# INFLUENCE OF COMPOSITION AND TECHNOLOGICAL FACTORS OF OBTAINING COMPOSITIONAL MATERIALS OF IRON-SELF-FLUSIVE ALLOY ON PHYSICO-MECHANICAL CHARACTERISTICS

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**Abstract.** Studies of the mechanical properties of powder composite materials based on iron alloyed with self-fluxing alloys obtained by different technologies: pressing powder mixtures, followed by sintering in hydrogen, sintering billets in vacuum, impregnation. Depending on the method of preparation and the content of self-fluxing alloys, the hardness of the materials varies from 48 to 57 HRC, the flexural strength is from 1130 to 1350 MPa, and the tensile strength is from 550 to 660 MPa. The highest indicators are materials obtained by sintering in vacuum and impregnation.
**Keywords:** *powder materials, self-fluxing alloy, pressing, sintering, infiltration, stamping, hardness, tensile strength.*

## Introduction

The rapid pace of development of industrial industries dictates the conditions for the creation of new materials and products from them, which would, along with high values of strength and durability, would be resistant to aggressive environments. When creating powder composite materials for work in heavy-duty units, it is necessary to take into account that such materials must be high-density, have high values of impact strength and corrosion resistance.

**Literature Review.** Modern production solves this problem by using alloy steel powders and high-energy methods of their compaction (Stepanchuk, Demy`denko, Biryukovy`ch, Shevchuk, 2013), (Stepanchuk, Bilyk, 2016) which are energy-intensive, technologically complex and do not always allow to obtain satisfactory performance.

One of the options for obtaining high-alloy powder materials with a high density of products is sintering in the presence of a liquid phase or impregnation of porous frames with a low-melting metal (Dubovyj, Stepanchuk, 2007) bond. In this case, as a low-melting metal component that forms a liquid phase during sintering or the melt of which permeates the porous frame, it is advisable to use self-fluxing alloys (SFA), especially on the basis of iron (Stepanchuk, 2013). The latter have a relatively low melting point up to 1100 ° C and high mechanical characteristics - hardness and toughness, wear resistance. In addition, such alloys are resistant to oxidation due to the fact that they have the property of self-fluxing (Stepanchuk., Demydenko, Demydenko, Shapoval, 2012).

Based on the above, the study of the conditions for obtaining such materials and their properties in order to determine the areas of their application is a very important task. The aim of the work was to study the influence of the composition of materials from Fe - SFA compositions and methods of their compaction on some mechanical properties - hardness, flexural strength and tensile strength. Materials for the study of mechanical characteristics were obtained by three technologies in the optimal modes defined in (Demydenko, Stepanchuk, Shapoval, 2012):

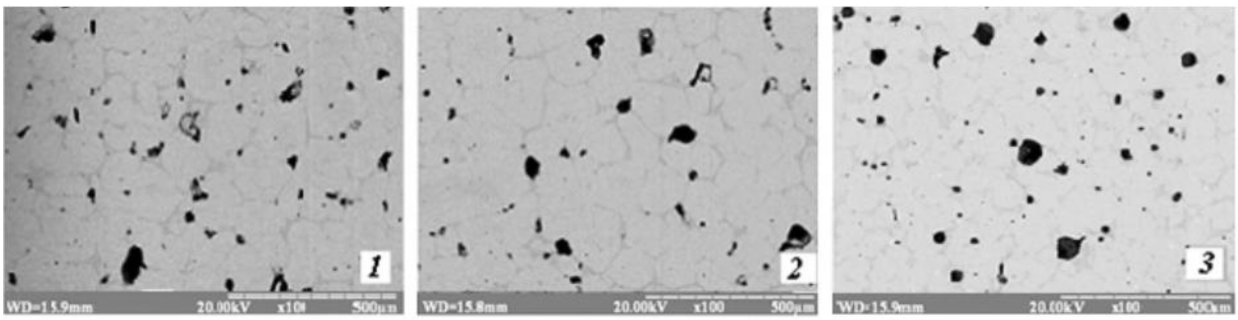
- pressing a mixture of source powders of iron and SFA, followed by sintering in hydrogen;
- pressing a mixture of raw iron powders and SFA, followed by sintering in vacuum;
- pressing from the original iron powders of porous blanks, followed by their impregnation with a melt of self-flux alloy in hydrogen and vacuum.

**Research Methodology.** In the case of obtaining materials by pressing followed by sintering in hydrogen, a mixture of powders of iron and self-flux alloy (Table 1) with different content of SFA - 10%, 15%, 20% and 30%, from which the samples were pressed at a pressure of 700 MPa and sintered them in a muffle furnace in hydrogen at a temperature of 1200 ° C for 45 minutes.

In the second case, the samples after pressing under the same conditions were sintered in a vacuum furnace in which a vacuum of 3.10-3 PA was created.

When obtaining samples, impregnations were pressed from iron powder into blanks with a pore volume, which would provide the content of the latter in the material in the material 10, 15, 20 and 30% when impregnated with SFA melt. Impregnation of porous blanks was carried out from below, as this leads to self-cleaning, the blanks were pre-sintered, as this contributes to minimal shrinkage and leads to the preservation of the original shape and size. The pore volume was determined by the method of work (Stepanchuk, Shevchuk, 2013).

**Research results.** The structure of materials obtained by the above technologies, their hardness, flexural strength and tensile strength were studied in the work. The structure was studied using a SEM-106 microscope. Hardness, flexural strength and tensile strength were determined by standard methods. The results are shown in Figures 1–3 and Table 1.




10% 20% 30%

*Figure 1. The structure of composite materials with different content of SFA sintered in hydrogen*

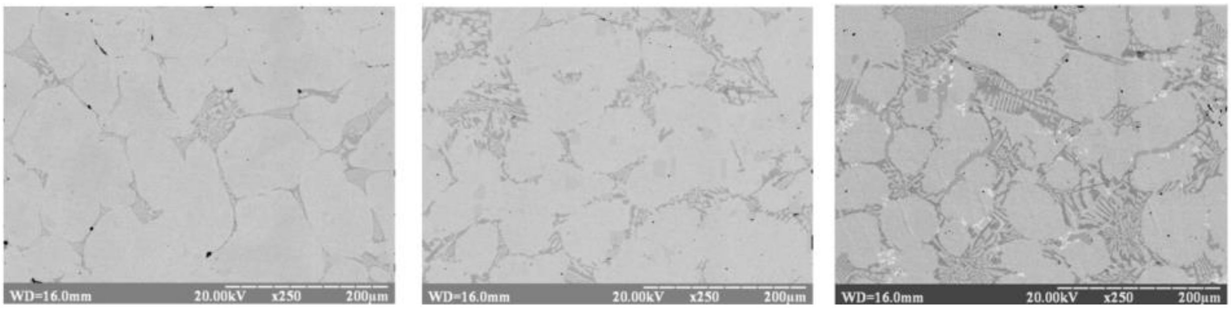



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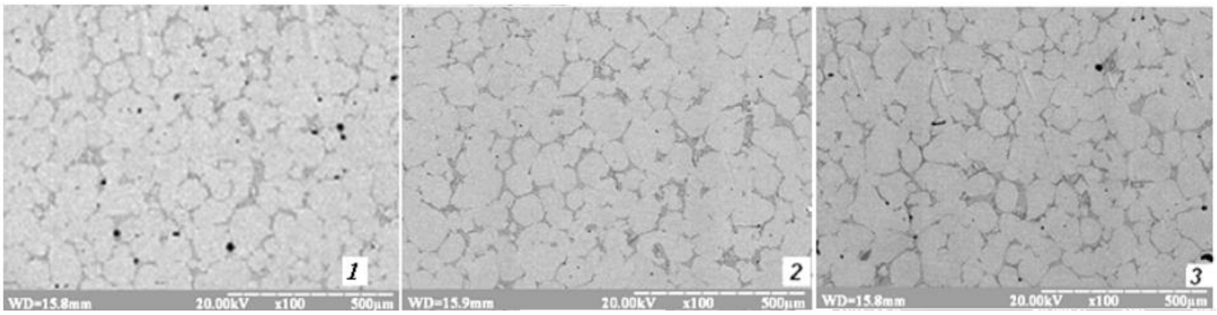
*Figure 2. The structure of the composite material with different content of SPA sintered in vacuum*




10% 20% 30%

*Figure 3. The structure of the composite material obtained by impregnation*

Metallographic studies have shown that the technology of production and composition of the material has a significant impact on the formation of the structure. Thus, samples sintered in hydrogen have a porosity (Fig. 1), which increases from 4% to 9% with increasing content of SFA (Table 1). The presence of porosity, as shown in (Demydenko, Stepanchuk, Shapoval, 2012) is due to the formation in the initial stages of sintering closed porosity. And the samples sintered in vacuum and obtained by impregnation have a non-porous structure (Fig. 2-3) with a uniformly distributed phase SFA. The formation of such a structure is facilitated by the absence of gas in closed pores during vacuum sintering and the absence of closed porosity during impregnation.

**Discussion of research results.** The study of physical and mechanical characteristics of materials shows that they depend on the porosity of the material and its content of SFA. As the content in the SFA material increases, the hardness increases from 20 to 48 HRC, and the flexural strength decreases from 1132 MPa to 965 MPa. The tensile strength remains virtually independent of the porosity (Radomyselskyj, Serdyuk, Shherban, 1985) and the content of SFA. This course of dependencies can be explained as follows.

The dependence of hardness should be consistent with modern ideas about the influence of porosity on the properties of powder products (Stepanchuk, Demy`denko, Biryukovy`ch, Shevchuk, 2013) according to which it should increase with decreasing the latter.

Table 1.

**Characteristics of composite materials from compositions Fe – SFA**

| Method of obtaining | The content of SFA,% | Properties | | | |
|---|---|---|---|---|---|
| | | Porosity,% | Hardness, HRC | Bending strength $\sigma_{bs}$, MPa | Tensile strength $\sigma_v$, MPa |
| By pressing with sintering in a hydrogen environment | 10 | 8,86 | 20 | 1132 | 560 |
| | 20 | 8,35 | 35 | 1046 | 550 |
| | 30 | 3,80 | 48 | 965 | 562 |
| Pressing with sintering in vacuum | 10 | 1,12 | 30 | 1100 | 640 |
| | 15 | 0,82 | 52 | 1350 | 664 |
| | 20 | 0,23 | 57 | 1262 | 660 |
| Melt | 10 | 0,81 | 24 | 1260 | 620 |

| | | | | | |
|---|---|---|---|---|---|
| impregnation of SFZ | 15 | 0,54 | 28 | 1300 | 645 |
| | 20 | 0,61 | 42 | 1325 | 640 |
| | 30 | 0,25 | 52 | 1278 | 615 |

But the reason for the increase in the hardness of the materials studied in the work may also be an increase in their content of SFA, which has a much higher hardness (Stepanchuk, Bilyk, 2016) than iron. The reason for the increase in hardness may also be the interaction of SFA with iron. As shown in (Stepanchuk, Bilyk, 2016), the interaction between them is the diffusion of the components of the SFA (C, Ni, Cr, B, Si) in iron particles and as a consequence of the change of phase composition (Fig. 4) with the formation of solid solutions and complex iron carboborides, which have a higher hardness than pure iron.

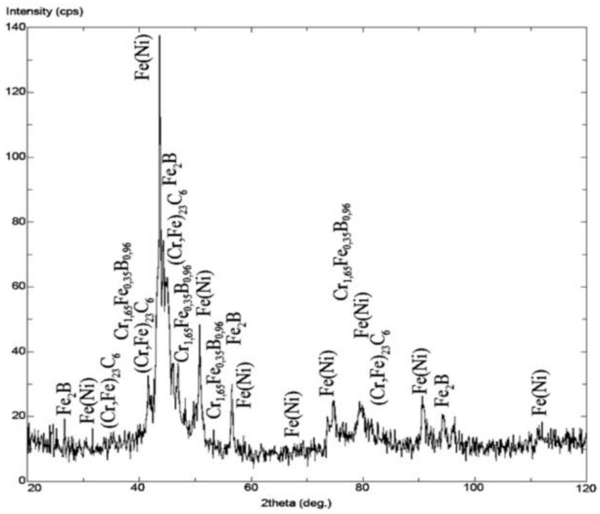



*Figure 4. XRD of the composite material Iron –SFA*

The study of tensile strength showed that it is weakly dependent on the porosity and content of SFA. Some non-monotonicity of the dependence may be due to competition from the effects of porosity and content of SFA. Weak dependence of tensile strength in the composition of the SPF may indicate that the predominant effect on the destruction of alloys Fe – SPF has a strength at the interface, the area of which in our case does not significantly depend on the content of SFA and can be estimated by the specific surface area of the original iron powder.

The study of the properties of the investigated materials obtained by pressing followed by sintering in vacuum showed that they are higher than in materials sintered in aqueous medium. In our opinion, the latter may be due to the fact that the obtained materials, regardless of their composition, have a porosity not exceeding 1.5 % (Fig. 2, Table 1) and have a structure with evenly distributed phase components. The phase of the SFA forms a uniform lace, inside which are placed grains of iron. Such a structure can be identified with "cellular".

Flexural and tensile strength is most important at a content of 15% SFA. An increase in the content of SFA leads to some decrease in these characteristics. The latter is consistent with the above considerations that the strength characteristics are predominantly influenced by the quality (strength) of the contact at the phase boundary. Increasing the amount of solid (brittle) component leads to some decrease in strength characteristics.

The properties of materials obtained by impregnation of porous frames from iron powder with a melt of self-flux alloy are similar to the properties of materials obtained by sintering in vacuum (Table 1). But in some cases, other things being equal (SFA content), they are slightly higher. Due to the similar structure of the materials obtained in this way, the latter can be explained by better refining of the surface between the grains and, thus, increasing its strength. The latter is consistent with the data of (Radomyselskyj, Serdyuk, Shherban, 1985) on the possibility of refining materials .

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## Conclusions

Studies have shown that the use of self-fluxing alloys based on iron allows to obtain composite materials with their participation by methods of powder metallurgy with high density, mechanical properties and a given structure. By changing the conditions of obtaining materials, you can create them with predefined properties by changing the quantitative composition of the material and adjusting its structure, which should be frame. It is established that the materials obtained by the method of impregnation of porous frames from iron with a melt of self-flux alloy have the highest mechanical characteristics. In this case, along with the formation of the frame structure there is an increase in strength between the phase components due to the refining of the surface at the phase boundary during impregnation.

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