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The influence of intensive plastic deformation on iron-based materials by free precipitation

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ABSTRACT:
The development of many branches of modern production is inextricably linked with the development of new materials with a certain complex of mechanical, physio-chemical and technological properties. One of the effective ways to obtain materials with clearly defined properties is powder metallurgy. Materials obtained by pressing the powder usually have a high residual porosity. In order to improve their mechanical properties, we suggest using free sludge. We experimentally investigated various methods of intense plastic deformation and measured the hardness and strength of the obtained samples. We believe that our results show that free sludge can be used for reducing porosity levels in powder materials on an industrial scale.

KEYWORDS:
powder metallurgy; reduction of porosity of materials; free sediment; increase of physical and mechanical properties of materials

1. Introduction

Today's development in many branches of modern production is inextricably linked with the development of new materials with a certain complex of mechanical, physiochemical and technological properties [1-12]. One of the effective ways to obtain materials with clearly defined properties is powder metallurgy [13-15]. Materials obtained by pressing the powder usually have a high residual porosity and as the result - low mechanical strength.

The analysis of recent research was carried out thoroughly. Porosity is an important characteristic because it is associated with such technical properties of the material as strength, water absorption, cold-resistance, thermal conductivity, etc. [16]. Light porous materials usually have low strength and high water absorption, where denser materials have high strength and low water absorption [17, 18].

The purpose of this study is to develop a model and investigate the process of intense plastic deformation by free precipitation.

2. Experimental method and analysis

For the experiments, we used iron powder PZHRV200.28. It was pressed in a steel collapsible mold with a working diameter of 10 mm at a pressure of 600 MPa. To remove the defama-

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tion, the obtained cylindrical briquettes were annealed in a hydrogen atmosphere for 1 hour. As a result, we obtained four briquettes with an average density of 6.9 g/cm^3 and an average porosity of 11.5%.

We investigated double free sludge with a rotation of 90° in the direction perpendicular to the direction of initial pressing. The briquettes were placed between steel plates, pressed at a force of 10 to 30 kN, rotated at an angle of 90° and pressed again. Experiments have shown that the density of the briquette increased to 24 kN, force on the press reaches its maximum of 7.63 g/cm^3 and begins to decline (Fig. 1).

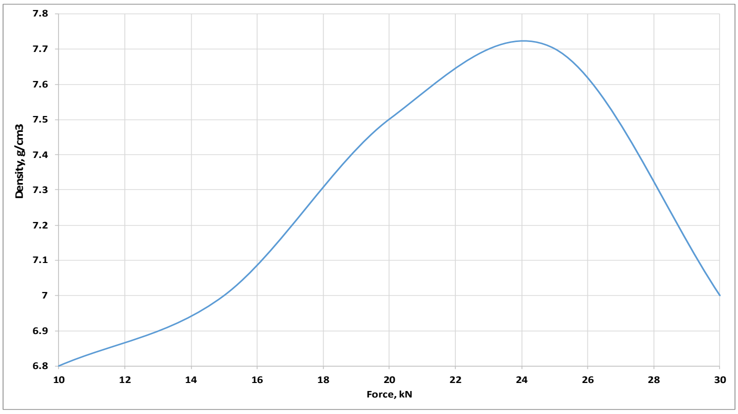

Fig. 1. The dependence of the density of the briquettes on the force of the press during the double free draft with a rotation of 90° in the direction perpendicular to the direction of the initial pressing

The advantages of this method for material porosity reduction are the simplicity of construction (a conventional press can be used) and the fact that the briquettes we obtained have a square cross-section (Fig. 2).

a) b) c)

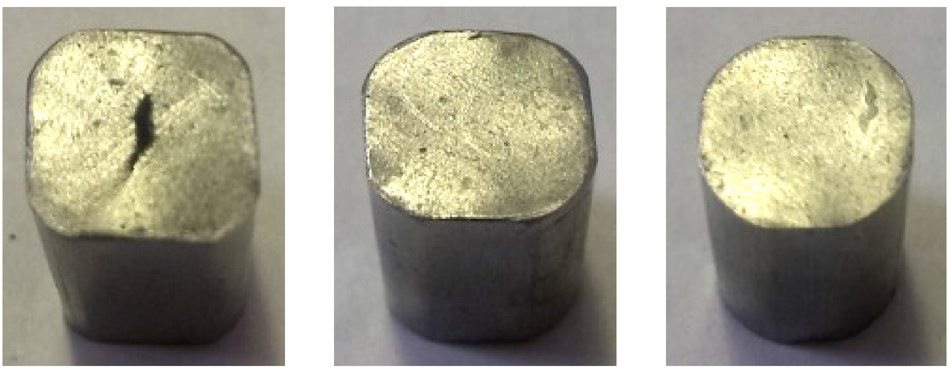

Fig. 2. Briquettes before (a), with maximal density (b) and after (c) double free draft with a rotation of 90° in the direction perpendicular to the direction of the initial pressing

We investigated the effect of free sludge in the direction of initial pressing on briquettes based on iron powder. The briquettes were placed between steel plates and pressed at a force of 10 to 80 kN. Samples based on iron powder were plastically pressed, and they increased in diameter and decreased in height. Experiments have shown that the density of the briquette increases to 75-80 kN, force on the press reaches its maximum 7.65 g/cm^3 and begins to decline (Fig. 3).

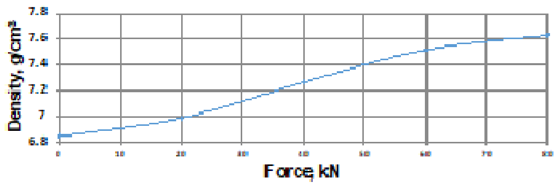

Fig. 3. The dependency of the briquettes density on the force of the press during free sludge in the direction of the initial pressing

This is due to the fact that on the briquettes side surfaces cracks begin to form in parallel to the direction of compression, that leads to increased porosity and reduced strength of materials (Fig. 4). Therefore, maximum density of the sample was obtained at a press force of 75-80 kN and was 7.65 g/cm^3, and the porosity was 1.9%.

Fig. 4. Briquette after free sludge in the direction of initial pressing

The advantages of this method for reducing the porosity of the material are the simplicity of design (a conventional press can be used) and low cost. However, the resulting briquettes are deposited at much higher press pressure.

An investigation of HRB hardness was performed on the TC-2 instrument using the Rockwell method by pressing the ball into the surface of the sample in accordance with the requirements of ISO 4498. The measurement results showed that there was an increase in hardness from 26-32 to 92-94 HRB.

Tests of the mechanical properties of materials were performed on a certified universal machine "CERAMTEST" with a capacity of up to 10 tons according to ISO 133314: 2011 (E), which is used for porous samples. The test results showed that the briquettes after molding from powder have a strength of 268-285 MPa (Fig. 5), after annealing and free precipitation, the strength of the samples increases to 785-864 MPa (Fig. 6), i.e. 3 times the original test results.

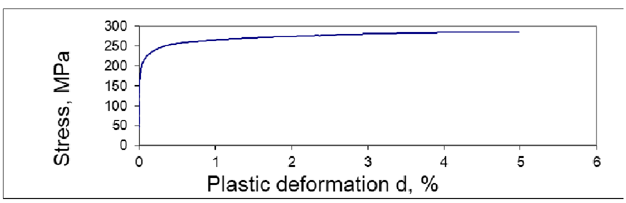

Fig. 5. Stress diagram – deformation after pressing

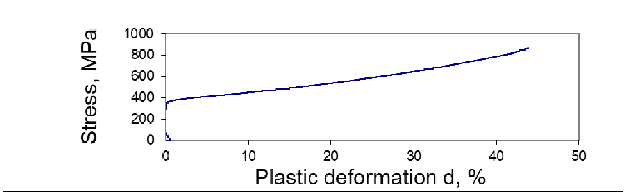

Fig. 6. Stress diagram – deformation after free deposition

3. Conclusions

We investigated the effect of intense plastic deformation on iron-based materials by free deposition. The obtained results showed that briquettes based on iron powder are deformed plastically with a regular decrease in the porosity of the material from 11.5 to 1.9%. We believe that our result is sufficient enough to use free deposition to reduce the porosity of powder materials on an industrial scale. The results of research have shown that the use of free deposition eliminates the operation of sintering for a certain class of powder materials for structural purposes, operating at moderate loads.

References

[1] Valiev R., Estrin Y., Horita Z., Langdon T., Producing bulk ultrafine-grained materials by severe plastic deformation, JOM 2006, 58.
[2] Valiev R.Z., Enikeev N.A., Murashkin M.Y., Utyashev F.Z., Using intensive plastic deformations for manufacturing bulk nanostructure metallic materials, Mechanics of Solids, 2012.
[3] Severe Plastic Deformation: Methods, Processing and Properties, Elsevier, 2018.
[4] Fedorchenko I.M., Franczevich I.N., Radomyselskij I.D., Poroshkovaya metallurgiya. Materialy, tekhnologiya, svojstva, oblastiprimeneniya, Naukova Dumka, Kyiv 1985.
[5] Libenson H.A., Osnovy poroshkovoi metalurhii, Metalurhiia, 1975.
[6] Khan M.K., The Importance of Powder Particle Sizeand Flow Behavior in the Production of P/M Parts for Soft Magnetic Applications, Powder Metallurgy and Powder Tech., 1980.
[7] Jones W.D., Fundamental Principles of Powder Metallurgy, Edward Arnold Ltd, London 1960.
[8] Upadhyaya G.S., Powder Metallurgy Technology, Cambridge International Science Publishing, 1996.
[9] Gusev A.I., Nanomaterialy, nanostruktury, nanotekhnologii, Fizmatgiz, 2007.
[10] Valiev R.Z., Aleksandrov I.V., Nanostrukturnye materialy, poluchennye intensivnoj plasticheskoj deformaciej, Logos, 2000.
[11] Segal V.M., Reznikov V.I., Kopylov V.I., Processy plasticheskogo strukturo obrazovaniya metallov, Nauka i tekhnika, 1994.
[12] Rabotnov Y.N., Soprotivlenie materialov, Fizmatgiz, 1962.
[13] Kuznecov V.D., Fizika tverdogo tela, Tomsk 1947.
[14] Sedov L.I., Vvedenie v mekhaniku sploshnoj sredy, Fizmatgiz, 1962.
[15] Bozhidarnik V.V., Sulim G.T., Elementy teorii plastichnosti ta micnosti, Svit, Kyiv 1999.
[16] Lahtin Yu.M., Leontieva V.P., Materialovedenie, Mashinostroenie, 1990.
[17] Meshkov Yu.Ya., Fizicheskie osnovy razrusheniya stalnyh konstrukcij, Naukova Dumka, Kyiv 1981.
[18] Poster A.R., Handbook of Metal Powders, 1966.

Wpływ intensywności odkształcenia plastycznego na właściwości materiałów na bazie proszków żelaza z zastosowaniem metody swobodnego prasowania

STRESZCZENIE:
Rozwój wielu gałęzi nowoczesnej produkcji jest nierozerwalnie związany z rozwojem nowych materiałów o specyficznym kompleksie właściwości mechanicznych, fizykochemicznych i technologicznych. Jednym ze skutecznych sposobów poszukiwania materiałów o nietypowych właściwościach jest wykorzystanie metody metalurgii proszków. Materiały otrzymane przez prasowanie proszku mają zwykle wysoką porowatość resztkową. Aby poprawić ich właściwości mechaniczne, zaproponowano zastosowanie swobodnego prasowania. Wykonano badania eksperymentalne, w których próbki materiału poddano badaniom odkształceniowym. Zakres pomiarów dotyczył twardości i wytrzymałości badanego materiału. Wyniki potwierdzają pozytywny efekt zastosowania swobodnego prasowania do zmniejszenia poziomu porowatości materiałów proszkowych z możliwością wdrożenia tej technologii na skalę przemysłową.

SŁOWA KLUCZOWE:
metalurgia proszków; zmniejszenie porowatości materiałów; swobodne prasowanie; poprawa właściwości fizycznych i mechanicznych materiałów