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THE DEFORMATION DEGREE OF VARIOUS MATERIALS DURING THE COMPRESSION TEST

***Abstract**: The results of the computer calculation of the compression process of the standard specimens made of aluminum, copper, armco iron, cast iron, ceramics and concrete are presented in the article. The analysis of the compression ratio of materials under conditions of shortening the specimen height by 50% from the initial height was performed. It is determined that the greatest degree of compression is observed during deformation of the specimens made of aluminum and concrete.*

***Key words**: the specimen, the compression test, deformation, ratio.*
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Introduction

Compression of the standard specimens is performed to determine the mechanical properties of brittle and ductile materials (for example, the compressive strength) [1]. The strength of material can be determined by the degree of volumetric deformation (fracture) of the specimen under the action of the applied load [2]. The analysis of fracture of the cast iron specimens during compression on the testing machine was performed in the work [3]. The specimen shortening under the load by 30% from the initial height leads to partial fracture of material (the symmetrical formation of cracks by the diameter at the angle of 50 degrees relative to the centerline of the specimen). Taking into account the fact that the nature of the cracks formation in the specimen on both sides is different, it can be concluded that the intensity of compression deformation of material along the section is different. The degree of compression deformation of brittle and ductile materials can be determined by the mathematical calculation of the dynamics of the compression process of the specimens on the computer. The ratio value will reveal the percentage of volumetric deformation of material during compression.

Materials and methods

The computer calculation of the compression process of the specimens models made of aluminum, copper, concrete, cast iron, armco iron and ceramics was implemented in the ANSYS Autodyn 14.5 program [4]. The specimens models were cylinders with the diameter of 4 mm and the height of 4.5 mm. Each specimen was subjected to the variable load applied to the free from basing the end surface of the model. Deformation of the specimens models was carried out in accordance with the Lagrangian formulation. The materials properties of the specimens and the compression test scheme are presented in the table 1 and in the Fig. 1, respectively.

Table 1. The materials properties and the compression test scheme of the specimens.

	Aluminum [5]	
	Reference density	2.71 g/cm^3
EOS	Equation	Shock
	Gruneisen coefficient	2.1
	Parameter *C1*	5.38×10^3 m/s
	Parameter *S1*	1.337
Strength	Equation	von Mises
	Shear modulus	2.69×10^7 kPa
	Yield stress	2.9×10^5 kPa
	Iron-C.E.	
	Reference density	7.89 g/cm^3
EOS	Equation	Linear
	Bulk modulus	1.64×10^8 kPa
	Reference temperature	300 K
	Specific heat	452.0 J/(kg×K)
Strength	Equation	Johnson-Cook
	Shear modulus	8.0×10^7 kPa
	Yield stress	2.9×10^5 kPa
	Hardening constant	3.39×10^5 kPa
	Hardening exponent	0.4
	Strain rate constant	0.055
	Thermal softening exponent	0.55
	Melting temperature	1.811×10^3 K
	Ref. strain rate (/s)	1.0
	Strain rate correction	1st order
	Al_2O_3 [7-8]	
	Reference density	3.9 g/cm^3
EOS	Equation	Shock
	Gruneisen coefficient	0.5
	Parameter *C1*	6.9×10^3 m/s

	Concrete (compressive strength is 25 MPa) [6]	
	Reference density	2.75 g/cm^3
EOS	Equation	*P* alpha
	Porous density	2.314 g/cm^3
	Porous sound speed	2.92×10^3 m/s
	Initial compaction pressure	2.33×10^4 kPa
	Solid compaction pressure	6.0×10^6 kPa
	Compaction exponent	3.0
	Solid EOS	Polynomial
	Bulk modulus *A1*	3.527×10^7 kPa
	Parameter *A2*	3.958×10^7 kPa
	Parameter *A3*	9.04×10^6 kPa
	Parameter *B0*	1.22
	Parameter *B1*	1.22
	Parameter *T1*	3.527×10^7 kPa
	Reference temperature	300 K
	Specific heat	654.0 J/(kg×K)
	Compaction curve	Standard
Strength	Equation	*RHT* concrete
	Shear modulus	1.67×10^7 kPa
	Compressive strength (*fc*)	3.5×10^4 kPa
	Tensile strength (*ft/fc*)	0.1
	Shear strength (*fs/fc*)	0.18
	Intact failure surface constant *A*	1.6
	Intact failure surface exponent *N*	0.61
	Tens./comp. meridian ratio (*Q*)	0.6805
	Brittle to ductile transition	0.0105
	G (elas.)/(elas.-plas.)	2.0
	Elastic strength/*ft*	0.7
	Elastic strength/*fc*	0.53

	Parameter *S1*	1.45
Strength	Equation	von Mises
	Shear modulus	1.0×10^8 kPa
	Yield stress	8.0×10^6 kPa
Armco iron [10]		
Reference density		7.87 g/cm^3
EOS	Equation	Linear
	Bulk modulus	1.64×10^8 kPa
	Reference temperature	300 K
	Specific heat	452.0 J/(kg×K)
Strength	Equation	Johnson-Cook
	Shear modulus	8.0×10^7 kPa
	Yield stress	1.75×10^5 kPa
	Hardening constant	3.8×10^5 kPa
	Hardening exponent	0.32
	Strain rate constant	0.06
	Thermal softening exponent	0.55
	Melting temperature	1.811×10^3 K
	Ref. strain rate (/s)	1.0
	Strain rate correction	1st order
Failure	Equation	Johnson-Cook
	Damage constant, *D1*	-2.2
	Damage constant, *D2*	5.43
	Damage constant, *D3*	-0.47
	Damage constant, *D4*	0.016
	Damage constant, *D5*	0.63
	Melting temperature	1.811×10^3 K
	Ref. strain rate (/s)	1.0

	Fractured strength constant *B*	1.6
	Fractured strength exponent *M*	0.61
	Compressive strain rate exp. alpha	0.032
	Tensile strain rate exp. delta	0.036
	Max. fracture strength ratio	1×10^{20}
Failure	Equation	*RHT* concrete
	Damage constant, *D1*	0.04
	Damage constant, *D2*	1.0
	Minimum strain to failure	0.01
	Residual shear modulus fraction	0.13
	Tensile failure	Hydro (P_{min})
Erosion	Equation	Geometric strain
	Erosion strain	2.0
	Type of geometric strain	Instantaneous
Copper [9]		
Reference density		8.9 g/cm^3
EOS	Equation	Shock
	Gruneisen coefficient	2.0
	Parameter *C1*	3.958×10^3 m/s
	Parameter *S1*	1.497
	Reference temperature	300 K
Strength	Equation	Piecewise JC
	Shear modulus	4.64×10^7 kPa
	Yield stress (zero plastic strain)	1.2×10^5 kPa
	Eff. plastic strain #1	0.3
	Eff. plastic strain #2	1.0×10^{20}
	Yield stress #1	4.5×10^5 kPa
	Yield stress #2	4.5×10^5 kPa
	Thermal softening exponent	1.0
	Melting temperature	1.0×10^{20} K
	Ref. strain rate (/s)	1.0

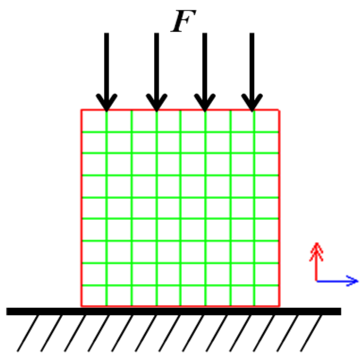

Figure 1 – The compression test scheme.

Results and discussion

Modeling the compression process was performed before shortening the model height by 50% from the initial height of the specimen. The calculated values of the compression ratio were obtained along the axis of the deformed specimen. The distance values on the graph are presented by the height values of the deformed specimen. The zero value for this coordinate axis of the graph is the reference point of the specimen height from the side of the applied load. The dependencies of the compression ratio of materials on the height of the deformed specimens are presented in the Fig. 2.

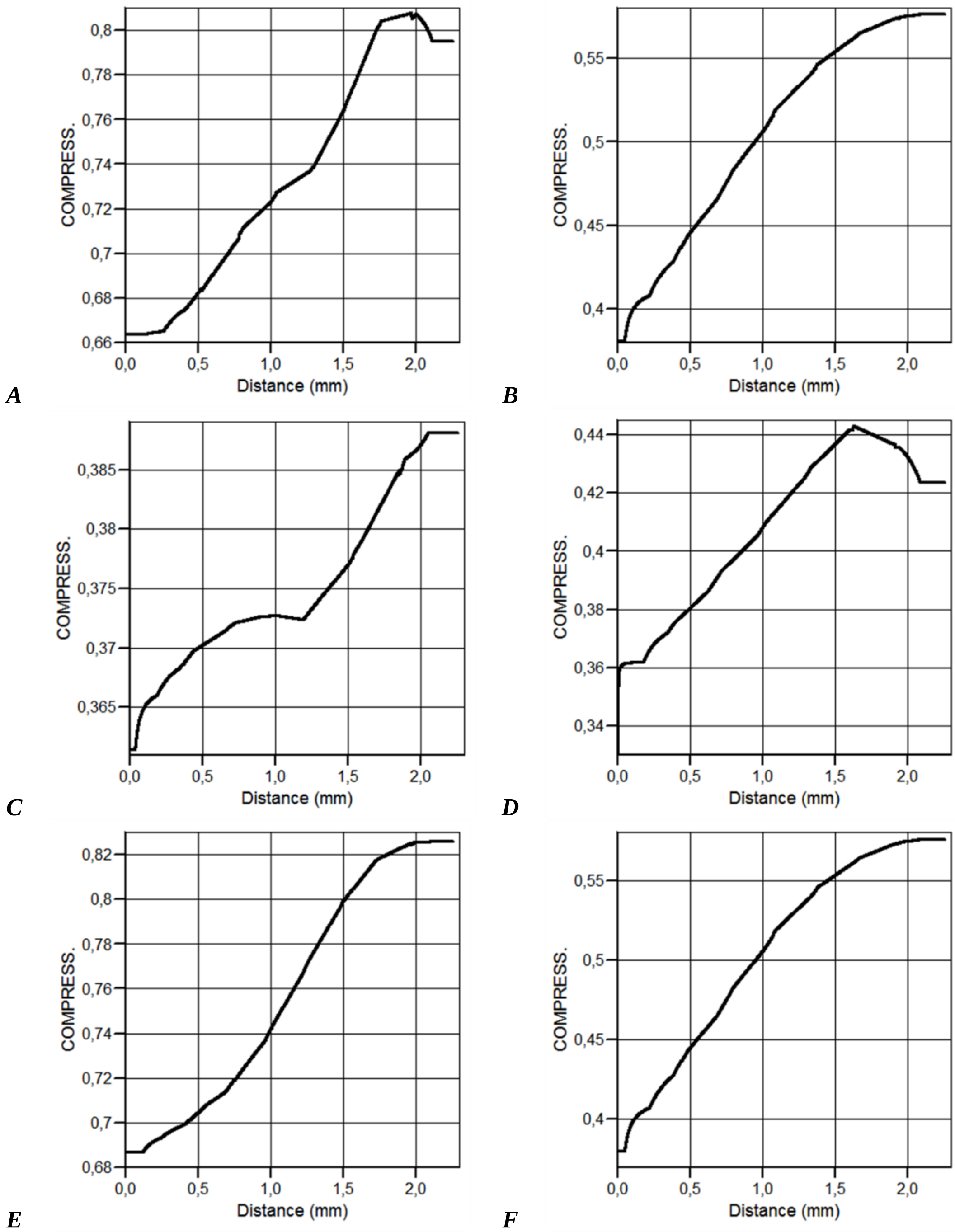

Figure 2 – The dependencies of the compression ratio of materials on the height of the deformed specimens: *A* – aluminum; *B* – iron-C.E.; *C* – Al_2O_3; *D* – copper; *E* – concrete (the compressive strength is 25 MPa); *F* – armco iron.

After analyzing the obtained graphs, it was determined that the greatest compressive strength is observed in the specimen made of ceramics. The compression ratio of ceramics during corresponding deformation is 0.39. In this case, the change range of the ratio value over the entire cross section of the specimen is no more than 0.03. This minimal change in the ratio value indicates the most uniform compression of material over the entire volume of the specimen. The lowest compressive strength is observed in the specimens made of aluminum and concrete. The compression ratio of these materials during corresponding deformation is 0.81 and 0.83, respectively. The change range of the compression ratios of aluminum and concrete increases by 5 times compared to ceramics. Iron-containing alloys are subjected to compression deformation in the same way and have the average values of the ratios. All materials are characterized by an increase in the compression ratio in the direction from the end surface on which the load is applied to the end surface on which basing the specimen is performed.

Conclusion

Thus, aluminum and concrete are destroyed during compression deformation of the volume by 50%, since the calculated compression ratio is 0.81-0.83 of 1.0 (where 1.0 is total failure of material). Compression of the ceramic products does not lead to the formation of significant change in the values of internal deformations in the volume. This indicates almost the same properties over the entire volume of deformed material. The compression ratio of ceramics is 0.39, which is half that of aluminum and concrete.

References:

1. (2011). *ISO 13314:2011. Mechanical testing of metals – Ductility testing – Compression test for porous and cellular metals.*
2. Khlystov, N., Lizardo, D., Matsushita, K., & Zheng, J. (2013). *Uniaxial Tension and Compression Testing of Materials*. 3.032 Lab Report, p. 19.
3. Chemezov, D., et al. (2020). Experimental study of fracture of the cast iron specimen during compression. *ISJ Theoretical & Applied Science*, 12 (92), 144-148.
4. (2020). *Autodyn User's Subroutines Guide*. ANSYS Inc., p. 120.
5. Grard, C. (1920). *Aluminium and its alloys. Their properties, thermal treatment and industrial application.* Constable & Company LTD, p. 226.
6. Sivakumar, G. (2010). *Compressive Strength of Concrete*. ICOMAT.
7. Doremus, R. H. (1990). Alumina-silica system. *Handbook of ceramics and composites*, Vol. 1: Synthesis and properties, New York, Basel, 23-34.
8. Galusek, D. (2010). *Ceramic oxides. Ceramics science and technology*, Vol. 2: Materials and properties, Darmstadt: Wiley-VCH, 3-58.
9. (n.d.). AMERICAN SOCIETY FOR TESTING MATERIALS (Revised Annually). “Copper and Copper Alloys.” *Annual Book of ASTM Standards*, Vol. 2.1 (2), (ASTM International, West Conshohocken, PA).
10. (n.d.). *ARMCO® PURE IRON. High purity iron.* AK Steel International, p. 24.