SOI: 1.1/TAS DOI: 10.15863/TAS
International Scientific Journal
Theoretical & Applied Science

p-ISSN: 2308-4944 (print) **e-ISSN:** 2409-0085 (online)

Year: 2020 **Issue:** 04 **Volume:** 84

Published: 21.04.2020 **http://T-Science.org**

QR – Issue QR – Article

Denis Chemezov
Vladimir Industrial College
M.Sc.Eng., Corresponding Member of International Academy of Theoretical and Applied Sciences, Lecturer, Russian Federation
https://orcid.org/0000-0002-2747-552X
chemezov-da@yandex.ru

Irina Medvedeva
Vladimir Industrial College
Master of Industrial Training, Russian Federation

Egor Salimov
Vladimir Industrial College
Student, Russian Federation

Evgeniy Varavin
Vladimir Industrial College
Student, Russian Federation

Vyacheslav Matveev
Vladimir Industrial College
Student, Russian Federation

Evgeniy Volnov
Vladimir Industrial College
Student, Russian Federation

Arseniy Korolev
Vladimir Industrial College
Student, Russian Federation

RECOMMENDATIONS FOR ASSESSMENT OF STRESS-STRAIN STATE OF THE METAL CYLINDRICAL SPECIMEN WHEN PERFORMING THE TENSILE TEST

***Abstract**: Results of the tensile test of the metal cylindrical specimen obtained by the computer simulation are presented in the article. Intensity of stress and strain of material over the entire time of stretching the specimen is calculated. The dependencies of strain and stress from variable load and elongation of the specimen, taking into account changing the temperature of material in the zone of predicted destruction, are obtained.*

***Key words**: the specimen, the tensile test, strain, stress, the time.*

***Language**: English*

Citation: Chemezov, D., et al. (2020). Recommendations for assessment of stress-strain state of the metal cylindrical specimen when performing the tensile test. *ISJ Theoretical & Applied Science, 04 (84),* 352-356.

Soi: http://s-o-i.org/1.1/TAS-04-84-61 ***Doi***: crossref https://dx.doi.org/10.15863/TAS.2020.04.84.61

***Scopus ASCC**: 2210.*

Introduction

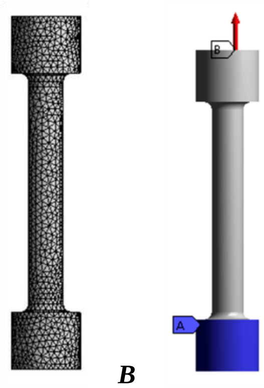
Determination of the number of the mechanical properties of metals is performed by the standard laboratory tests for tensile or compression of the specimens on the special machines [1-10]. The flat or cylindrical metal specimens are subjected to variable load until material is partially destroyed. Essence of the method is in determining elongation of the specimen under load and building the diagram of conditional stresses from the strain degree of material.

The mechanical properties of metals and alloys are obtained on the basis of the large number of the performed tests for tensile or compression of the specimens. The neck on the specimen, formed during plastic deformation, allows determining the destruction place of material. The laboratory tests of the specimens allow determining stress-strain state of materials in the general form. Volumetric deformed state of the specimen material can be represented by the computer simulation of the stretching process in the three-dimensional statement. This will allow obtaining the dependencies for calculating strain and stress, taking into account changing the temperature of the specimen material.

Materials and methods

The simulation of the stretching process of the cylindrical specimen on the testing machine was performed in the Ansys software environment. The three-dimensional solid model of the steel specimen with the following dimensions was built for implementation of the experiment: the overall length of the specimen – 62 mm, the initial diameter of the specimen – 6 mm, the distance between shoulders of the specimen – 42 mm, the diameter of the grip section – 12 mm, the length of the grip section – 10 mm, the radius of fillet – 1.5 mm. The specimen material had the following properties: density – 7850 kg/m^3, the coefficient of thermal expansion – 1.2×10^{-5}, specific heat – 434 J/(kg×K), thermal conductivity – 60.5 W/(m×K), resistivity – 1.7×10^{-7} Ohm×m, compressive yield strength – 250 MPa, tensile yield strength – 250 MPa, tensile ultimate strength – 460 MPa, the reference temperature – 22 °C, alternating stress in the range of 10…1×10^6 cycles – 3999…86.2 MPa, the strength coefficient – 920 MPa, the strength exponent – -0.106, the ductility coefficient – 0.213, the ductility exponent – -0.47, the cyclic strength coefficient – 1000 MPa, the cyclic strain hardening exponent – 0.2, the Young's modulus – 2×10^5 MPa, the Poisson's ratio – 0.3, the bulk modulus – 1.6667×10^5 MPa, the shear modulus – 76923 MPa, relative permeability – 10000.

The initial conditions for modeling the stretching process of the metal specimen are presented in the Fig. 1.



A *B*

Figure 1 – The initial conditions for modeling: *A* – dividing the specimen model into the finite elements; *B* – setting the specimen fixation (A) and direction of load application on the specimen (B).

The solid model of the cylindrical specimen was divided into 16107 finite elements, which allowed to obtain the detailed display of stress-strain state of material. The specimen model was positioned vertically. The lower part of the specimen was rigidly fixed in the device of the testing machine (not shown). Variable load along the axial line acted on the upper part of the specimen. Changing load from the stretching time of the cylindrical specimen is presented in the table 1.

Table 1. Changing load from the stretching time.

Time, s	0	5×10^{-5}	1×10^{-4}	1.5×10^{-4}	2×10^{-4}	2.5×10^{-4}	3×10^{-4}	3.5×10^{-4}	4×10^{-4}
Force, N	70000	1.4×10^5	2.1×10^5	2.8×10^5	3.5×10^5	4.2×10^5	4.9×10^5	5.6×10^5	6.3×10^5
Time, s	4.5×10^{-4}	5×10^{-4}	5.5×10^{-4}						
Force, N	7×10^5	7.7×10^5	8.4×10^5						

The maximum energy error of 0.1 was taken into account in the calculation. The shell shear correction factor was accepted 0.8333. The solver target is the AUTODYN.

Results and discussion

The specimen model was subjected to elongation under the action of variable increasing load. The degree of strain and stress of material was determined based on the calculated contours applied to the specimen model after stretching. Stress-strain state of the specimen model after stretching is presented in the Fig. 2.

Maximum deformation occurred in the volume of the grip section of the specimen. The specimen lengthened by 12.6% of the overall length. The contours of maximum shear elastic strain of the red indicate the place of probable partial destruction of the specimen material. Destruction occurred below the radius of fillet. The initial diameter of the specimen is subjected to equivalent stress along the entire length at the moment of destruction. The radii reduce stress of the specimen material by 1.5 times. Destruction of the specimen was accompanied by increasing the material temperature in the deformation zone by almost 10 times.

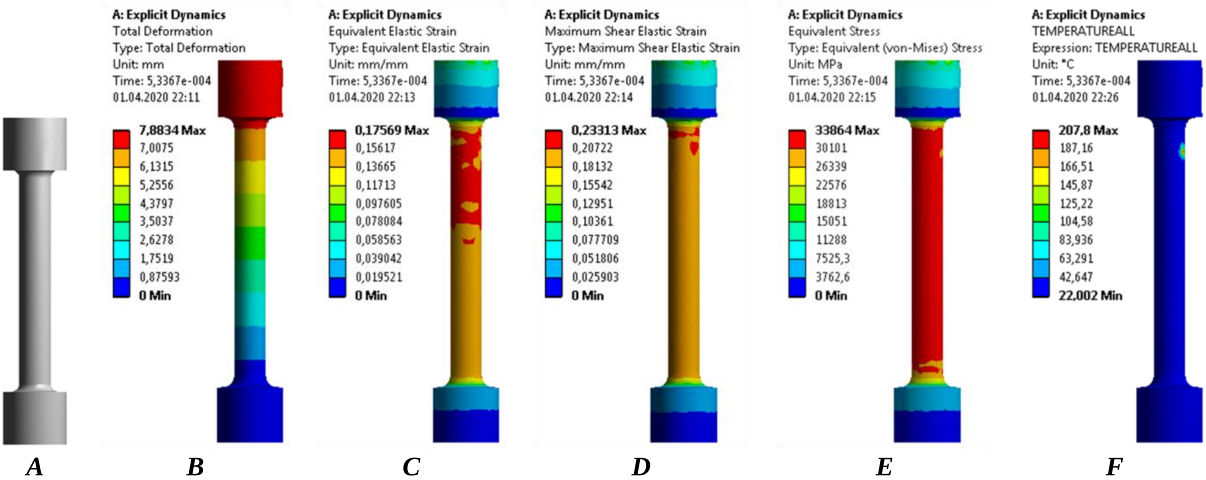


Figure 2 – Stress-strain state of the specimen model after stretching: *A* – the specimen model before stretching; *B* – total deformation of the specimen; *C* – equivalent elastic strain of the specimen; *D* – maximum shear elastic strain of the specimen; *E* – equivalent stress of the specimen; *F* – the temperature of the specimen after deformation.

Equivalent elastic strain $\bar{\varepsilon}_{el}$, maximum shear elastic strain γ_{el}, equivalent stress σ_{eq} and the temperature T of the specimen material can be expressed through the specimen elongation Δl and variable load F (kN). The calculated formulas (1-4) are valid if the ratio of the initial diameter to the distance between shoulders of the specimen is 1:7.

$$\bar{\varepsilon}_{el} = \frac{3F + 4960\Delta l + 690}{250000} \quad (1)$$

$$\gamma_{el} = \frac{F + 28050\Delta l + 4520}{1000000} \quad (2)$$

$$\sigma_{eq} = \frac{13125F - 4.2584455 \cdot 10^{7}\Delta l - 8.484988 \cdot 10^{6}}{10000} \quad (3)$$

$$T = \frac{5442F - 424765\Delta l - 222082}{10000} \quad (4)$$

The dependencies of total deformation, equivalent stress, pressure, and strain velocity of material from the specimen stretching time are presented in the Figs. 3-6.

Total deformation and equivalent stress of the specimen material change by one function. The values of these parameters increase and decrease (for the some time ranges of the stretching process). This indicates that elastic strains occur in the specimen material when stretching. The range of minimum pressure in material has the negative values that characterize the specimen stretching, the range of maximum pressure in material has the positive values that characterize the specimen compression. So as destruction of the specimen occurs at the end of the time range of the stretching process then strain velocity of material at this moment will be the highest.

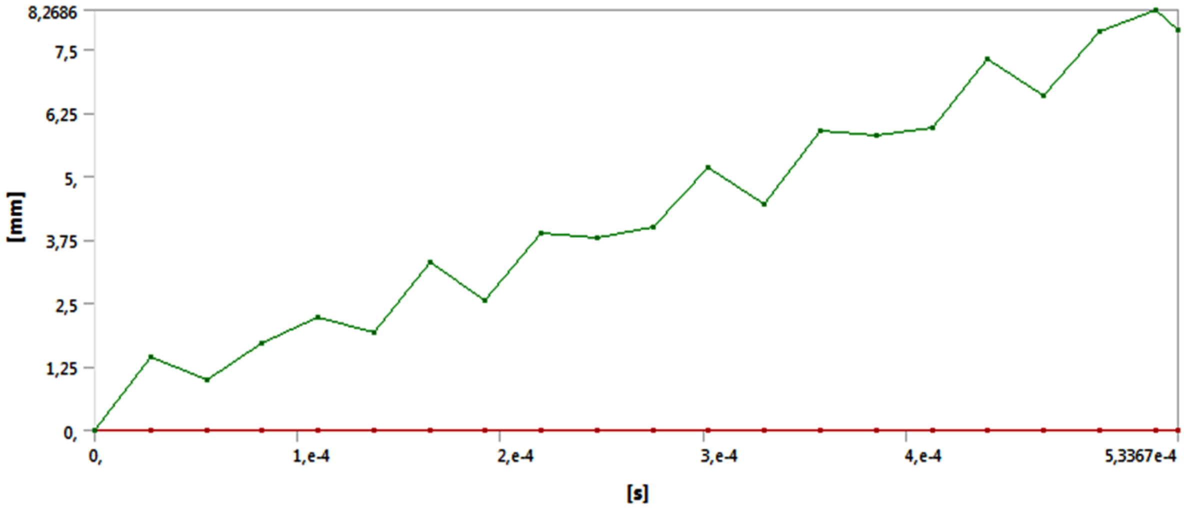


Figure 3 – The dependencies of total deformation of material from the specimen stretching time.

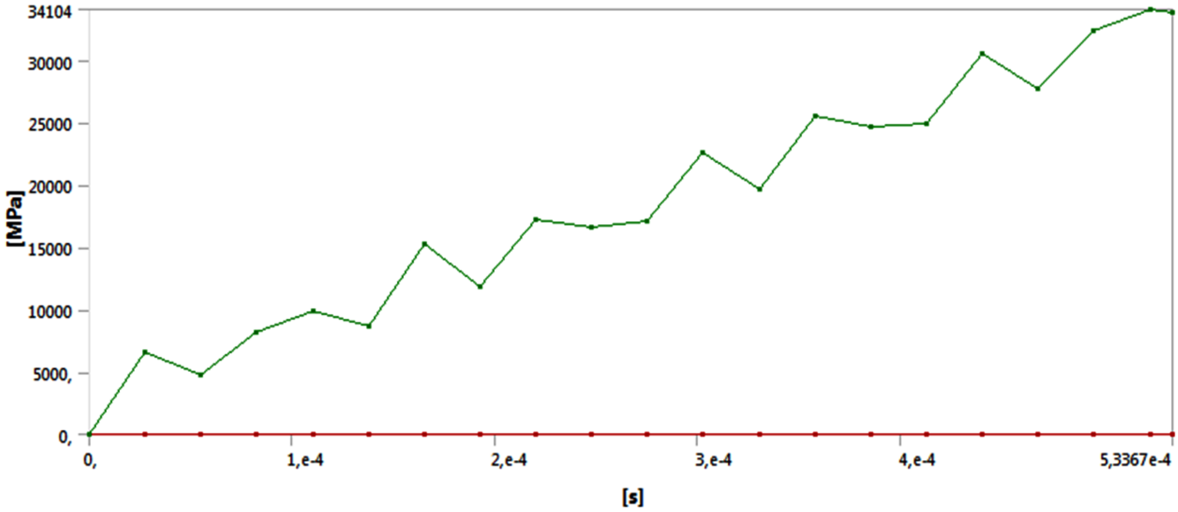


Figure 4 – The dependencies of equivalent stress of material from the specimen stretching time.

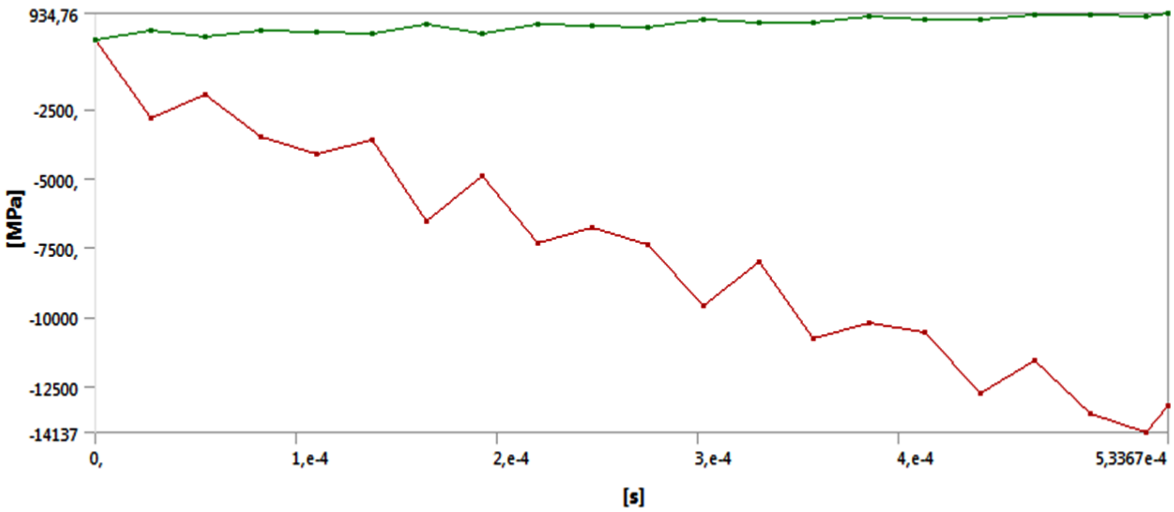


Figure 5 – The dependencies of pressure in material from the specimen stretching time.

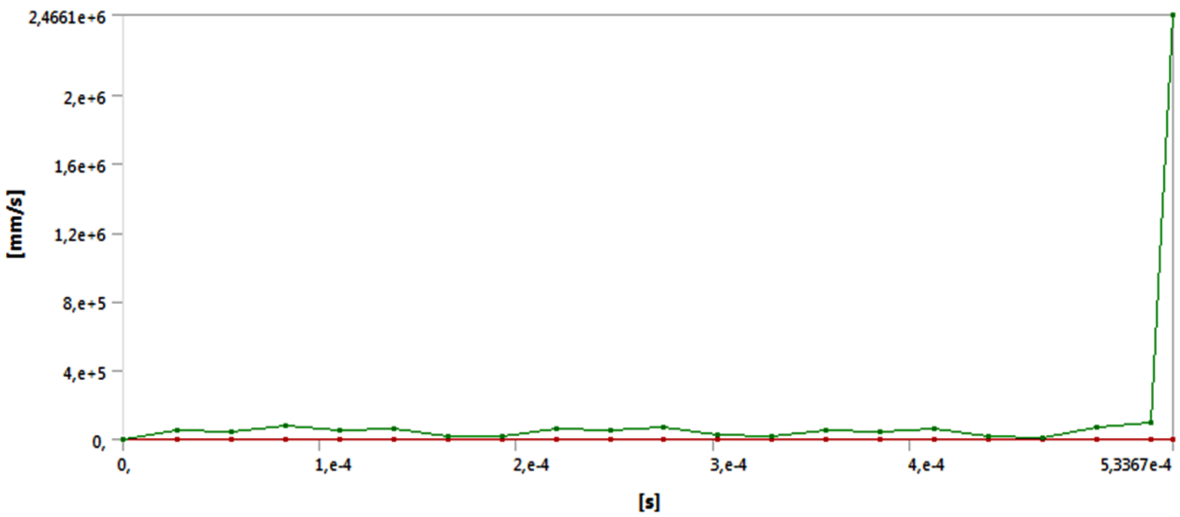


Figure 6 – The dependencies of strain velocity of material from the specimen stretching time.

Conclusion

The following recommendations were formulated based on the analysis of modeling the stretching process of the cylindrical specimen on the testing machine:

1. Maximum plastic deformation occurred in the specimen material, where variable load was applied.

2. The calculated values of equivalent elastic strain, maximum shear elastic strain, equivalent stress and the temperature of material can be obtained by substituting the known values of load and elongation of the specimen into the analytical formulas (1-4). The temperature of material increases by 10 times when maximum shear elastic strain of the specimen is 0.233 mm/mm.

3. Material is subjected to plastic and elastic strains during stretching the specimen. Elastic strains occur up to destruction of the specimen material.

References:

1. (2013). ASTM E8/E8M-13. *Standard Test Methods for Tension Testing of Metallic Materials*.
2. (2009). ISO 6892-1. *Metallic materials. Tensile testing. Method of test at ambient temperature*.
3. (2011). ISO 6892-2. *Metallic materials. Tensile testing. Method of test at elevated temperature*.
4. Czichos, H. (2006). Springer Handbook of Materials Measurement Methods. *Berlin: Springer*, 303-304.
5. Nicholas, T. (1981). Tensile testing of materials at high rates of strain. *Experimental Mechanics 21*, 177-185.
6. Holt, D. L., Babcock, S. G., Green, S. J., & Maiden, C. J. (1967). The Rate Dependence of the Flow Stress of Some Aluminum Alloys. *Trans. ASM, 60*, 152.
7. Li, H., Fu, M. W., Lu, J., & Yang, H. (2014). Ductile fracture: Experiments and computations. *Int. J. Plast.*, *27*, 147-180.
8. Kraisnik, M., Vilotic, D., Sidanin, L., & Stefanovic, M. (2015). Various Approaches to Defining the Criteria of Ductile Crack in Cold Bulk Forming Processes. *Ann. Fac. Eng. Hunedoara*, *13*, 213-218.
9. Goijarets, A. M., Govaert, L. E., & Baaijens, F. P. T. (2001). Evaluation of ductile fracture models for different metals in blanking. *J. Mater. Process. Technol.*, *110*, 312-323.
10. Bjorklund, O., Larsson, R., & Nilsson, L. (2013). Failure of high strength steel sheets: Experiments and modelling. *J. Mater. Process. Technol.*, *213*, 1103-1117.