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Tensile strength of materials obtained by electric pulse consolidation of powders

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Abstract

For materials obtained by electro pulse consolidation, two methods for determining fracture resistance of thin brittle disks—bend testing on pivot rings and so-called Brazilian test — are comparatively analyzed on the example of such brittle materials as gray cast iron, graphite, SIALON and alumina. In most cases, good agreement between the results obtained by the above techniques was observed.

Keywords: electric pulse consolidation, strength of materials, small specimens, Brazilian test, bending of thin disks on pivot ring

Bending of thin disks for on the ring support

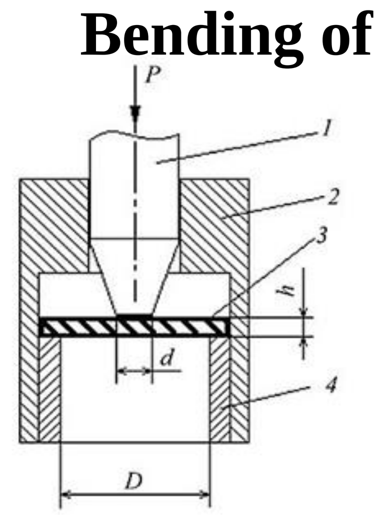

Figure 1.Schematic of bend testing: 1 indenter, 2 ferrule, 3 specimen, 4 pivot ring

$$\sigma_B = \frac{3P_{max}}{8\pi h^2}\left[4-(1-\mu)\left(\frac{d}{D}\right)^2+4(1+\mu)\ln\frac{D}{d}\right] \quad (1)$$

In equation (1) h is the thickness of the disk; d and D are the diameters of the punch and support, respectively; μ is the Poisson's ratio [1].

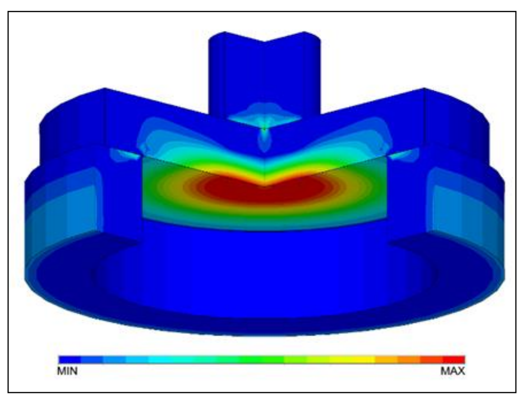

Figure 2. Distribution of main strains during bend testing.

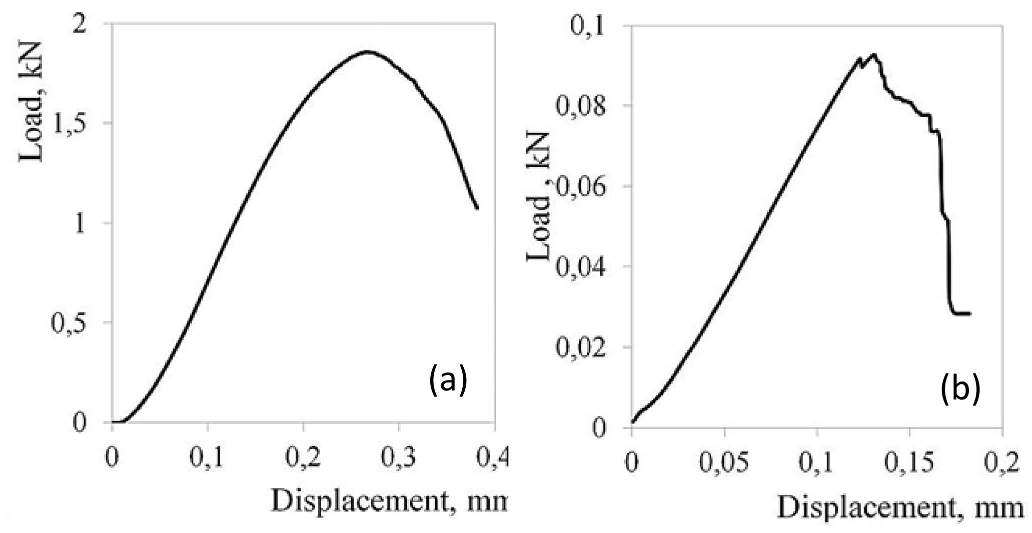

Figure 3.The P–ω diagrams for bend testing of disks D = 10 mm, h = 1.5 mm of cast iron (a) and graphite (b).

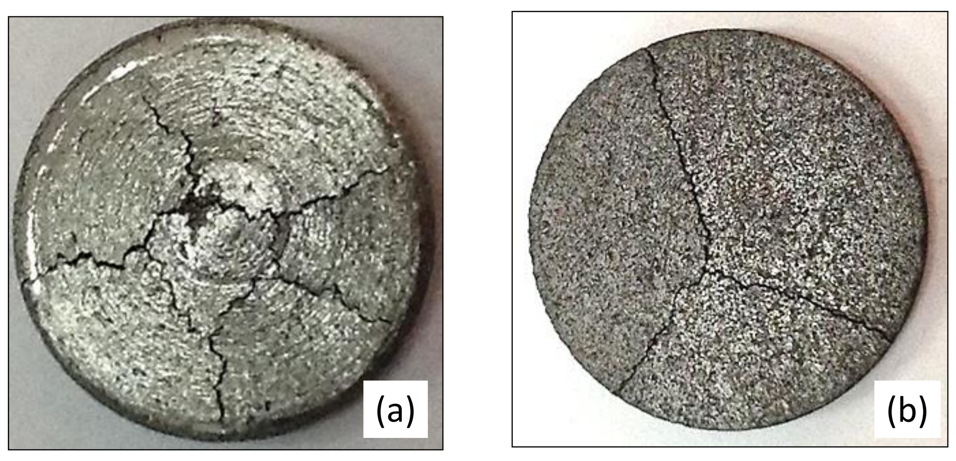

Figure 4.Overall view of plastic cracked cast iron (a) and brittle graphite (b) for disks D = 15 mm.

Results

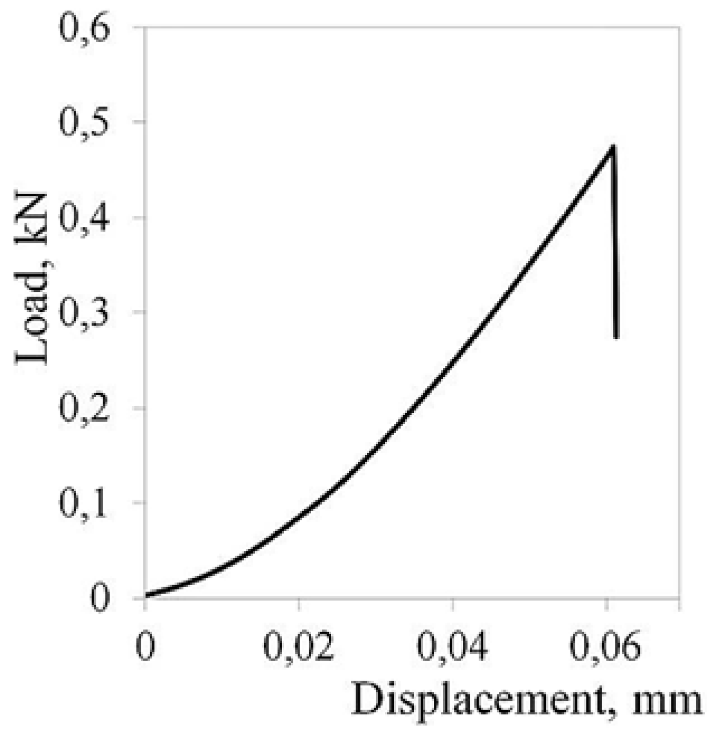

Figure 5. The P–ω diagram for bend testing of 15-mm disks derived from combustion-synthesized SiAlON powder.

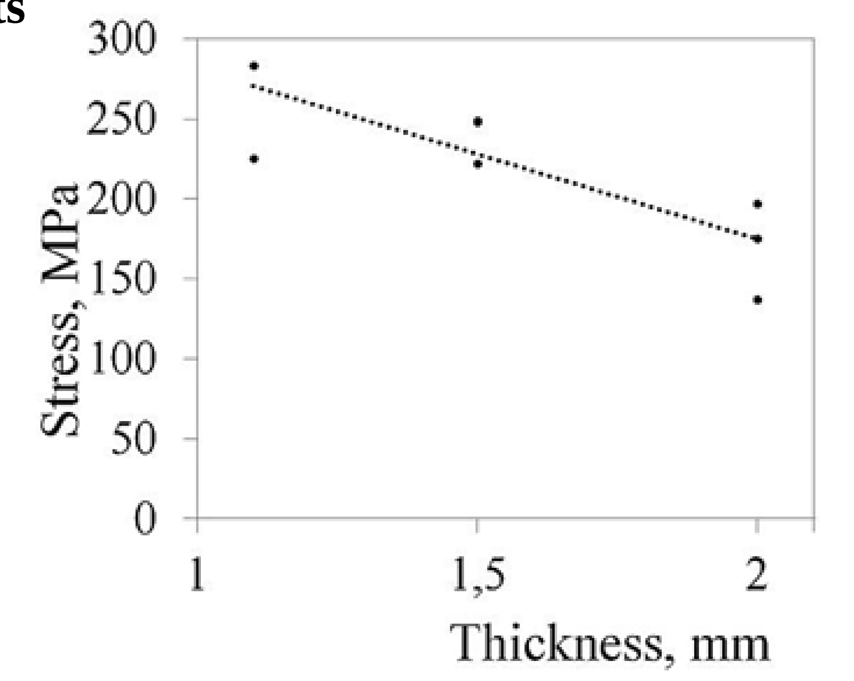

Figure 6. Breaking stress as a function of disk thickness for β-SiAlON –30% BN+8% Y2O3 composite.

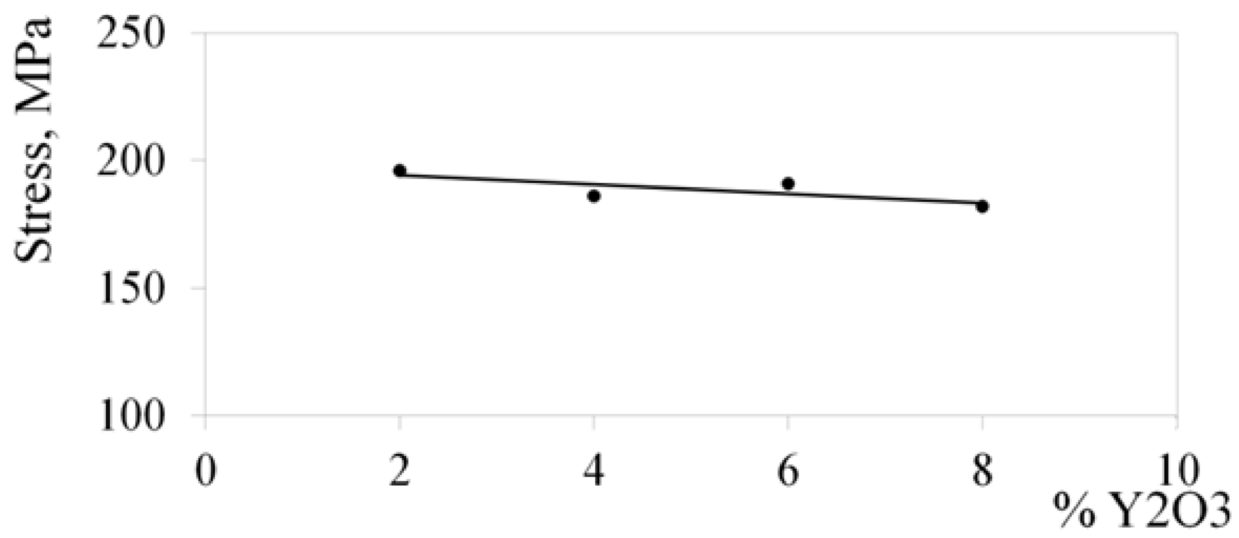

Figure 7. Breaking stress vs Y2O3 percentage in β-SiAlON.

Brazilian testing of short cylinders

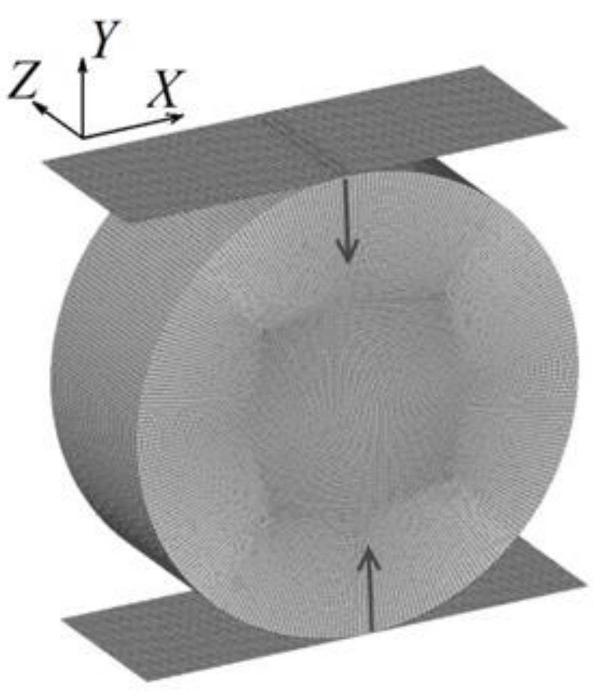

Figure 8. Schematic of Brazilian test.

$$\sigma_t = \frac{2P}{\pi t D} \quad (2)$$

In equation (2) P is the maximum load sustained by the specimen, t is the thickness of the specimen, D is its diameter [2].

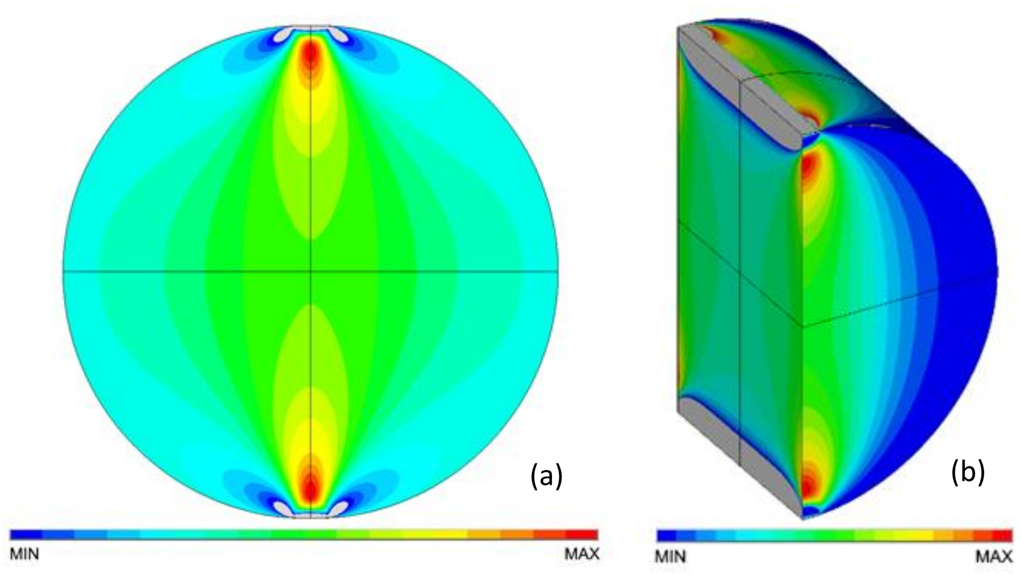

Figure 9. Distribution of compression strain ε_x (a) and first main stresses (gray areas with $\sigma_1 < 0$) (b) in disk-shaped specimens.

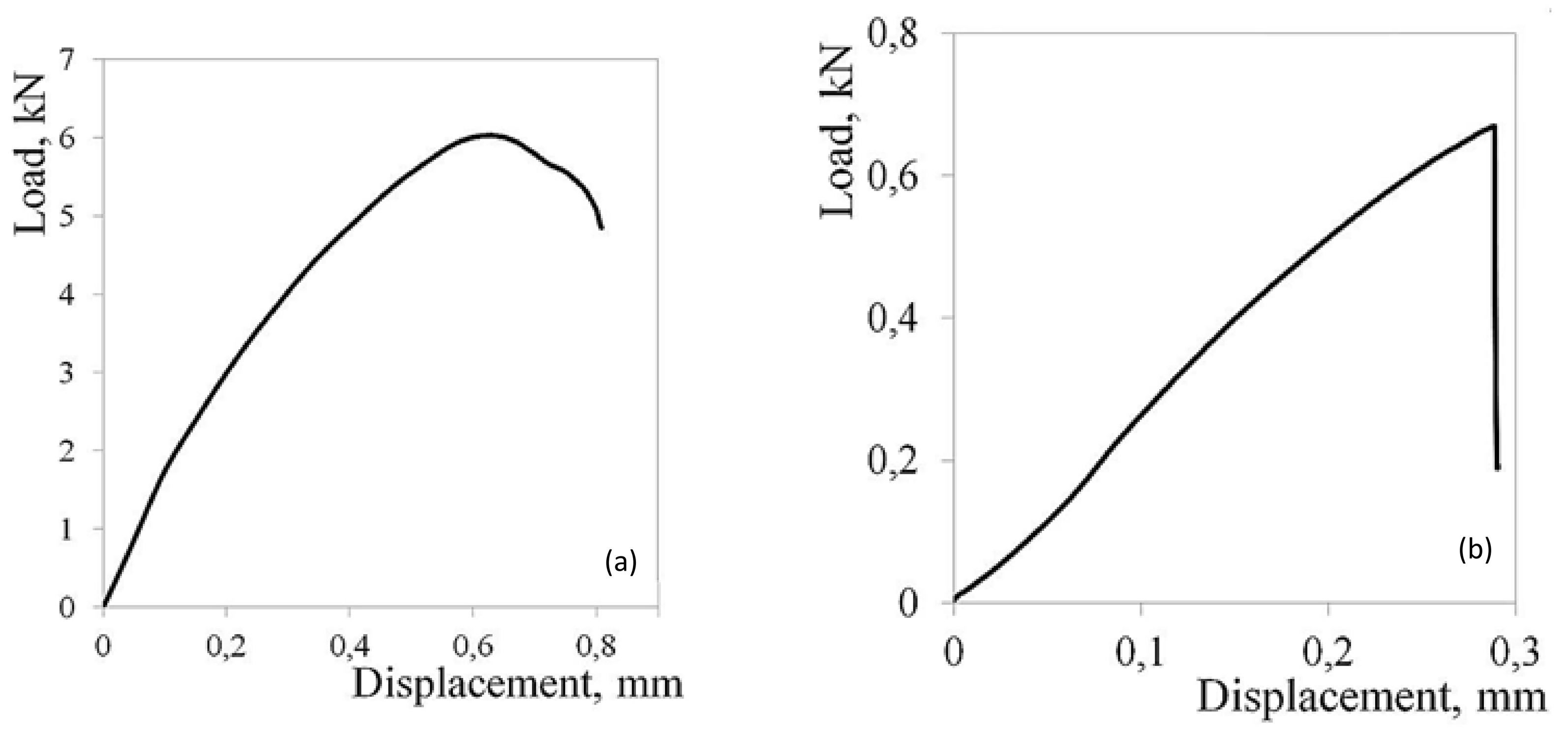

Figure 10. Compression diagrams in Brazilian testing of cast iron 10×4 mm (a) and ARV-1 graphite 8×8 mm (b) disks.

Samples of heavy alloy WNiFe (90W-7Ni-3Fe) obtained by high-voltage consolidation

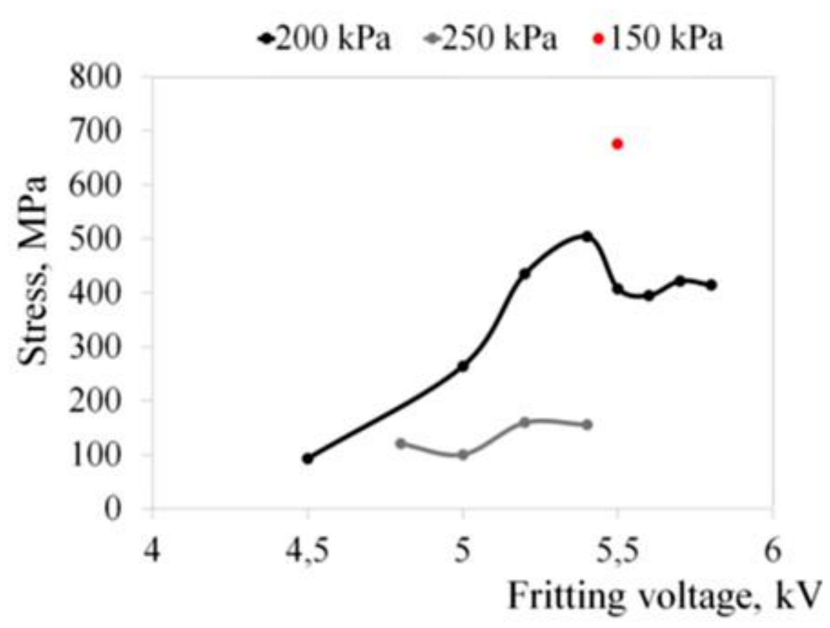

Figure 11. Breaking stress of WNiFe alloys consolidated at 150, 200, and 250 kPa as a function of fritting voltage.

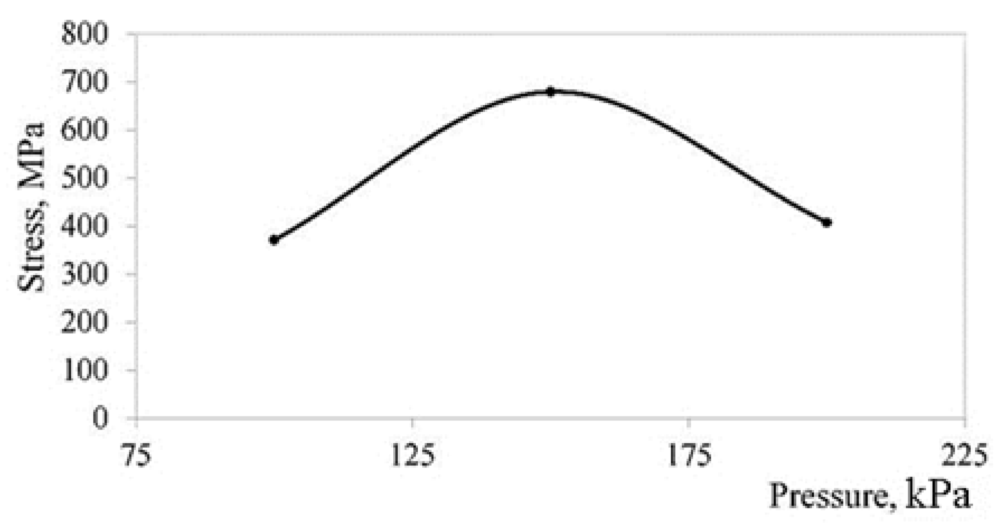

Figure 12. Fracture stress as a function of fritting pressure.

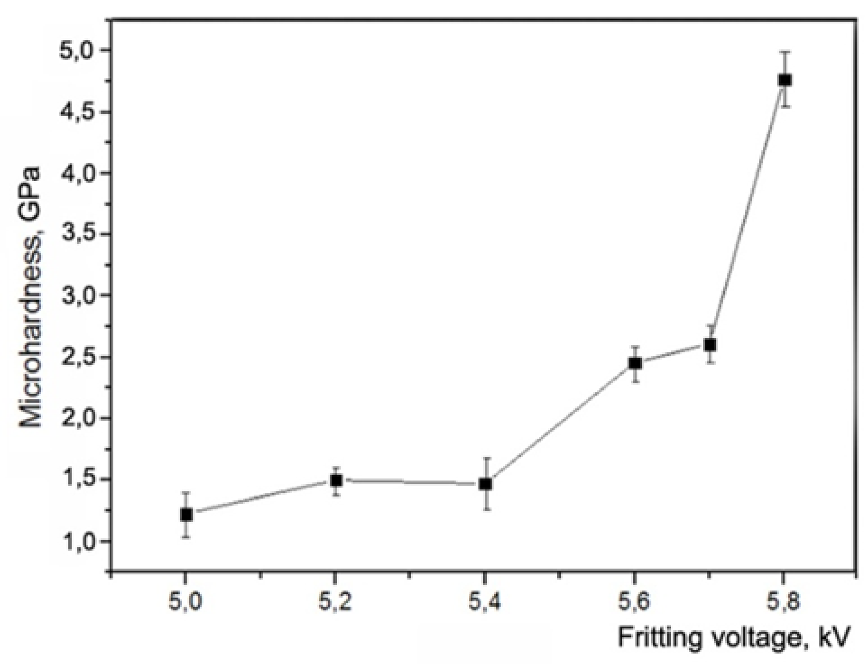

Figure 13. The sample microhardness as a function of fritting voltage

Samples of aluminum oxide obtained by SPS

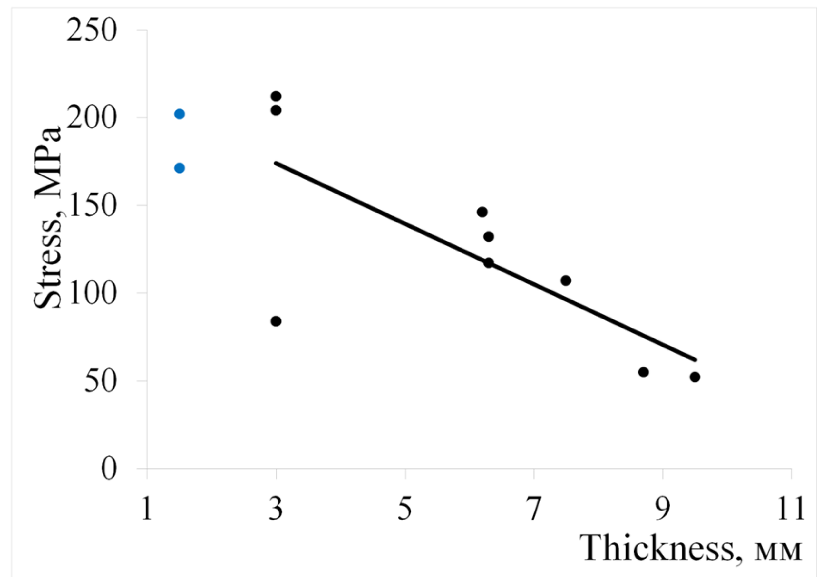

Figure 14. Breaking stress of alumina disk 10 mm in diameter as a function of disk thickness.

The blue points show the bending of the disks with a diameter of 15 mm and a thickness of 1.5 mm on the pivot support.

Conclusions

For materials obtained by electro pulse consolidation, two methods for determining fracture resistance of thin brittle disks — bend testing on pivot ring and Brazilian test — have been comparatively analyzed using cast iron, graphite, SiAlON and alumina as reference samples. In most cases, good agreement between the results of the above testing procedures is observed, especially if material failure is preceded by plastic deformation (as in case of cast iron). In case of brittle failure (graphite), the results of testing by the above methods are by 20 and 50% lower than true values, respectively. The strength of consolidated materials depends on sintering temperature/pressure and presence/absence of dopants.

References

[1] Tumanov AT, editor, Methods for Strength Testing of Metals. Moscow: Mashinostroenie; 1974. 320 p.
[2] ASTM D3967-95a Standard. Test Method for Splitting Tensile Strength of Intact Rock Core Specimens.