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The Use of Thin Disc Samples for the Determination of the Tear Resistance of Brittle Materials

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Abstract

Technical requirements of complex systems the nuclear industry is obliged to develop new types of materials and methods mechanical tests to determine their mechanical properties. The development of known and development of new methods of mechanical testing is an important task for nuclear power. It is proposed to use the test of bending small thin disk specimens simply supported along the contour, to determine the resistance of material to tensile strain. The results of computer analysis of stress-strain state and test a thin disk specimens made of brittle materials are cast iron and graphite as a possible model, and directly samples made by electro-impuls methods are presented. It is shown the effect of size of specimens on the resistance to their destruction and different character of deformation and destruction of samples of cast iron and graphite. The possibility of application of thin disc samples for the determination the resistance to tensile strain of the composite ceramics based on SiAlON with various additives Y2O3, SiC, TiN, and boron carbide B4C is confirmed.

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1. INTRODUCTION

Powder metallurgy plays the important role in the development of technologies of creation of materials with desired properties. Along with traditional methods of sintering, methods of electric pulse impact (EPI) are actively developing in the production of materials that use simultaneous impact on the powder billet short high-voltage pulse of electric current and mechanical pressure. The method of obtains materials with desired properties by EPI is based on researching small samples with thickness from 1 to 10 mm and a diameter from 10 to 15 mm.

Standard methods for determination of materials resistance to rupture under tension to samples of such small size is not applicable. To assess the strength of these materials it is necessary to use alternative test methods. The main criterion of selection of such alternative methods is the presence of zone with the maximum tensile stresses in the test of sample.

The investigated method for the determination of brittle strength of materials — test drives on a bend on the ring support. It was used to determine the brittle strength of hardened steel disks with a thickness of 3-6 mm and a diameter of 60 mm [1, 2]. By brittle failure of the specimen occurs its division into many pieces.

2. RESULTS AND DISCUSSION

2.1. Computational analysis of bending small thin discs on the ring support

Modeling of the process of loading a disk sample was produced in the verified computational complex ANSYS Mechanical [3]. The estimated model is a flat task, the main element of symmetry is a radial cross — section of the compressed disc. The thickness of the disc ranged from 1 to 2 mm diameter punch from 1 to 3.75 mm at a constant disc diameter of 10 mm and the support ring is 7.5 mm. The material model assumes perfectly elastic. The modulus of elasticity of the material is assumed to be 100 GPa. To create the model we used second order elements PLANE183, as well as elements of contact interface TARGET169 and CONTACT172. As the contact algorithm used an advanced method of Lagrange multipliers.

The loading was carried out kinematically, the task equal to the prescribed displacement to the nodes on the surface of the hard stamp. At the same time to restore the curve "load-displacement", the force acted in the form of the total reaction forces at the nodes with prescribed displacement in the direction coinciding with given displacements.

Fig. 1 shows a picture of the distribution of total stresses, which were obtained numerically in accordance with the maximum load at which the specimen was destroyed in the experiment.

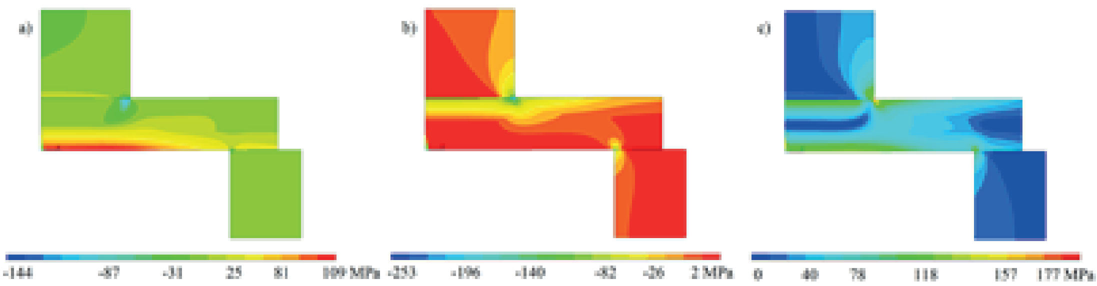

Figure 1: Isosurfaces of the component of the stress state of the disk: a – σ_1, b – σ_3, c – τ_{max}.

Distributions shown in Fig. 1 are characteristic to solve the tasks practically in all range of loading, that is, the pattern of the stress distribution over the body is not changed. Figure 1(a) clearly shows the presence of zone with the maximum tensile stresses (red), which satisfies the selection criteria of the methodology. There is compression (green) in the contact area of the stamp and disc, as well as the presence of features (blue) in the contact area along the contour of the interaction of the punch and disk (Figure 1(b)), which affects the distribution of the maximum shear stresses (Figure 1(c)).

A study of the stress-strain state model revealed that the region of contact between a stamp and the disk occurs triaxial stress state. On the outer side of the disc, as one would expect, there is a plane stress with maximum tensile stresses, which cause brittle fracture of the sample. The origin of the destruction is possible under the action of the maximum tangential stresses in the contact zone. Figure 2 shows the stress distribution through the thickness of the sample. The beginning of the x-axis corresponds to the contact area of the stamp and disk.

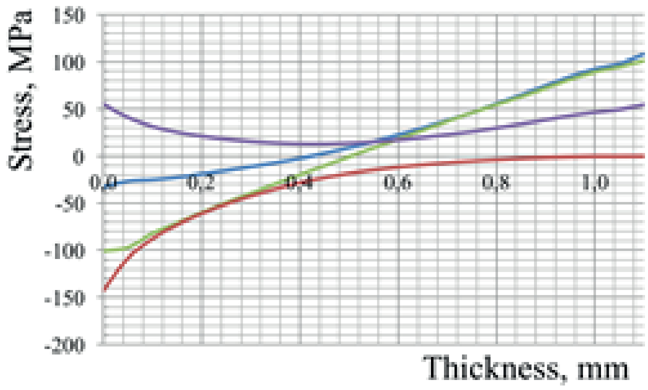

Figure 2: The stress distribution through the thickness of the sample • – σ_1, •– σ_2, •– σ_3, • – τ_{max}.

It is seen that in the contact region is dominated by the maximum shear stresses, and on the reverse side of the disk main tensile stress is maximum. The main compressive stresses on the opposite side of the disk tend to zero, which confirms the biaxial stress state.

We investigated the dependence of the deflection from the size of the disc and diameter of the punch. The influence of the studied parameters of the model on the maximum stress level is not detected.

3. Testing of model materials for circuit bending on the ring support

As model materials, whose physical and mechanical properties are well studied, were selected cast iron SCH 10-40 and graphite MPG-6.

3.1. Tests of cast iron samples

In developing methods of testing, disks from cast iron had diameters of 10 and 15 mm, the thickness was changed within 1 - 2 mm.

Comparison of numerical analysis of the stress-strain state and experimental results allows to conclude that the cast iron in this scheme of loading viscous collapses under the action of tensile stresses. First, the maximum shear stresses lead to the destruction of cut, trying to push the "stopper" but at the first crack they are disclosed under the action of tensile stresses. These statements were confirmed by the emergence of pushed through "crater" in the contact zone and the embossed shape of the stamp from the back side of the disc (Fig. 3).

Figure 3: Destroyed the sample with radial cracks and the embossed shape of the stamp.

The presence on the diagrams (Fig. 4, a) of cast iron sections a gradual decrease of load after the maximum indicates the gradual divergence of the destroyed parts of the sample. Crack propagation in the radial direction suggests that they are disclosed under the action of tensile stresses. There is slow crack propagation.

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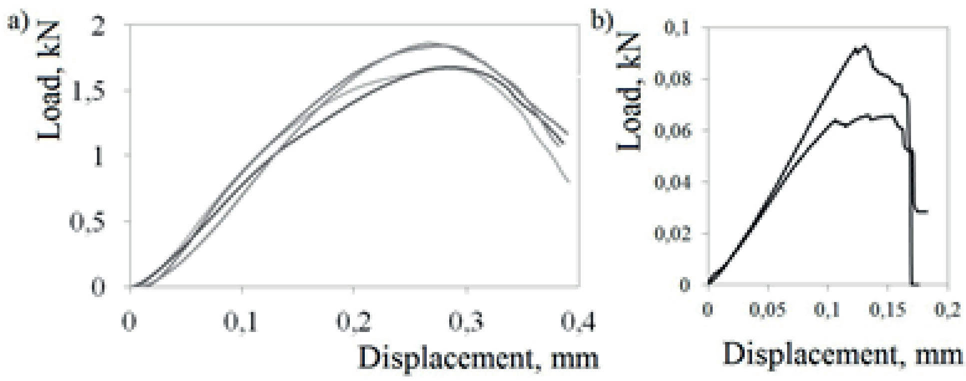

Figure 4: Machine deformation diagram of bending iron (a) and graphite (b) disk.

3.2. Test graphite samples

Discs of graphite were two sizes Ø xt: 15x 1.8 mm and 15x1,7 mm. Machine characteristic deformation diagram of a graphite disk is shown in Fig. 4, b. You can see that the diagrams substantially differ from the diagrams of samples from cast iron. The destruction of the graphite disc is at maximum load. Stages in the diagram indicate stepwise crack growth. We observe the explosive nature of the destruction and the final dynamic crack propagation in the sample. The test results obtained stress values are on average 20% greater than the values of the material strength in tension for cast iron and graphite.

4. Tests of thin disks obtained by spark-plasma sintering, according to the scheme of bending of the disk on the ring support

The method of bending samples of small size is used in the study of the tear resistance of the materials SiAlON and boron carbide B4C obtained by spark-plasma sintering.

Thin disks of SiAlON destroyed completely fragile with linear stress-strain diagram (Fig.5) before break, separating into many pieces. Revealed no influence of change of thickness in the range of 1 – 2 mm on the characteristics of tensile fracture. The impact of modes of production samples and the influence of the percentage content of yttrium oxide Y2O3 in a -SiAlON structure, the influence of various additives on the strength were researched.

Observed weak dependence of the strength on the percentage of inclusions of yttrium oxide Y2O3 in a -SiAlON structure. It was also investigated the influence of

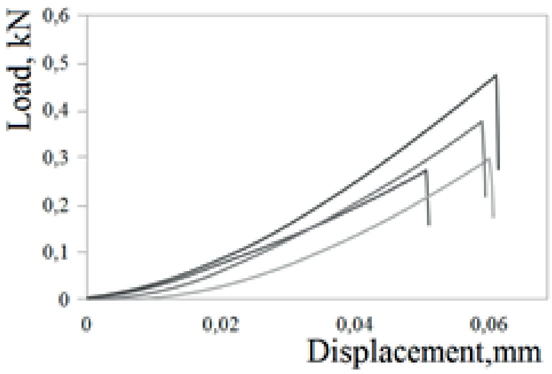

Figure 5: Diagrams of deformation of SiAlON samples.

addition of 2SiC, 4SiC, 2TiNk, 4TiNk, 2TiNm, 4TiNm on the strength characteristics at various temperatures of sintering. The increase of sintering temperature in the investigated range for all cases gives a more solid structure (Fig. 6).

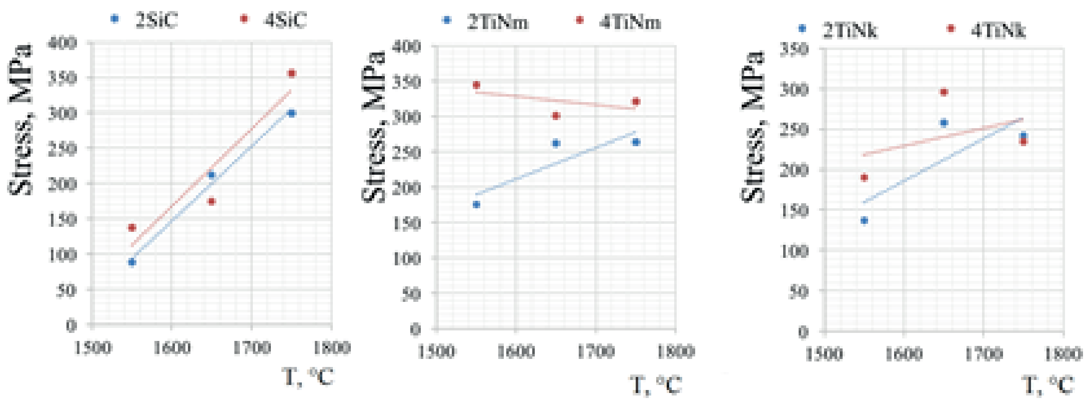

Figure 6: The dependence of the breaking stress from the sintering temperature for different additives 2SiC and 4SiC, 2TiNm and 4TiNm, 2TiNk and 4 TiNk.

Similar dependencies of increasing of the strength of the structure with increasing sintering temperature in the studied range were obtained for the additives fine-grained and coarse-grained titanium nitride of two types.

All of the discs of boron carbide were destroyed completely fragile at the line graph of the bend to fracture, splitting into many pieces. Marked deterioration of the strength properties of the samples obtained at a pressure of 60 MPa. This mode regardless of the sintering temperature showed the worst results.

5. CONCLUSION

The development of known and elaboration of new methods of mechanical testing is an important task for nuclear power. By calculation, using FEM, and experimentally was shown the possibility of indirect determination of the tensile strength of brittle materials according to the results of the Flexural testing of small disk samples, simply supported on the contour. The results of the study of a range of materials, resulting electric pulse impact method are shown.

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