Numerical Analysis of Strength Properties of Anatomical General Surgical Tweezers

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The purpose of the work was to perform a numerical analysis, with the FEM method, of anatomical tweezers loaded with the forces of 10 and 50 N. Tweezers consist of two arms connected permanently by welding and are used for holding tissues. ANSYS software was used for the simulation. The force of 10 N expresses the gripping force during correct handling of tweezers, whereas the force of 50 N simulates a very high load on tweezers. Distribution of stresses, deformations and displacements created during tweezers' work was obtained as a result of the simulations conducted.

Keywords:, Computational materials science; Finite Element Method, Stress, Strain, Deformation, Anatomical surgical tweezers

A contemporary technological development makes it necessary to look for new constructional solutions that aim at the improvement of the effectiveness and quality of a product, at the minimization of dimension and mass as well as the increasing of reliability and dimension stability in the operation conditions [1-6]. Tweezers are classified as picking tools consisting of two arms produced in a plastic working process and connected permanently by welding. They are intended for short-term use as they lack pawls. The basic function of tweezers is to hold tissues during a surgical procedure. They can also be used for detaching the held organ or tissue, and also for removing different foreign objects from a body. Tweezers fall into the group of self-opening tools, however feature no spring parts; this function is ensured by appropriate elastic properties of the material they are made of. Tweezers generally are made of stainless steel [7-10].

Broadly conceived Computer Aided Design is an inevitable part of modern material design. This is mainly associated with the fact that computer techniques allow to solve numerically numerous important and complex, in the context of calculations, technical issues in a relatively simple and rapid manner [11-19]. The technological and economic focus of production engineering requires the optimisation of the existing manufacturing processes. Computer simulation is the right tool for gaining the necessary knowledge on such processes. It therefore seems obvious that smart prediction with the use of artificial intelligence tools is another step bringing us closer to the better exploration of the essence of research [20-33].

Due to the rapid development of computer-aided techniques, the Finite Elements Method (FEM) is currently one of the more important numerical analysis methods and is widely used in many fields of materials engineering. The created numerical models and computer simulations enable to precisely describe the structure and to identify the properties of new materials [34-40] analysed within their entire volume and to describe features of these new materials [41] or work of entire elements eg. in engines [42].

The created numerical models and computer simulations enable to precisely describe the structure and to identify the properties of the materials analysed within their entire volume. Laboratory examinations in the field of metal science allow, in many cases, to measure only the chosen values and parameters within limited areas due to complex shapes and variable properties of the investigated parts' cross section. The FEM method has also been applied for determination of material properties such as hardness, stresses, displacements and deformations [43-51].

The work presents the distribution of stresses and displacements in a numerical model of tweezers loaded with various forces.

Investigation methodology and computer simulation

Anatomical general surgical tweezers with the total length of 90 mm were designed in Autodesk Inventor Professional 2014 software to perform computer simulation of the distribution of stresses and deformations based on documents made available by manufacturers of surgery instruments (fig. 1). Dimensional data of the tweezers and the construction form are shown in figure 2.

A mesh of finite elements was applied onto a geometrical model of the tweezers representing their actual dimensions; a model was obtained as a result of discretisation with a finite number of elements of 110,000 and with a number of nodes of 170,000, as shown in

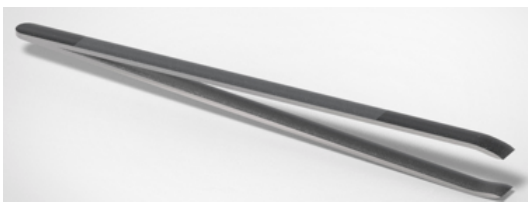

Fig. 1. Geometric model of anatomical tweezers

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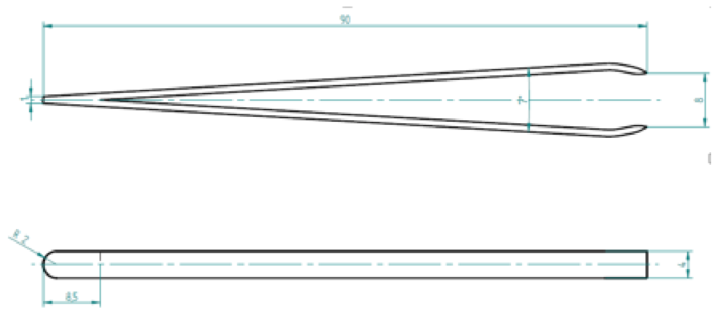

Fig. 2. Dimensional drawing of designed anatomical tweezers

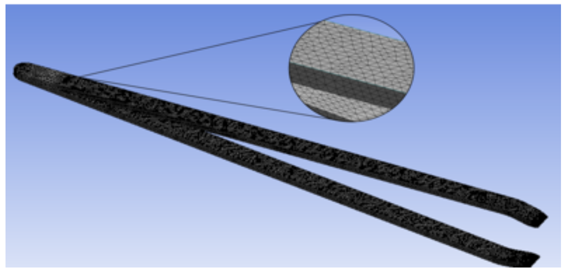

Fig. 3. Model of anatomical tweezers after discretization

figure 3. A geometrical model of the tweezers was fixated permanently in the gripping part and a force of 10 and 50 N was applied onto the arms.

The load was distributed evenly onto the external surfaces of both arms; the force of 10 N reflects the operator's gripping force during correct use whereas 50 N represents a very high load on the tweezers (fig. 4). The tweezers are made of X20Cr13 stainless steel, with the chemical composition shown in table 1. Material selection was made according to PN-EN 10088-1: 2007, with a list of stainless steels with mechanical properties shown in table 2.

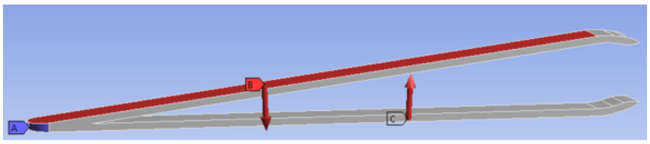

Fig. 4. Boundary conditions; A-fixed support, B,C - the same forces

Results and discussions

Distribution of stresses, deformations and displacements created in the tweezers' during loads was obtained as a result of the simulations conducted. It was observed both, in case of the loading force of 10 and 50 N, that maximum values of stresses, deformations and displacements are located in the same places.

For the load of 10 N, the maximum value of stresses was 451 MPa, while for the load of 50 N it was 639 MPa. In both cases, the value of the maximum stress is located in the place where tweezers' arms are welded. Minimum values were obtained in the place where they were fastened. Variable bending of arms depending on the load applied is shown on diagrams (fig. 5).

The maximum deformation for the load of 10 N with the value of 0.2% is located near the place where the both arms of tweezers are welded. By analogy, for a load of 50 N, the place of maximum deformation also occurs within the area where both tweezers arms are welded and it accounts for 0.3%. The minimum value in both cases was

Table 1
CHEMICAL COMPOSITION OF X20Cr13 STEEL

Chemical composition (%) – maximum value								
C	Si	Mn	P	S	Cr	Mo	Ni	V
0.16 – 0.25	1	1.5	0.04	0.02	12 - 14	-	-	-

Table 2
MECHANICAL PROPERTIES OF X20Cr13 STEEL

Density [g/cm3]	Modulus of Elasticity [GPa]	Poissons Ratio	Tensile Strength, Ultimate, R_m [MPa]	Tensile Strength, Yield, R_e [MPa]
7.7	215	0.3	700	600

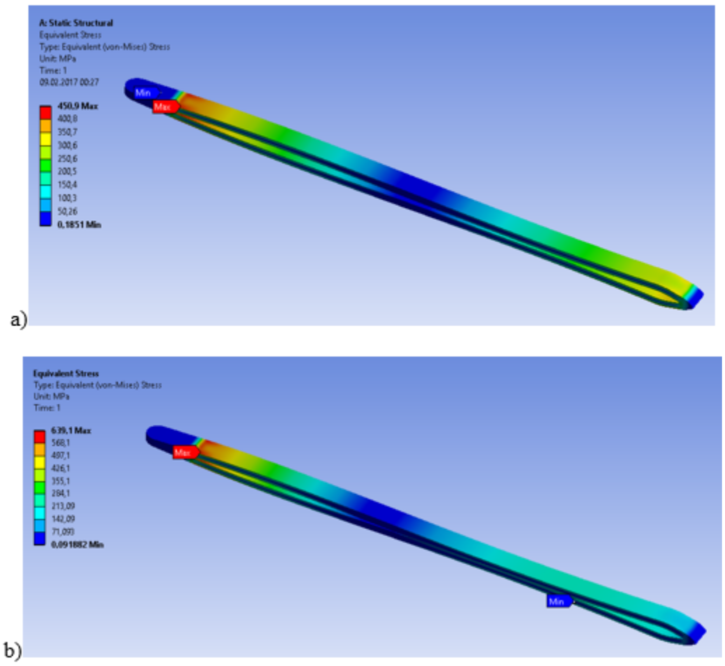

Fig. 5. Von Misses Stress obtained using variable loads a) 10 N, b) 50 N

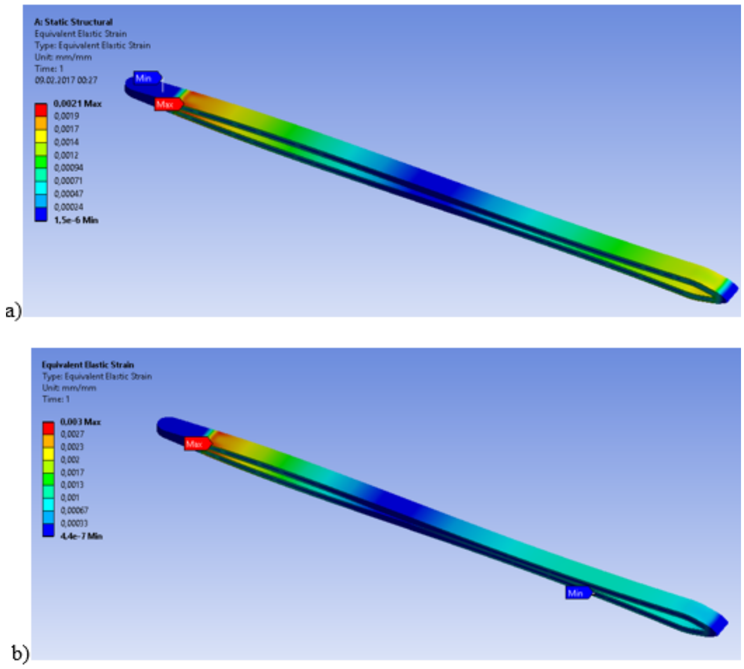

Fig. 6. Von Misses Stain obtained using variable loads a) 10 N, b) 50 N

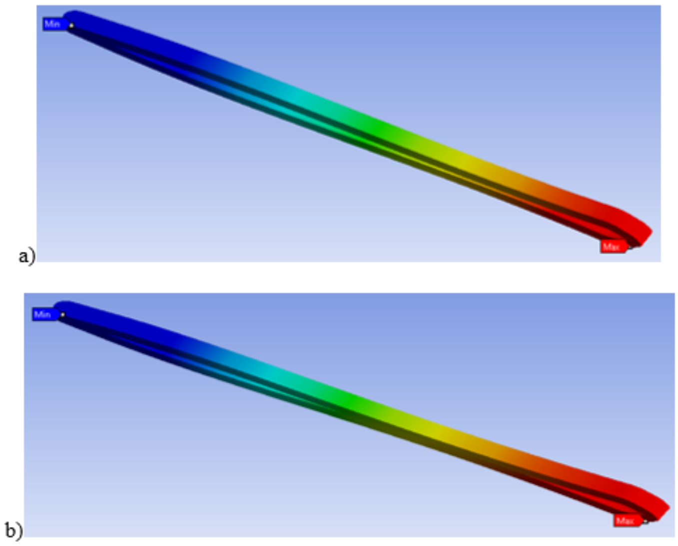

Fig. 7. Total deformation obtained using variable loads a) 10 N, b) 50 N

obtained in the place where tweezers are fixed permanently (fig. 6).

The identical value of maximum displacement of 4 mm located in the upper part of tweezers was seen for both loads. The minimum value is located in the place of fastening and is 0 (fig.7). The results of the numerical analysis of distribution of stresses, deformations and displacements in the anatomical tweezers made of X20Cr13 steel are listed in table 3.

Table 3
THE RESULTS OF ANALYSIS OF ANATOMICAL TWEEZERS MADE OF STEEL X20Cr13.

ANALYSIS		I	II
total load		10 N	50 N
maximum value	Stress [MPa]	451	639
	Stain [mm]	4	4
	Deformation [%]	0.2	0.3

Conclusions

The Finite Elements Method is an excellent tool for solving engineering tasks and it is cheaper to perform a simulation than to perform laboratory tests; moreover, it greatly reduces the time of problem solving and produces reliable results. Laboratory examinations in the field of metal science allow, in many cases, to measure only the chosen values and parameters within limited areas due to complex shapes and variable properties of the investigated parts' cross section.

It was observed based on maximum stresses and deformations that for a load of 10 N, the tweezers are working within an elastic range without causing any changes or damages to their constructional form. Yield strength is exceeded for a load of 50 N, both, based on the maximum stress and the occurring deformations. This fact may signify that the system is working in the plastic range, which may directly influence the tweezers' usable properties. The distance between the tweezers arms at the constructional stage was 8 mm, and a maximum displacement for each arm of 4 mm was obtained for both analyses. The obtained result of displacements signifies the correctness of the analysis performed and that contact exists between the tweezers arms under the influence of load.

Acknowledgements: The publication was partially financed by statutory grant from Faculty of Mechanical Engineering, Silesian University of Technology for year 2017.

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Manuscript received: 15.11.2017