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ASSESSMENT OF THE IMPACT OF THE CONDITIONS OF THE DISK MICROSAMPLE FIXATION ON THE PUNCH TEST DIAGRAM, TAKING INTO ACCOUNT THE FRACTURE PROCESS

One of the key parameters, used for the current control of the equipment state to provide its reliable operation is mechanical characteristics of the construction materials, in particular, strength characteristics. The most correct method of their determination is distractive test for uni-axial tension of the samples, manufactured from the investigated materials. The cutting of a certain volume of the material, needed for the fabrication of the sample can be critical for the carrying capacity of the construction. That is why, the indirect methods of the mechanical characteristics determination are developed to minimize the volume of the material, used for samples manufacture. Small punch test can be refereed to these methods. As this method is not standardized, the conditions of the tests are chosen by the researchers at their discretion. The given research considers the impact of the selection of one of the parameters, namely, the clamping force, on the results of the study. Steel 45 was chosen as the model material. Numerical modeling was carried out without taking into account and taking into account sample clamping force, equaled 5, 7.5 and 10 kN. The value of the von Mises equivalent stress in the clamped zone of the sample did not exceed 264 MPa. To take into account the fracture process Gurson – Tvergaard – Needleman (GTN) model was used. The problems was simulated in the dynamic formulation, using the explicit integration scheme. Diagrams of disk microsample punching in the coordinates «load» – «deflection» at the given conditions of fixing is given. By the results of the study it was determined that the force of sample clamping does not influence greatly the punching diagram, that is why, to decrease the time, needed for the numerical calculations it can be neglected. In the course of the experimental tests it was recommended to select the clamping force of the sample so that to avoid plastic deformation of the sample in the area of the clamping.

Key words: *small punch test, friction coefficient, disk microsample.*

Introduction

Safe operation of the equipment during the project time frame and postproject period is very important task in modern economic conditions of the energy sector of Ukraine. One of the basic means to provide the reliable operation is the control of the current state of the constructions and equipment material. This control is carried out both by means of visual aids, non-destructive tests and by means of the values of the mechanical characteristics of the materials, in particular, strength characteristics. There exist numerous methods of their determination. But the most correct method is uniaxial tension test. However, manufacturing of the samples for such tests requires the availability of certain volume of metal, but in the condition of the operating equipment it is often impossible without violation of the integrity of the equipment and impact on the operation process. The development or improvement of the indirect methods of the mechanic characteristics determination, can be the solution of this problem, as these methods use small-size samples.

Problem set up

One of the methods, enabling to determine the mechanical characteristics without inflicting damage to the carrying capacity of the structure is the small punch test [1 – 4]. The essence of the method lies in the deformation of the disk microsample by the indenter in the form of a ball, with the registration of the punch diagram in the coordinates «load» – «deflection». Further certain parameters of this diagram are connected with the corresponding mechanical characteristics by means of the correlation ratios. Disk microsample of a certain thickness and diameter is manufactured from the minicuts of the material of the real constructions. Typical scheme of loading and fixation of the disk microsample is shown in Fig. 1.

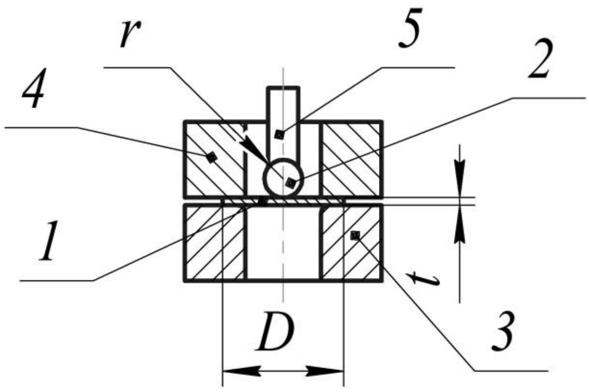


Fig. 1. Typical scheme of the loading and fixation of the disk microsample: (1) – sample; (2) – indenter; (3) – low clamping matrix; (4) – upper clamping matrix; (5) – rod of the indenter holder

Nowadays there are no international standards, which would strictly regulate the test procedure by means of the small punch test. Main developments of this method are realized in the working document regarding the preparation to the standardization [5]. That is why, the researchers use in their research various geometric parameters of the samples and equipment as well as the conditions of the test procedure and sample fixing. For instance, in the process of the experimental tests different values of the clamping force of the sample in the experimental equipment are applied. The authors of paper [6] clamped the test piece by the load of 7 kN. In other research [7] the investigators applied the clamping force of 15 kN. Fixation of the sample by the loads of different values can influence the punch diagram and, correspondingly, the determination of the mechanical characteristic.

Aim and task of the research

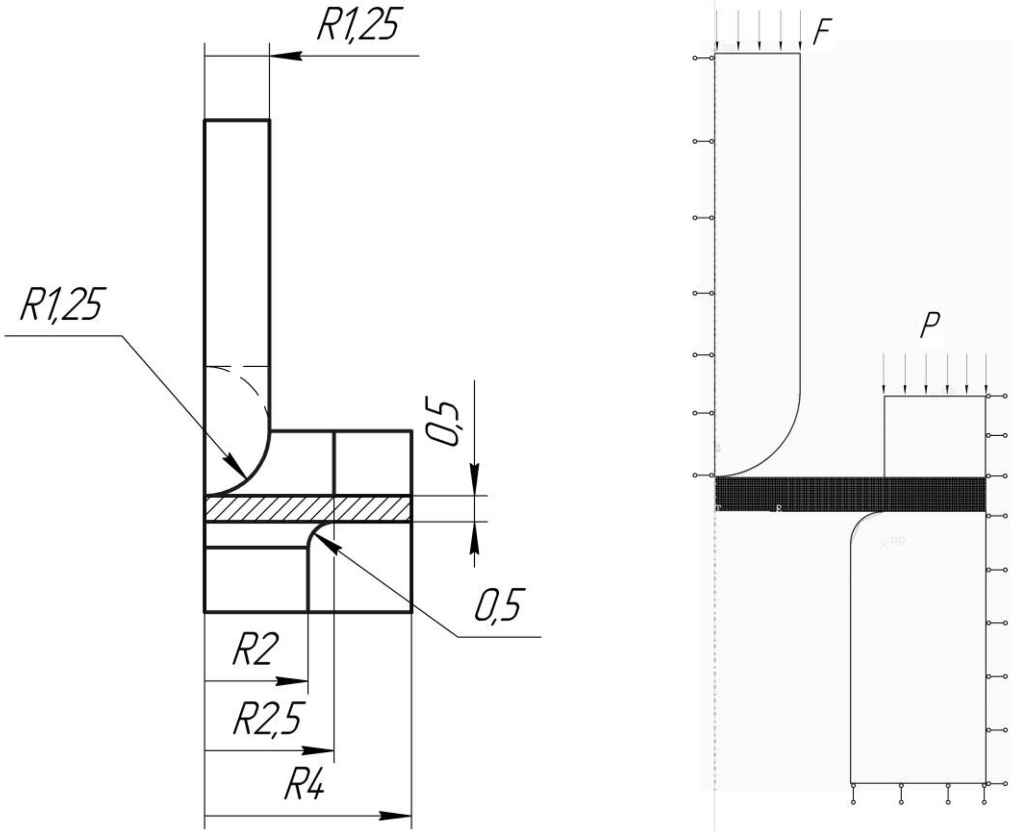
The aim of the given research is to study the impact of the fixation conditions of the disk microsample in the experimental equipment, namely, clamping force.

Results of the research and discussion

Study of the impact of the clamping force of the disk microsample between the low and upper clamping matrices on the punching diagram was carried out by means of the numerical modeling using the software, based on the finite elements method.

Due to the axial symmetry of the model the axially symmetric contact problem in spring-plastic formulation was considered. Geometrical parameters of the model, presented in Fig. 2a, are selected with the account of the construction of the experimental equipment, developed in the G.S. Pysarenko Institute of the Strength Problems of the National Academy of Science of Ukraine for the performing of the tests , applying the method of the disk microsample punching [8]. In this case the indenter and the rod of the holder (considered as an integral unit), as well as upper and lower clamping matrices were modeled as ideally rigid bodies.

Displacement of the indenter and the rod of its holder was limited in radial direction (Fig. 2b). Low and upper matrices were considered in the first approximation as rigidly fixed. For modeling of the interaction of the construction elements three contact pairs were created: indenter-sample, sample-upper clamping matrix and sample-low clamping matrix. Boundary conditions of the contact pairs were set with the assumption that the friction force on the surface of the contact has normal and tangensoid components. The value of the friction factor was taken to be equal 0,18. The sample was modeled axially symmetric quadrilateral elements. Fig. 2b presents the calculation scheme of the model.



(a) (b)

Fig. 2. Geometric parameters of the model (a) and calculation scheme (b) for the numerical modeling of the process of the disk microsamples deformation

As the model material steel 45 was selected in the delivery conditions with the following characteristics: strength boundary $\sigma_{в}$ = 677,6 MPa; yielding boundary $\sigma_{0,2}$ = 353,9 MPa; elasticity module E = 199600 MPa.

In the first approximation the material was modeled without the account of the fracture process. The results of the calculations in this case differ greatly from experimental results (Fig. 3). Model Gurson – Tvergaard – Needleman (GTN) was used for the account of the fraction process [9-11]. Such model describes the behavior of the ductile porous material and takes into account both the formation and growth of the pores and the mechanism of the ductile fraction, caused by their coalescence.

For the assessment of the impact of the finite elements dimensions on the results of the numerical modelling of the process of the disk microsample punching calculation schemes with various dimensions of the finite elements were considered : 0,08 mm; 0,04 mm; 0,02 mm i 0,01 mm. The initial values of the GTN model parameters were taken for the account of the fracture process. Close curves «load» – «deflection» are obtained for the finite element meshes with the dimensions of the finite elements of 0.02 .. and 0.01 mm., that is why, in further calculations the scheme with the dimensions of the finite elements of 0.02 mm was used. This enabled to decrease considerably the time of calculations. The problem in this case was modeled in the dynamic formulation using the explicit scheme of integration.

For the determination of the parameters of GTN model large volume of calculations is carried out to obtain the satisfactory coincidence of the numerical and experimental punch diagrams.

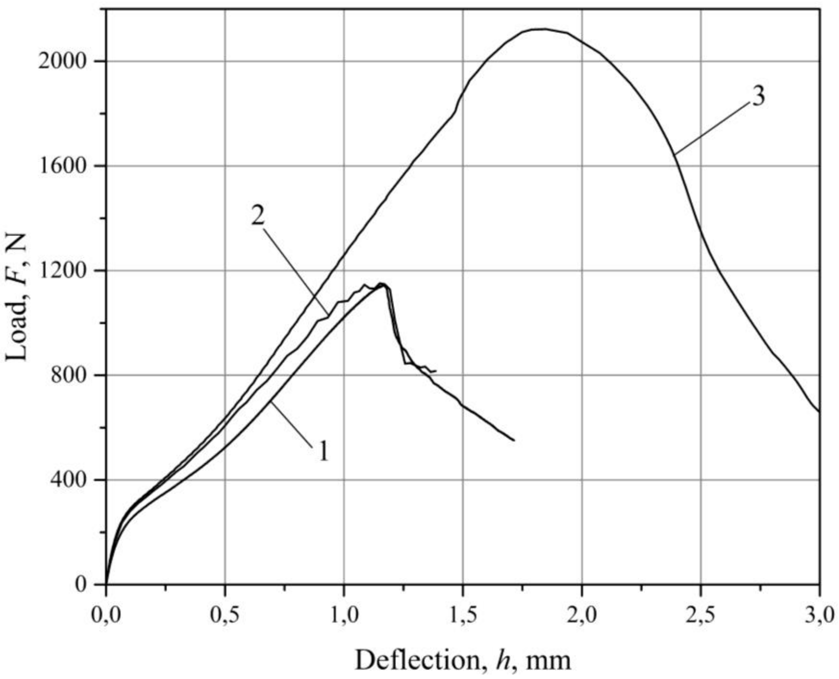


Fig. 3 Experimental (1) and calculation diagrams of the disks microsamples deformation, taking into account GTN model (2) and without it (3).

Study of the impact of the conditions of the disk microsample clamping in the experimental equipment, namely, the clamping force , was carried out in the following way. Certain load was applied to the upper matrix and the calculation of the punching process of the disk microsample was performed. Fig. 4 shows the punching diagram in the coordinate «load» – «deflection» both without the account and with the account of the force of the sample clamping that equaled 5, 7.5 and 10 kN. At such values of loading on the upper matrix the level of the equivalent von Mises stress in the zone of the sample clamping did not exceed 264MPa. As it is seen from the obtained results, the force of the sample clamping does not influence considerably the punching diagram. That is why, to decrease the time and simplify the numerical calculations this force may be neglected. However, in the process of the experimental tests the clamping force of the sample should be selected so that to avoid plastic deformation of the sample in the clamping area, taking into account the geometric parameters of the experimental equipment and the sample.

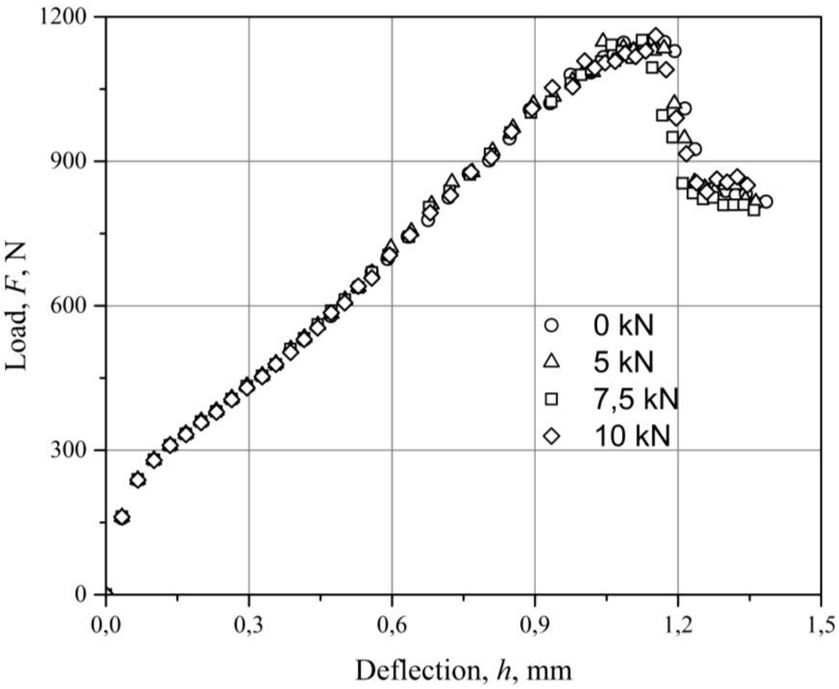


Fig. 4. Diagrams of the deformation of the disk microsample, made of steel 45 at various forces of the sample fixation

Conclusions

The impact of the disk microsample clamping conditions in the experimental equipment, namely the impact of the clamping force was studied. By the results of the studies it is established that the force of the sample fixation does not influence greatly the punching diagram. That is why, to decrease the time and simplify the numerical calculations it may be neglected. Selecting the value of the sample clamping force in the experimental equipment the plastic deformation of the sample in the clamping area should be avoided.

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