Computer Simulation of Static Tensile Test Using the Finite Elements Method

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The work presents the results of a computer simulation of one of the most widespread strength tests, i.e. a static tensile test, performed with the use of two design tools - ANSYS and SolidWorks software. Strength tests were performed with the ZWICK Z100 tensile machine. The shaped sections used in the analysis were made of AW-6060 aluminium alloy. The computer simulation results were referenced to the actual tensile test results and it was found they are comparable. It can be concluded on such basis that a computer simulation is an alternative to time-consuming and costly laboratory tests.

Keywords: analysis and modeling, computational materials science, finite element method, strength tests

The finite elements methods (FEM) is now one of the most popular methods for solving various engineering issues [1-4]. The method’s key advantage is versatility because different areas with complicated geometry, also those inhomogeneous and anisotropic, can be easily schematised, which makes it eligible as a good tool for modelling various engineering issues [5-12].

Generally, the FEM is a reliable method of solving differential partial equations after their prior discretisation in the appropriate space. Discretisation is carried out locally in small areas with simple, but any shape (called finite elements). This is a typically computer-based method of determination of strains, deformations, generalised forces and displacements in the analysed construction of any type. The method is based on the splitting of a system into a finite number of finite elements. Certain approximations are made within each element, and unknowns are represented by interpolation functions by means of values of such functions in a finite number of points, called nodes [13-16].

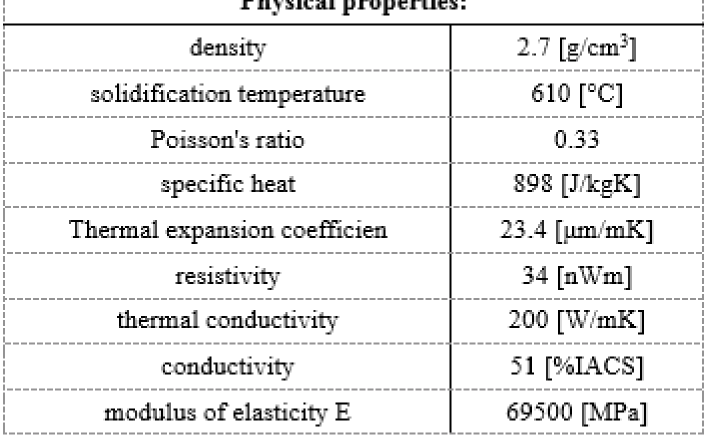
Calculations can be carried out in a two-dimensional space, where discretisation, usually, consists of dividing an area into triangles. Such a solution allows to calculate the values occurring in the section of a given system. This entails certain constraints through, resulting from the specificity of the issue being solved. Considering the progress of computer technologies in the recent years, the majority of simulation packets are capable of solving issues in a three-dimensional space. In discretisation, an area is usually divided into tetrahedrons. Such modelling is deprived of fundamental constraints of the 2D technology, but is much more demanding in terms of a computer memory and computing capacity [17-19].

The material the samples are made of is AW-6060 aluminium alloy featuring medium tensile strength and medium fatigue strength [20-23]. It is susceptible to decorative anodising and welding. It has found its application in manufacture of rods and aluminium profiles. Owing to high susceptibility to pressing, profiles with complicated shapes can be produced [24-30].

The aim of the work is computer simulation of a static tensile test and to compare its results with results of a station-based tensile test.

Investigation methodology and computer simulation

A static tensile test was carried out in accordance with all OHS rules and regulations on the ZWICK Z100 tensile machine for samples with a circular section and the diameter of a work part of 10 [mm], made of AW-6060 aluminium alloy. Table 2 presents the chemical composition of AW-6060 aluminium alloy; table 1 presents physical properties of a given aluminium alloy. The samples



Physical properties:	
density	2.7 [g/cm^3]
solidification temperature	610 [°C]
Poisson's ratio	0.33
specific heat	898 [J/kgK]
Thermal expansion coefficien	23.4 [μm/mK]
resistivity	34 [nWm]
thermal conductivity	200 [W/mK]
conductivity	51 [%IACS]
modulus of elasticity E	69500 [MPa]

Table 1
PHYSICAL PROPERTIES OF ALUMINIUM AW-6060

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PA38 / 6060 [%]									
Si	Fe	Cu	Mn	Mg	Cr	Zn	Ni	Zr	Ti
0.3	0.1	Max	Max	0.35	Max	Max	-	-	Max
0.6	0.3	0.1	0.1	0.6	0.05	0.15	-	-	0.1

Table 2
CHEMICAL COMPOSITION OF ALUMINIUM AW-6060

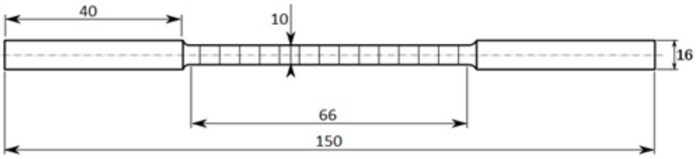


Fig. 1. Dimensioned sample

Fig. 3. Samples after rupture

Fig. 2. Samples before test

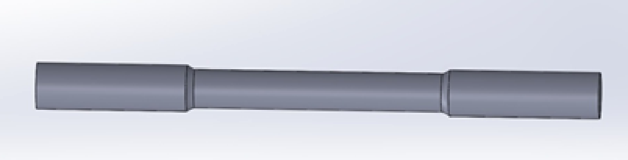
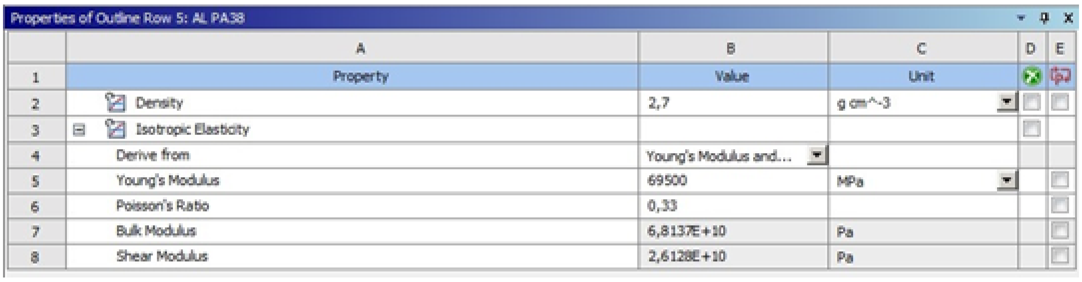


Fig. 4. Finished sample made in SolidWorks



Properties of Outline Row 5: AL PA38

	A	B	C	D	E
1	Property	Value	Unit		
2	Density	2,7	g cm^-3	☐	☐
3	Isotropic Elasticity			☐	
4	Derive from	Young's Modulus and...			
5	Young's Modulus	69500	MPa		☐
6	Poisson's Ratio	0,33			☐
7	Bulk Modulus	6,8137E+10	Pa		☐
8	Shear Modulus	2,6128E+10	Pa		☐

Fig. 5. Properties of the material typed in ANSYS Workbench

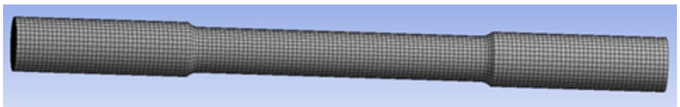


Fig. 6. Generated mesh

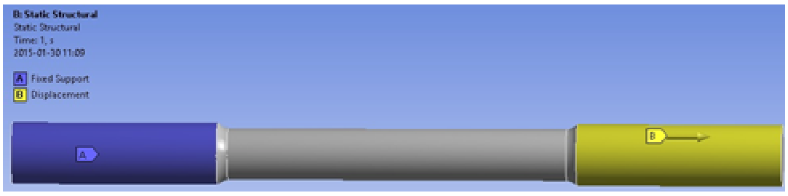


Fig. 7. Determination of fixed support (A) and displacement (B) on sample holders

used for testing were made of aluminium rods with the dimensions shown in figure 1 and figure 2 presents aluminium samples before a strength test and figure 3 shows samples after rupture.

A geometric sample model was prepared in SolidWorks software, and was then exported to ANSYS. Figure 4 shows a geometric sample model with the actual dimensions. Material data for samples, necessary to perform a computer simulation, is shown in figure 5. A net of finite elements shown in figure 6 was generated in ANSYS software for the mentioned geometric model. Boundary conditions were then applied onto the geometric model (fig.7), and one of the holders was immobilised for this purpose and directional displacement was applied on the other, which was read from figure 9.

Results and discussions

Figure 8 shows the results of a static tensile test as a chart of all four samples. It can be noticed that sample 1 deviates from the rest, it has no effect on further results, though.

Linear range of tensile test results was only taken into account for further tests, involving mainly computer simulation, as shown in figure 9. The values of relative elongations were read from the charts shown in figure 9 and were juxtaposed in table 3.

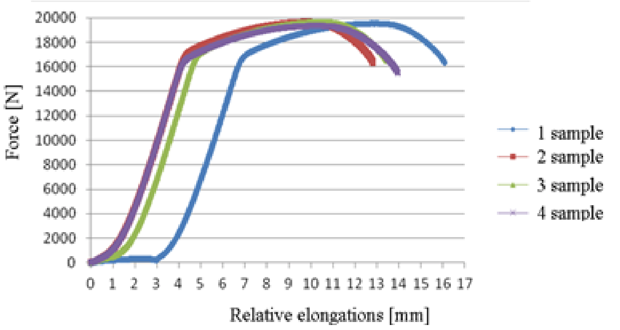


Fig. 8. Results of the static temsile tests of four samples in graph form

sample number	Δl [mm]
sample 1	3.39
sample 2	3.20
sample 3	3.30
sample 4	3.20
average	3.27

Table 3
VALUES OF RELATIVE ELONGATIONS

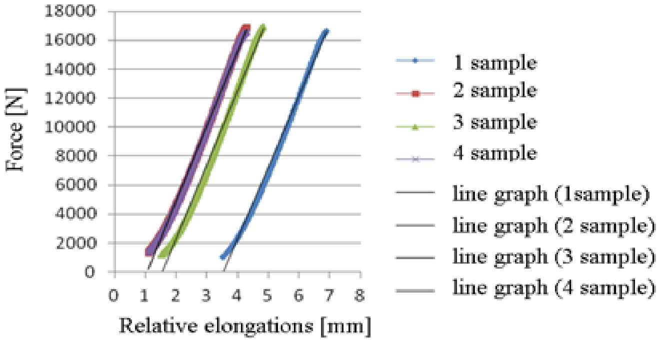


Fig. 9. Linear range of results from static tensile tests

The strain σ was calculated according to formula 1 on the basis of the force F value read from the chart and by knowing the initial diameter of sample S. The relative deformation ε was then calculated according to formula 2 by reading absolute elongation of sample Δl and lengths of the initial work part of the sample lo from chart 9. The last stage was the determination of actual strains based on the relative deformation ε and strain ε according to formula 3.

$$\sigma = \frac{F}{S} = \frac{16764}{78{,}5398} = 213{,}4559 \qquad (1)$$

where:

σ - tresses [MPa]

F - force [N],

S - initial cross-section of shaped section [mm^2]

$$\varepsilon = \frac{\Delta l}{l} = \frac{3{,}27}{66} = 0{,}049545 \qquad (2)$$

where:

ε - relative deformation

Δ l - absolute elongation [mm],

l - length of the work part of the sample prior to rupture [mm].

The calculations above indicate, for maximum strain σ = 213.4559 [MPa] and maximum relative deformation ε = 0.049545, that the maximum actual strains account for:

$$\frac{\sigma}{\varepsilon} = \frac{213{,}4559}{0{,}049545} = 4308{,}082 \qquad (3)$$

The results of computer simulation of strains resulting from elongation of 3.27 [mm] are presented graphically and in a table (fig. 10). The cumulation of strains in the central part of the sample is visible, in the so-called test section on which, normally, for correctly mounted samples and appropriately conducted test - material continuity is compromised.

A comparative analysis was undertaken of the results of strains obtained by computer simulation with the results of calculations, and a static error was determined.

The results of strain simulations are fully adequate for the results of the calculations, and a statistic error is not more than 2.3 %.

Conclusions

The above article presents results of a static tensile test performed with an experimental method based on which the value of strains was calculated. Computer simulation was made with the Finite Elements Method by determining boundary conditions identical as in a static tensile test:

- the value of strains obtained in a station-based test was 4308.082 [MPa],

- the value of strain in a test section produced from computer simulation was 4408.5 [MPa].

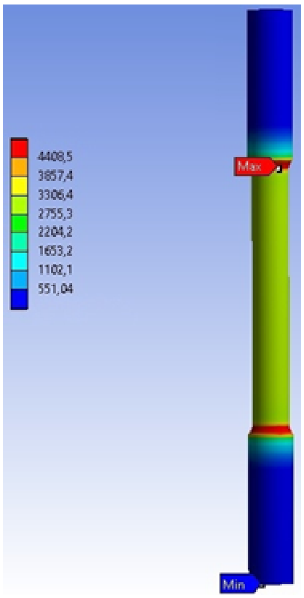


Fig. 10. Graphical representation of the results of computer simulation of stress

The obtained results of strains in the test section of the sample after performance of simulation were compared with the results of experimental investigations and an error of 2.28 [%] was calculated.

It can be asserted, considering the ratios of actual results and the simulated results described above, that computer-based tools aiding material engineering allow to achieve tests results susceptible to a certain small error resulting from the scatter of parameters, both, for materials and for the processes they are subjected to.

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