FINITE ELEMENT ANALYSIS OF THE BEHAVIOR OF A PART FROM THE FORKS AND LEVERS CLASS

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Abstract: *In the context of grouping and classifying technological processes for different categories of parts, made of different specific materials, different scientific research methods are tried. One of the criteria would be that of the functionality of the parts, which is based on the finite element method, through which the behavior of a certain structure is observed in certain operating conditions when it is made of a certain material. Through the finite element method presented in this article, the state of stresses and displacements for a part made of steel is determined. The part is part of the lever and fork category as it is presented in the article. Knowing how the part behaves in a certain functional context is very important because it allows the optimization of the geometric shape of the part or the choice of another type of material.*

Key words: economic, costs, manufacturing, Ol, Al, PLA, CF

1. INTRODUCTION

One of the categories of parts encountered in the industry is the one called ‘Levers and forks’. From the analysis of the drawing presented in figure 1, it can be concluded that the part under study is part of this class. This classification is found in several specialized references, including Amza et al. [1]. The typical technological process for parts in the “levers and forks” class includes a series of mechanical processing applied to sheet metal semi-finished products or to cast, free-forged, stamped or welded semi-finished parts, in the following approximate order (the most general case):

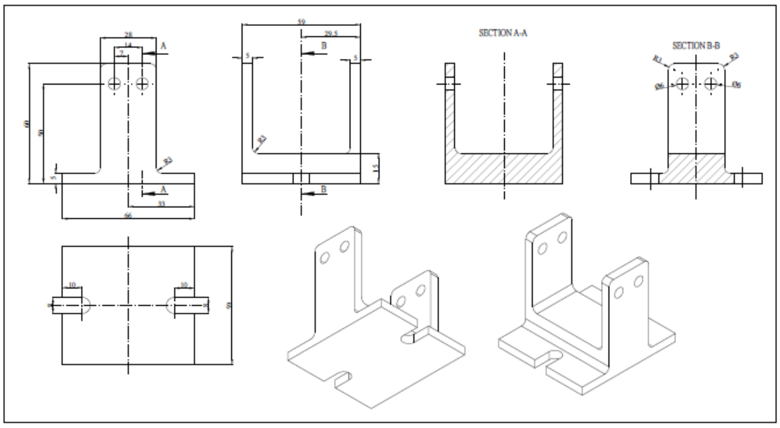
1. – processing of the rod head and a hole, which constitute the technological bases;
2. – roughing processing of the main surfaces (functional and assembly);
3. – roughing processing of the secondary surfaces;
4. – finishing processing of the main surfaces;
5. – processing of the holes;
6. – heat treatment;

7. – smoothing of the front faces and high-precision holes;
8. – final inspection.

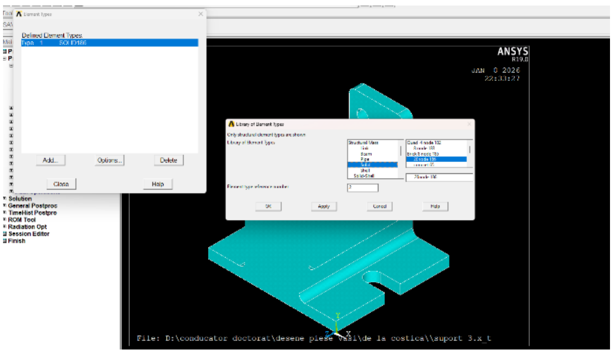
2. FEM ANALYSIS OF A STEEL FORK-TYPE PART

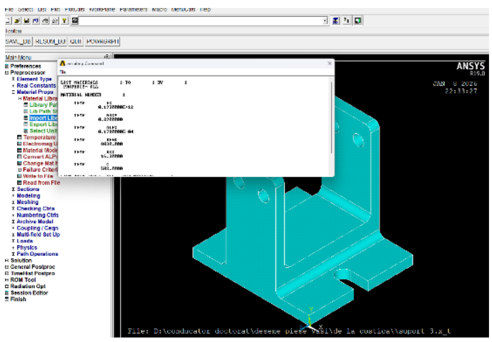
Lever and fork-type parts can be used in different industries. A possible variant of such a part is shown in Figure 1 a. As a consequence of the fact that their functional role can be different and the material from which they are made is different. In industry, the most used method for choosing the optimal material from which a part is made is the optimal values method. In the case of a part in this category being made of steel, as can be seen as a result of applying the optimal values analysis method presented in Table 4.1, the study carried out using the finite element method - MEF will be presented below. Through this method, which is used in the vast majority of scientific works, whether it is engineering, medicine, civil or military construction, a structural analysis was carried out that will provide as an answer the deformations and corresponding stress states that appear in the studied structure.

Next, for all the cases analyzed for the lever-type part, which differ from each other by the type of material used, the input data for the problem are presented. In the case of the steel part (general construction steel is considered here), the modulus of elasticity Y = 1.93·1011 N/m2, the Poisson's ratio ν = 0.29 and the density ρ = 8038 kg/m3 are considered.



a.





b. c.

Figure 1. Presentation of input data in the structural analysis of the fork type part made of steel:
a. - execution drawing of the part; b,c – presentation of the mechanical properties of the selected material, steel

To solve the necessary structural problem, the SOLID186 discretization element is chosen. This element continues all the equations necessary to solve the proposed problem and will be used for all structural analyses of the fork-type part. It is an element with 20 nodes. For the similarity of the study the input data must be identical. Thus, in figure 2 a the first input data application is presented, namely the application of the embeddings. These are made on the "sole" of the lever in the area of the two milled channels. The application of the embeddings is represented in the image by attaching a blue triangle to each selected node. As a loading state, a pressure of $2 \cdot 10^9$ N/m^2 is applied to the lower part of the four bores. These data will remain identical for all other analyses that will differ only by the choice of material.

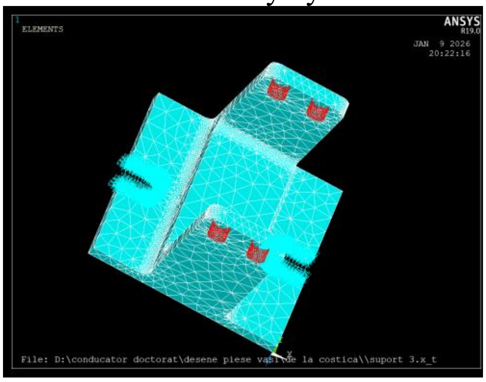
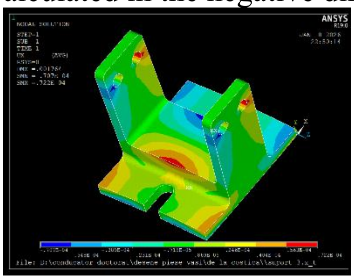
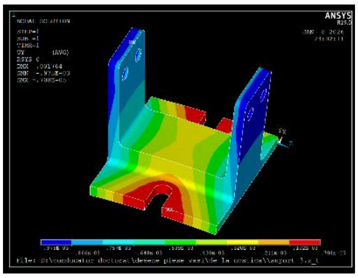


Figure 2. Presentation of the input data of the problem: the part embeddings and the application of pressure in the part bores

As a result of performing a structural analysis, the first series of results, namely the displacements of the structure, is presented in Figure 3. Figure 3 shows the displacements calculated on the three axes as well as the sum of the displacements. For all types of displacement analysis, the program presents a color map in which the maximum values are presented in red as displacements in the positive direction of the studied axis while the maximum values calculated in the negative direction of the studied axis are presented in blue.



a.



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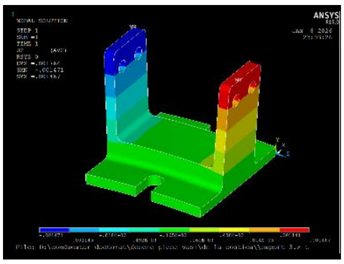
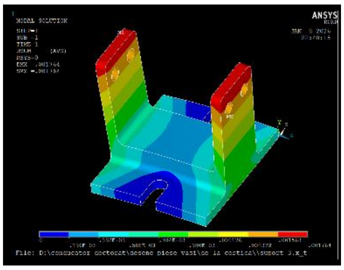


c.



d.

Figure 3 Presentation of the displacements of the fork - type part on the axes for the steel part:
a. – OX; b. – OY; c. – OZ; d. – USUM

Between the two extremes of the displacements these are presented with the other colors presented in each figure separately. Thus, the values presented in table 1 are calculated.

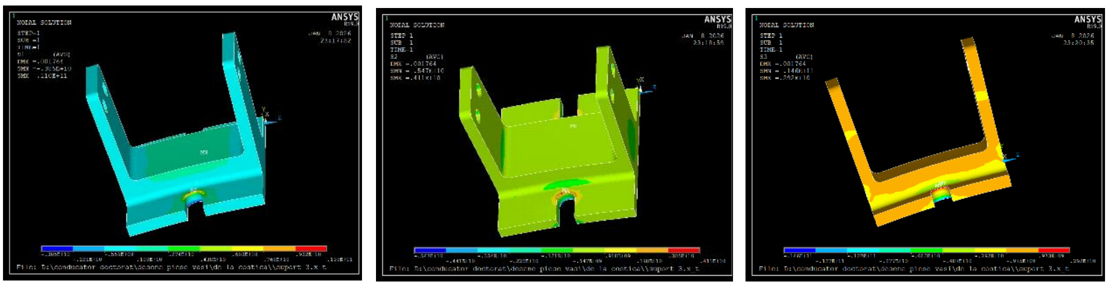
Table. 1 Calculation of deformations reported to the three axes OX, OY, OZ

	UX [mm]		UY [mm]		UZ [mm]	
Values	In the positive direction of the axis	In the negative direction of the axis	In the positive direction of the axis	In the negative direction of the axis	In the positive direction of the axis	In the negative direction of the axis
	0.072	0.07	0.007	0.97	1.46	1.47

As can be seen from the analysis of these values, on the OX and OY axes, the deformation values are of the order of hundredths of a millimeter or microns, values generally accepted in the machine building industry. Higher values are found along the OZ axis. However, this value, depending on the functional role of the part, may be acceptable. The second set of results provided by the structural analysis refers to the analysis of the state of mechanical stresses that appear in the studied structure as a result of the application, in this case, of pressure in the presented areas. The first set of stresses are those called principal stresses. These stresses by their definition calculate in a balanced way the state of tensile and compressive stresses in the case of S2 type stresses, while S2 type stresses calculate predominantly the state of tension in the material and S3 type stresses the state of compression of the material. Thus, in figure 4 a the calculation of the S1 type stresses is presented, in figure 4 b the S2 type stresses and for the S3 type stresses the stresses are calculated in figure 4 c, their values being presented in table 2. From the analysis of the presented values it can be observed how they do not exceed in any of the presented situations the value of the modulus of elasticity of the material. Consequently its behavior will be elastic. It is worth noting that however these values are relatively close to the modulus of elasticity of the steel especially in the case of tensile stresses for S1 type stresses and compressive stresses for S3 type stresses. The maximum values of the stresses appear in the area of the part embedding, in the upper part being tensile stresses and in the lower part compressive stresses.

Table. 2 Calculation of principal stresses S1, S2, S3

	S1 [N/m^2]		S2 [N/m^2]		S3 [N/m^2]	
Values	Tensile	Compression	Tensile	Compression	Tensile	Compression
	0.11 E11	0.38 E10	0.41 E10	0.54 E10	0.29 E10	0.14 E11



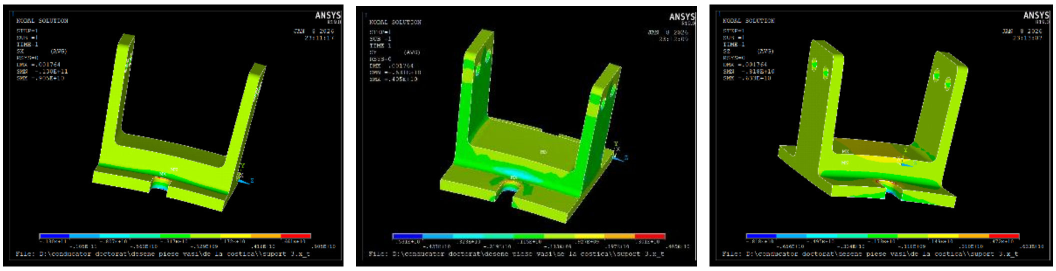
a. b. c.

Figure 4 Calculation of the principal stresses for the steel part: a. – S1; b. – S2; c. – S3

The second type of calculated stresses is the one that relates their value to the three orthogonal axes. In this sense, in figure 5, the SX, SY and SZ type stresses are presented. The values of these stresses are presented in table 3. In this case too, the stress values are important, with values close to the modulus of elasticity of the material for the tension state in the case of SX stresses and for the compressive stresses when calculating the stresses reported to the SZ axis. As a general overview, even in this situation the value of the modulus of elasticity is not exceeded. The maximum values are also found in the embedding area of the part, in the upper part the tensile stresses (red color) are present and in the lower part the compressive stresses (blue color).

Table. 3 Calculation of stresses reported to the three axes OX, OY, OZ

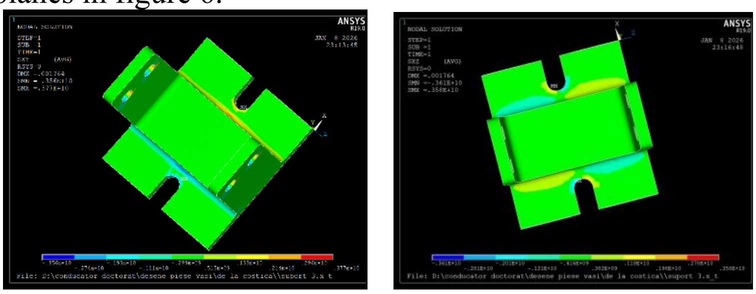
	SX [N/m^2]		SY [N/m^2]		SZ [N/m^2]	
Values	Tensile	Compression	Tensile	Compression	Tensile	Compression
	0.11 ·E11	0.38· E10	0.41· E10	0.54· E10	0.29· E10	0.14· E11



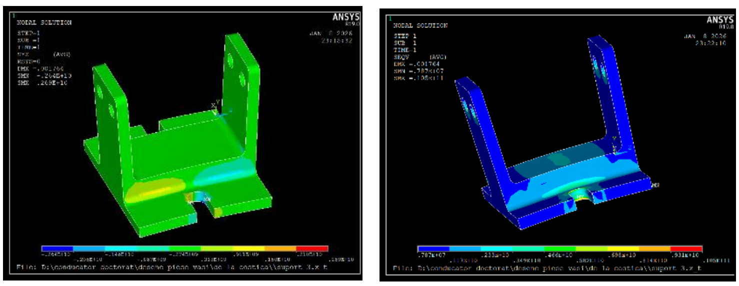
a. b. c.

Figure 5 Presentation of stresses related to the axes for the steel part:
a. – OX; b. – OY; c. – OZ

The third type of calculated stresses are shear stresses. These are presented in relation to the three orthogonal planes in figure 6.



a. b.



c. d.

Figure 6 Presentation of shear stresses for the steel part in the plane: a. – OX; b. OY; c. – OZ

The values of these stresses are presented in table 4.5. As can be seen from their analysis, as numerical values they no longer present the maximum values calculated in the case of the previous stresses, their values being calculated in a more compact domain. And in this case the excess of the elastic modulus of the material is not recorded. The arrangement of the maximum values of the stresses, however, is distributed differently from the previous cases in the sense that for example the maximum values for the SXY stresses are found at the intersection of the base plate with the upper part of the part. The fourth method of calculating the stresses is the so-called Von Mises. Their presentation is made in figure 6.6 d. In this case the calculation of the stresses is no longer made taking into account the state of tension or compression of the material. The stresses are calculated in this case only in absolute value, from their minimum values to their maximum values. As can be seen from the analysis of figure 6.6d, an increase in the maximum value is observed closer to the modulus of elasticity of the material but lower than it.

Table. 4 Calculation of stresses reported to the three orthogonal planes XOY, XOZ, YOZ and of the Von Mises stresses

	SXY [N/m^2]		SXZ [N/m^2]		SYZ [N/m^2]		VM [N/m^2]	
Val.	Tensile	Compression	Tensile	Compression	Tensile	Compression	Min.	Max.
	0.37·E10	0.35· E10	0.35·E10	0.36· E10	0.26·E10	0.26·E10	0.78·E7	0.1·E11

3. CONCLUSION

The paper presents a structural analysis of a part from the class of forks and levers made of steel. This analysis was designed to make comparisons between different materials, each of which results in different states of displacement and stresses in the material. The stresses that appear in the material are calculated relative to the OX, OY and Oz axes. At the same time, the S1, S2, S3 type stresses, the shear stresses in the three planes and Von Mises stress are also presented. For each of these stresses, a comparison is made with the modulus of elasticity of the material in order to observe how this part behaves in the presented working conditions.

4. REFERENCES

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