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EXPERIMENTAL STUDY OF TENSILE FAILURE OF THE STEEL SPECIMEN

***Abstract**: The results of experimental tensile testing of round steel specimens were presented in the article. The dependence of load change on the specimen elongation was obtained. The structure of the specimen material in the failure zone was studied.*

***Key words**: the specimen, tensile testing, failure, load, material.*
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Introduction

During tensile testing, the metal specimen [1] of the certain shape is fixed with grip sections into the grips of the testing machine and is subjected to continuous, smooth deformation until failure. The stages of material deformation during tensile are displayed on the tensile diagrams, which present the dependence of applied load on the elongation value of the "reduced" section of the specimen. The mechanical properties of material during tensile are calculated based on this dependence.

Currently, the large number of studies (theoretical and practical) have been conducted on this topic [2-10]. Elastic limit, yield strength and tensile strength of materials with different carbon content were determined. The volumetric deformed state of the round and flat specimens during tensile was obtained by the computer simulation. The process of materials tension at different loading rates of the specimens was described.

On the example of tensile study of the several steel specimens with low loading rate, it is possible to determine the error in calculating the mechanical properties by mathematical processing the obtained experimental data and observing the process of material failure.

Materials and methods

Tensile testing of the round steel specimens was performed three times for obtaining the average values of the mechanical properties of material and predicting the failure zone of the specimen. Three round specimens were made of Fe37-3FN steel (EN). The specimens before testing had the following dimensions: the overall specimen length – 43 mm, the diameter of the "reduced" section of the specimen – 3.8 mm, the length of the "reduced" section of the specimen – 27 mm, the length of the grip section of the specimen – 8 mm, the diameter of the grip section of the specimen – 8.7 mm, the radius at the base of the grip section – 2 mm. The round specimens for performing tensile testing are presented in the Fig. 1.

Figure 1 – The specimens for performing tensile testing.

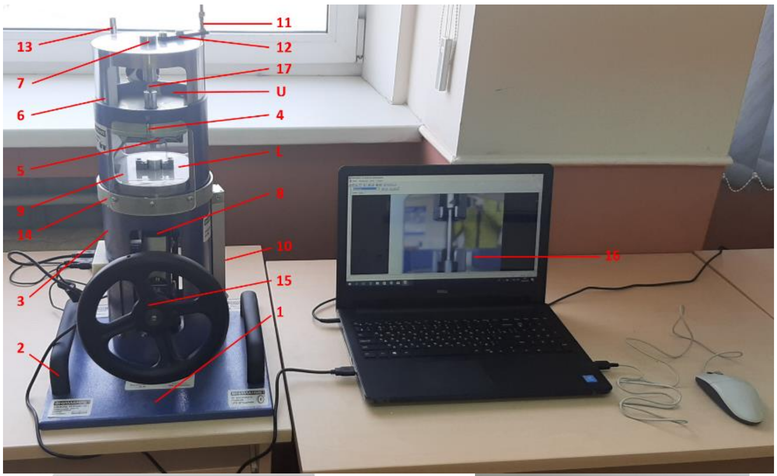
Tensile testing was performed on the "TM-20" special testing machine. The machine is designed for testing the specimens made of various materials for tensile, compression, shear and bending. The main technical characteristics of the machine:

- maximum force developed by the machine – 20 kN;
- the maximum stroke of the movable frame (the support) – 38 mm;
- the measurement range of displacement of the movable support – 0…20 mm;
- the scale factor of meter of displacements of the movable frame (the support) – 0.01 mm;
- the dimensions of the upper workspace in the "tensile" zone – not less than 35 mm;
- the dimensions of the lower workspace in the "compression" zone – not less than 51 mm;
- the machine length – 320±20 mm;
- the machine width – 320±20 mm;
- the machine height – 550±20 mm;
- average time until failure – not less than 500 hours;
- the weight – no more than 30 kg.

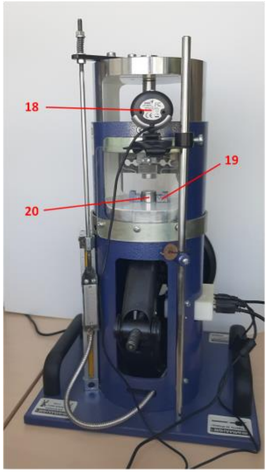
The general view of the testing machine is presented in the Fig. 2. The upper and lower devices for setting the round specimen into the machine are presented in the Fig. 3.

On the base *1* of the machine there are the column *3* and the transport handles *2* for carrying. The elastic element *5* of the force-measuring device is placed on the fixed beam *4*. The upper grip *7* is mounted on the movable support *6* for testing. Vertical displacement of the support *6* relative to the column *3* is carried out using the screw jack *8* (rotation of the handwheel *15*). Two working zones are formed between the fixed beam *4* and the support *6*: *U* (upper) – for tensile and shear testing and *L* (lower) – for compression and bending testing. The devices intended for relevant testing are installed in these zones. The lower zone during the compression and bending tests of the specimens made of brittle and low-plastic materials is closed by the transparent protective screens *9* installed on the clip *14*. The displacement sensor *10*, connected to the support *6* by the rod *11* through the spring-loaded rocker *12*, is installed on the back of the column *3* for measuring displacements of the support *6*. The strain gauges are pasted on the elastic element *5* for measuring strain. Visual control of the test specimen *17* is carried out using the video camera *18* mounted on the post *13*. The signal from the displacement sensor *10*, the elastic element *5* and the video camera *18* is transmitted and processed to the electronic information unit installed in the lower part of the column *3*, which has the USB port for connecting to the personal computer *16*. The information about the testing process is provided in the graphical form using the special software. The devices *19* and *20* are used for bending and compression testing, respectively.

A



B



C

D

Figure 2 – The equipment for carrying out tensile testing: *A* – the front view of the "TM-20" testing machine and the computer; *B* – the rear view of the "TM-20" testing machine; *C* and *D* – the side views of the "TM-20" testing machine. *I* – the USB input for the data transfer to the computer, *II* – the USB input for turning on the video camera, *III* – the USB input for turning on the machine.

Figure 3 – The upper (left) and lower (right) devices for tensile testing of the round specimens.

The lower device for tensile of the specimens is fixed on the machine by means of the special metal ramrod. Tensile was performed until failure of the cross-section of the steel specimen.

Results and discussion

The steel specimen was subjected to constantly increasing load. In this case, the specimen lengthens, and the cross-section decreases. The neck (narrowing) appears on the "reduced" section of the specimen, which determines the failure zone. Failure occurs approximately at the distance of ¼ of the "reduced" section of the specimen.

The tensile testing process of the round specimens is presented in the Fig. 4.

A  *B*  *C* 

Figure 4 – Performing tensile testing of the first specimen: *A* – loading the specimen; *B* – the neck formation on the "reduced" section of the specimen; *C* – failure of the specimen.

Deformations in material are presented on the specimen tensile diagram. The following stages can be highlighted on the graph: displacement by 0.56 mm in absence of load is the backlash elimination in the machine mechanism; displacement from 0.56 mm to 0.9 mm at maximum load of 3312 N is the elastic zone (reversible deformations of material); displacement from 0.9 mm to 1.13 mm at maximum load of 3624.11 N is the yield zone (the specimen elongation without increasing applied load); displacement from 1.13 mm to 2.6 mm at decreasing load to 1007.09 N is the softening zone (the neck formation and subsequent failure of the specimen). The dependence of applied force on the specimen elongation is presented in the Fig. 5.

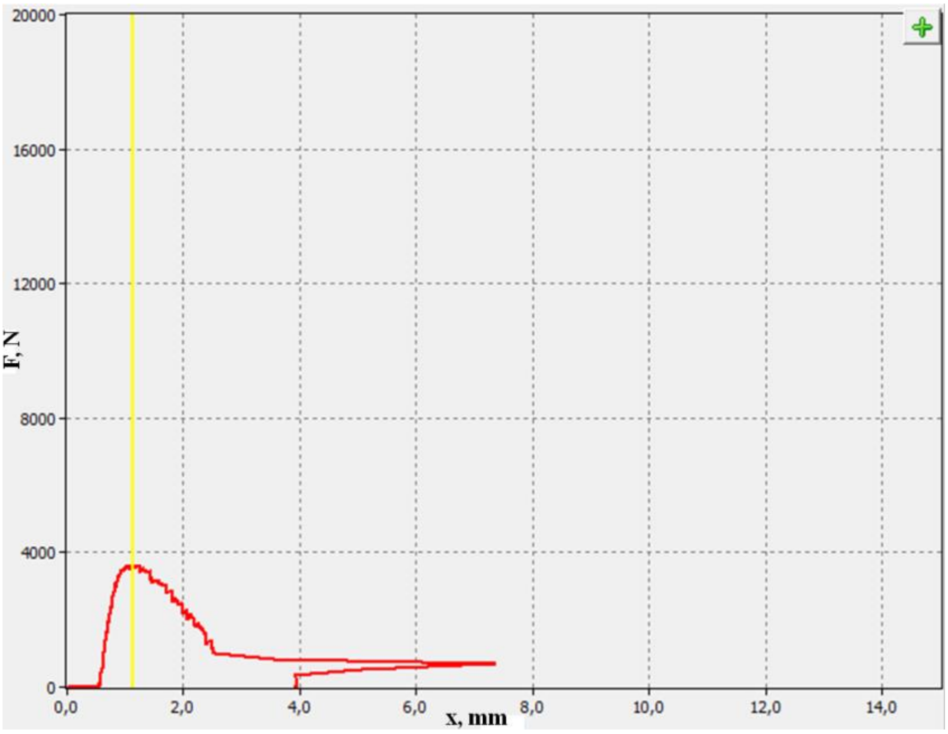


Figure 5 – The dependence of applied force on the specimen elongation.

Tensile of three identical round specimens showed that maximum tensile load, which leads to resistance of material, changes by average of 22 N. The round specimens after tensile testing are presented in the Fig. 6. The necks diameters of the specimens were measured after failure:

- the first specimen – 2.6 mm;
- the second specimen – 2.5 mm;

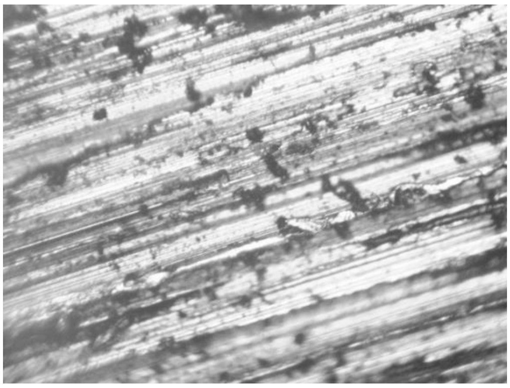
- the third specimen – 2.8 mm.

Thus, the predicted diameter of the steel specimen at which failure occurs is (0.65...0.73)d_0, where d_0 is the initial diameter of the "reduced" section of the specimen, mm.

Figure 6 – The specimens after testing.

The material structure of the destroyed specimen and the material structure before testing are presented in the Fig. 7. The images of the material structure (100x magnification) were obtained using the 4XB metallographic microscope. Since the specimens were made on the lathe, it is possible to compare the macrostructure of material after machining and plastic deformation. The marks of the different depth are formed on the surface of the specimen from the cutting tool after machining. The steel specimen has the granular structure after cold plastic deformation.

A



B

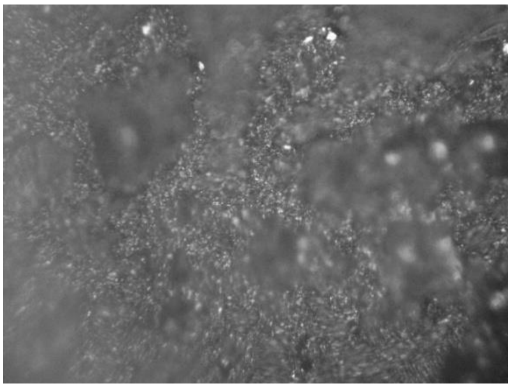


Figure 7 – The structure of the specimen material before testing (*A*) and in the failure zone (*B*).

Conclusion

Failure of material occurs at elongation of the short round steel specimen by 6%. For the similar sections of the machine parts, it is recommended to apply the calculated dependencies of 0.65d_0...0.73d_0, at which material failure occurs. The granular structure, which indicates material strength, is formed on fracture of the specimen.

References:

1. (n.d.). *GOST 1497-84. Metals. Methods of tension test.*
2. 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.
3. Chemezov, D., Pavlukhina, I., Bakhmeteva, M., & Petrenko, A. (2020). The dependencies of tension strain from stress of the flat steel

specimen. *ISJ Theoretical & Applied Science*, 08 (88), 101-104.

4. Bychkova, A. A., & Minaeva, S. Yu. (2015). *Tensile testing of a steel sample.* International scientific and technical conference of young scientists of BSTU named after V. G. Shukhov, 2137-2139.
5. Zaydes, S. A., & Rudyh, N. V. (2010). Experimental evaluation of stressed state of steel samples by the metallographic image. *Bulletin of Irkutsk State Technical University*, 5(45), 26-31.
6. Nicholas, T. (1981). Tensile testing of materials at high rates of strain. *Experimental Mechanics*, vol. 21, 177-185.
7. Harding, J., Wood, E. O., & Campbell, J. D. (1960). Tensile Testing of Material at Impact Rates of Strain. *J. Mech. Eng. Sci*., 2, 88-96.
8. Lucas, G. E. (1983). The development of small specimen mechanical test techniques. *Journal of Nuclear Materials*, 327-339.
9. Eiichi, W., et al. (2015). Overview on recent progress toward small specimen test technique. *Fusion Engineering and Design*, 2, 1-5.
10. Makwana, D., Patel, A. K., & Dave, K. G. (2016). A Review of miniature specimen tensile test method of tungsten at elevated temperature. *International Journal of Engineering Development and Research*, Volume 4, Issue 2, 132-139.