JOURNAL OF ENGINEERING SCIENCES
ЖУРНАЛ ІНЖЕНЕРНИХ НАУК
ЖУРНАЛ ИНЖЕНЕРНЫХ НАУК

Web site: http://jes.sumdu.edu.ua

DOI: 10.21272/jes.2018.5(1).c2 Volume 5, Issue 1 (2018)

UDC 621.619.73

Research of Mechanical Properties of Thermite Material on the Basis of Steel Dross

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Article info:
Paper received: February 22, 2018
The final version of the paper received: April 1, 2018
Paper accepted online: May 6, 2018

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Abstract. Important direction in the development of technologies for the recycling of wastes of industrial productions is inclination on the use energy saving technologies. The article deals with general aspects of methods of utilization of industrial wastes by methods of powder metallurgy. One of the same methods, which is highly effective and technologically, is the method of utilization of dross by using it as the main component of exothermic mixtures. On the basis of experimental research composition of exothermic charge based on the scale of steel was developed and proposed that can be used for surfacing the details of responsible designation. The choice of main and alloying components of charge was conducted on the analysis of literature data and the calculation of the required chemical characteristics of the material. According to the chemical composition, the termite material can be attributed to qualitative structural steels. Important characteristic of this material is the lack of content of harm fulimpurities, such as sulfur and phosphorus. Research of mechanical properties showed that material has a high resilient deformationon a compression and durability. The analysis of diagram deformation allows to assert that plastic decomposition prevails upon the destruction of the material. The hardness of material at different depths of sampling is different, which indictates the impact of the technological parameters of combustion of exothermic mixtures on the properties of the material. Investigation of impact strength showed that the change in the temperature of the test does not significantly affect its change, which indictates the suitability of the developed termite steel for the surfacing of parts working under reverse friction and shock loads.

Keywords: exothermic mixture, dross, SVS, aluminothermy, material, mechanical description.

1 Introduction

One of important tasks for the further development of Ukrainian industry is the complex use wastes of industrial productions. Wastes of metallurgical and metal-working enterprises of Ukraine are distributed as follows: slags – 57–63; mineral wastes (scrap of refractory materialsand inlet components) – 4–6; scrap metal – 15–17; dust, waste products; dross – 9–13; others – 2–4. A significant amount of waste products in the wastes of metallurgical and metal-working enterprises contains from 45 % to 72 % of iron, 6.0–9.5 % of carbon and 0.5–4 % of zinc [1]. This raw material can be used for an agglomeration and in a converter steel production, manufacturing products on their basis and other. However, 90 % of the wastes after different metallurgical and technological processes together folding in some waste products storage units where they are preserved. The burial and folding of them in the deposits waste products to perform unusual influence on quality of surface and underground waters in general the ecological situation. The methods of powder metallurgy allow the use of such wastes in the technological processes of manufacturing products, which allows them to reduce substantially their cost and non-waste production provides practically.

2 Literature Review

Efficiency of wastes using of metallurgical enterprises, namely domain slags and waste products, in the manufacture of building materials proved in works [2, 3]. However, despite the economic efficiency, such technologies are rarely used in practice. While scrap metal and metals scab are convert practically fully by using them as the basic raw material for the manufacture of products.

A separate point is to allocate dross and sludge, the use of which is insignificant enough due to the high content of impurities such as abrasive, lubricating and cooling liquids. For the use of sludge requires expensive and costly technologies on their renewal [4–6], while a dross, as a rule, only needs to be crushed and sift.

At present existent the file of utilization proposed technologies or processing of dross, as oiled so dry. Most of the proposed technologies are reduced to its briquette with the further use in agglomeration processes [7,8]. Known methods for using dross for the manufacture of porous products are presented in the works [9, 10]. Such application of dross is conditioned by high maintenance in it iron oxides, that in combination with more easy metals e high content of iron oxides in it, which, in combination with lighter metals are capable of recovery with the release of high temperatures (SVS synthesis).

Application of dross in SVS processes allows one only sintered powder mixtures due to a heat that is distinguished, but also fully to proceed in iron from his oxides, is dross. Efficiency of such technologies is practically and theoretically proven and sometimes applied in industry [11–13]. The dross of steel often serves as the basic component of exothermic mixtures, that used for heating of the gate systems, manufacture of thermite steel, metals welding and component manufacturing by exothermic melting. However, without regard to plenty of researches and theoretical calculations of alumetermic processes with the use dross of steel very small attention is spared to the study of properties the materials obtained. Research of the physical, mechanical and chemical properties of thermite steels and conformities to law of their change will allow to have a close idea about the processes of relation of material at the exothermic burning, to get dependences of mechanical and physical properties on composition, dispersion and technological parameters of burning of charge. Such knowledge will allow forecasting properties of exothermic steel on the stage of development.

The results of researches the temperature indexes burning of exothermic mixtures, given in work [14], allow us to derive the relationship between the specific surface of the pyrophoric powder and the oxides to minimize the activation energy of the SVS reaction. It has been proved that reducing the size of powder contributes to uniformity of reaction. These data are useful in developing the composition of exothermic mixtures. Research of the phase separation of intermetallic of the Fe-Al system obtained in the mode of SVS and its kinetics, described in [15], shows the mechanism of their formation during the rapid heating that occurs in burning exothermic and cooling below the crystallization temperature. During slow heating the formation of intermetallic compounds ofFe_2Al_5 and $FeAl_2$ begins below the melting point of aluminium. When the heating speed is high, intermetallic is formed after the aluminium is cured. These data are key at an idea about the structure and phase formation of thermite metals.

The research aim is determination of the mechanical descriptions of new material which received by metal thermite method.

3 Research Methodology

Exothermic waste products was prepared on the basis of dross steel of 18Ch2N4MA of forging and stamping production of LLC “Kovelsilmash”. The chemical properties of thermite steel directly depends on the composition of the charge. As known [16], the content of aluminium in thermite steel in an amount 0.15–0.20 % leads to deterioration of it plastic and mechanical properties. For saturated and improvement of mechanical properties of thermite steel in composition of exothermic charge enter a ferromanganese and ferrosilicon [17–18]. Introduction to the charge of copper in an amount 3–5 % leads to a uniform passage of the reaction and allows to increase the combustion temperature by 100–150 °C. In addition, copper increases pirofornist charges and assists the best dissociating of liquid metal from a slag [19]. Established that the oxygen balance of 18Ch2N4MA of dross steel forging-stamping production is 22.5–25.0 % O_2, which is lower than that required for stable reaction passage and full blown out of the charge. Introduction to the exothermic charge powder of saltpetre potassium in an amount 7–9 % provides stable combustion due to the uniform distribution of the oxygen balance of the charge. An addition of saltpetre potassium allows bringing down a temperature of ignition of the charge and increase its caloric content.

Therefore, proceeding from the foregoing and using data [20] next composition of exothermic waste products was select (Table 1).

Table 1 – Mass particle of components of exothermic waste products, the masses %:

Dross of steel 18Ch2N4MA	68–72
Aluminium powder PA-3 GOST 6058-73	16–20
Copper powder PMS-1 GOST 4960-75	3–5
Potassium saltpetre GOST 19790-74	7–9
Ferromanganese FMn75A	0.5–0.8
Ferrosilicon FS 45	1.5–2.2

Granulometric composition of the exothermic mixture in mm: iron-aluminum termite; 0.3-0.5 dross; 0.3 powder of aluminum; 0.1 copper powder; 0.4–0,5 powder of potassium saltpetre; 0.1 powder of ferrosilicon and ferromanganese.

As a result of the exothermic reaction a monolithic sample was obtained, the chemical composition of which is given in Table 1.

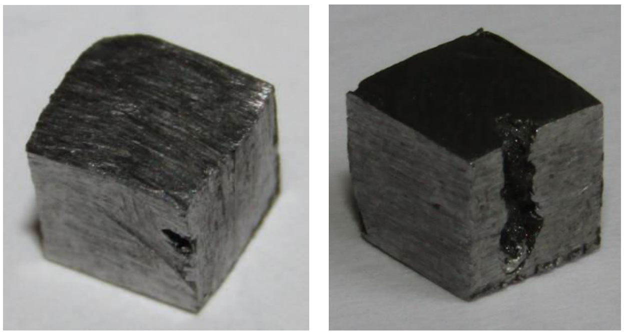
Correlation of part of metal and slag 63:37.

Table 1 – The chemical composition of the material obtained

Test	Chemical composition, %						
	C	Si	Cr	Fe	Mo	Mn	Ni
1	0.43	0.21	0.22	98.79	0.07	0.17	0.05
2	0.38	0.2	0.25	98.83	0.05	0.19	0.10

The presence of high content of aluminium is explained by division incomplete of metal and slag at passing of exothermic reaction. Identified vanadium probably formed from iron oxides as it is geochemically close to Fe, Mn, Cr, Al, Ti. The presence of vanadium in the amount of 0.2 % and more increases the stability of steel release.

Researches of the obtained steel strength at compression conducted on a machine MT 120-40. With the aim of reduction of force of friction that may break the uniaxial elastic-deformed state, on the butt-end surfaces of standard inflicted a paraffin layer. A standard was executed in cube form with sizes a (5 ± 0.5) mm. Pressure of tests of 40 MPa. Researches conducted on a monolithic sample (Fig. 1 a) and a sample with defect (Fig. 1 b).



a b

Figure 1 – Samples for strength tests:
a – monolithic sample; b – sample with defect

Depth of pore on sample with defect 0.7–0.9 mm, volume 26 mm^3. The sample with the defect was placed so that the defect axis was parallel to the load axis. The loading speed was determined from the formula [21]:

$$\frac{d\varepsilon}{dt} = (0.01...3),\ \text{min}^{-1}. \quad (1)$$

Figure 2 shows that the deformation curve is characteristic for plastic destruction. Section *AB* is the plane of flow. On this area is displacement of atomic layers in relation to each other. On the *BC* section there is strengthening of material by changing the internal structure of the sample, as a result of what a standard shows resistance to deformation. Section *CD* is theplastic deformation. On this section increases the cross-section of the sample. Section *DE* is the discharge curve and shows the zone of elastic deformation of the sample and residual deformation. This deformation curve is characteristic for the dependence of $S_s(\varepsilon_l)$. For such deformation curves intensity of strengthening at insignificant degrees of deformation and then sharply increases [21].

The deformation curve for a defective sample is shown on Figure 3.

As evidently on Figures 2–3, the change in linear deformation for a defect sample is practically no different from the deformation for a monolithic sample. It testifies to strong interatomic connections and low speed of crack propagation.Border of strength material, that was determined by hardness dynamic of TD-42M presents 870–920 MPa.

Hardness measuring conducted on a hardness of HR-150A according to GOST 9013-59. Hardness for a raw sample is given on the HRA scale. As an indenter used a diamond tip with a corner at the top of a 120°, loading 590 N. Measuring of hardness conducted on different depths of the sample.

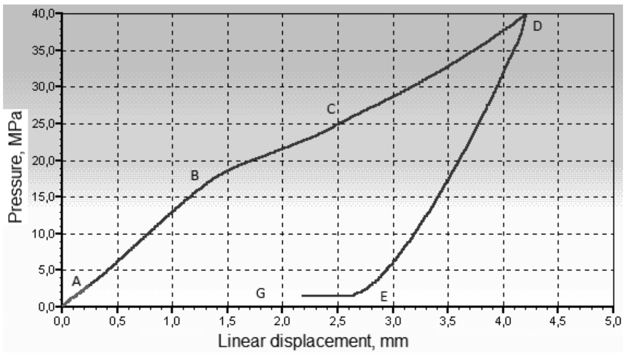


Figure 2 – Dependence of linear deformation
on the applied force for a monolithic sample

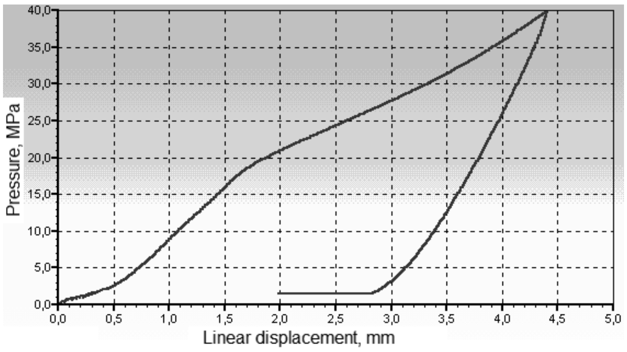


Figure 3 – Dependence of linear deformation
on the applied force for a defective sample

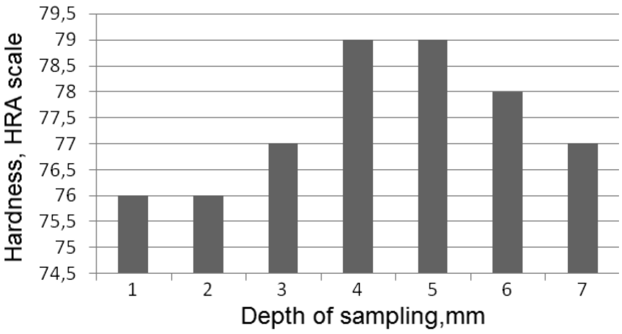


Figure 4 – Hardness of the raw sample
depending on sample depth

The change in hardness depending to taking on sample depth is explained change in the chemical composition of the resulting exothermic mixture combustion. The trend of change in hardness suggests the effect of the technological parameters of combustion of exothermic mixtures on the properties of the materials obtained. The change in the granulometric composition of the mixture toward the consolidation of the powders allow increase the hardness. This happened to a lower fill density, which in turn leads to a better passage of gases and, as a consequence, reduces the consolidation of the alloying elements in the upper part of the material.

Important characteristic of the structural strength of materials is the impact strength. It depends both on the strength and on the plasticity of the material. Research impact strength on the pendulum copier MC-30.

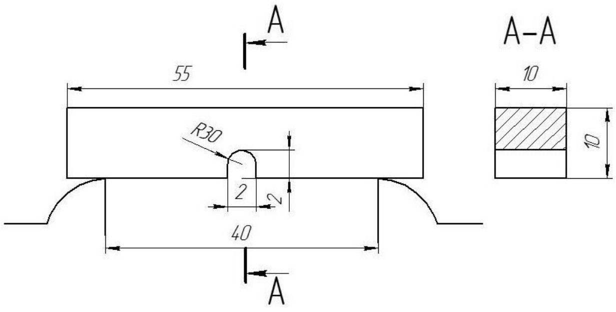


Figure 5 – Design scheme of sample and geometric parameters

For research of impact strength took away sample that no apparent external defects (shells, cracks) and complied with the requirements of GOST 10708-82.

The sample was mounted on the supports of the cow so that the incision was on the opposite side of the impact. Researches conducted at a temperature 60, 40, 20, 0, and –20 °C.

KCU for the raw material at different temperatures is shown on Figure 6.

According to the results of tests samples with U similar incision, the minimum impact strength of the material at a temperature -20 °C, that presents 150 J/cm^2, that is sufficient for materials that work in the conditions of reversible friction and temperatures 40-60 °C.

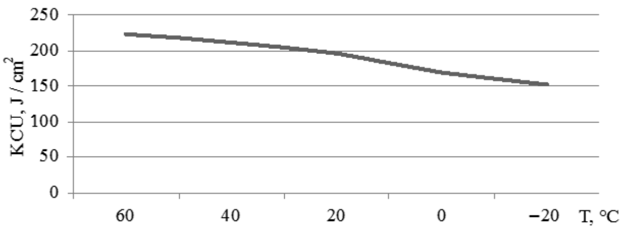


Figure 6 – Impact strength of raw sample

4 Conclusions

The composition of the exothermic charge with the production of steels has been developed. The research results of mechanical properties of steel allow thermite hypothesis about influence of technological parameters of the combustion mixture on the mechanical properties of the material shown by changing the hardness of the sample depending on the depth of sampling. The experimental data obtained show strong interatomic bonds and a low speed of crack propagation. Border of material strength presents 870–920 MPa. Impact strength of raw standard presents 170–220 KCU and is sufficient for material work in the conditions of the dynamic loading and reversible.

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Дослідження механічних властивостей термітного матеріалу на основі окалини сталі

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Анотація. Важливим напрямом у розробці технологій утилізації відходів промислових виробництв є нахил на використання енергозберігаючих технологій. У статті розглядаються загальні аспекти способів утилізації промислових відходів методами порошкової металургії. Одним з таких методів, що є високоефективним та технологічним, є метод утилізації шлаку, який використовується як основна складова екзотермічних сумішей. Вибір основних і легуючих компонентів матеріалу проводився на основі аналізу літературних даних та розрахунку необхідних хімічних характеристик матеріалу. Відповідно до хімічного складу термітний матеріал можна віднести до якісних конструкційних сталей. Важливою характеристикою цього матеріалу є брак вмісту шкідливих домішок, таких як сірка та фосфор. Дослідження механічних властивостей показало, що матеріал має значні пружні деформації при стисканні та довговічність. Аналіз діаграми деформації дозволяє стверджувати, що при руйнуванні матеріалу переважають пластичні деформації. Твердість матеріалу на різних глибинах відбору проб є різною, що обумовлює вплив технологічних параметрів горіння екзотермічних сумішей на властивості матеріалу. Дослідження ударної в'язкості показали, що зміна температури випробувань істотно не впливає на її зміну, що свідчить про придатність розробленої термітної сталі для наплавлення деталей, що працюють за умов реверсивного тертя та ударних навантажень.

Ключові слова: екзотермічна суміш, окалина, СВС, алюмотермія, матеріал, механічні характеристики.