resultant displacement variation for study no. 6

4. Conclusion

FEM simulations performed on a gear housing submitted to static loads, using six different mesh sizes, revealed that the mesh density have a high significance to the accuracy of the results. The differences between the maximum von Mises stresses obtained in the six studies reach 20%. These deviations can lead to high risks of failure if in the designing process it is worked with small safety factors.

For the part submitted to analysis the differences between the resultant displacements obtained in the six studies are insignificants. This conclusion is valid also for the equivalent strains.

The variation of maximum element size does not lead to major changes in the distributions of the stresses, displacements and strains. The maximum values remain in the same area of the part.

The large deviations of the maximum stresses indicate that the finite element method simulations must be associated with classical design methods: calculus and experimental analysis.

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