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AL-W-B POWDER COMPOSITE MATERIALS

AL-W-B PRÁŠKOVÉ KOMPOZITNÍ MATERIÁLY

Abstract

Powder materials containing an aluminum matrix and W-B fibers are investigated. For manufacturing of Al-W-B powder composite materials the technological wastes of boron-aluminum, containing 25...40% boron-tungsten fibers, are used.

The macro and microstructure of the powder material with the average size of particles 0.1...2.0 mm that is made by crushing of the basic product in the disintegrator was investigated. Crushing was carried out in several operations until obtaining the fibrous powder of the intended size. Powder contains the aluminum matrix in which the extended needle-shaped and crystal-like boron-tungsten fibers are evenly distributed. Here the content of boron by the volume is from 18 to 47% and tungsten up to 1.5%. Due to high hardness of material the crushing of hot pressed composite takes the sufficient energy input. The axial fracture of fibre and strain hardening of the aluminium matrix are occurred.

Depending on the degree of crushing the particle size is from 0.2 to 1.5 mm. It is concluded that a new material we could characterize as a fibrous powder. The apparent density of a powder is 0.6...1.5 g/cm³ and micro hardnes of particles of a firm phase is 2...70 GPa. After sintering the density of samples were 2.1...2.3 g/cm³ and compression strength were 70...90 MPa. After testing the character of destruction of the samples was defined as quasi-fragile.

The main directions of application of investigated material are offered. There are using as grinding elements for the polishing tool, as ligature in metallurgy and ceramic manufacture and application as constructional products in building and mechanical engineering.

Keywords: a boron-tungsten fiber, crushing, compaction

1. Introduction

Fibrous composite materials with metal matrix are effectively used in newest technical industries because of their high durability, small weight and other valuable properties [1]. Among such materials the aluminum composites, reinforced by the fibers of boron, tungsten and carbide of silicon are widely known [2, 3].

Properties of such composites, depending on technological parameters of manufacturing process, the volumetric maintenance of fibers and other factors are considered in works [3, 4].

The problems of reprocessing and rational waste management arise at different stages of the composites manufacturing, especially at the stage of utilization. One of the new directions of the use of technological wastes of boron-aluminum composites is its crushing into powder. For the first time this direction we offered in our work [6]. Powder production is accompanied by numerous acts of fracturing. It is know that during deformation and fracture the high density of structural defects, nanostructure and micro cracks network are formed. When the process of milling takes place in the active medium, like in air, oxides and other chemical compounds may be formed both on external and
internal interfaces. As a result, powders obtained through crushing of Al-B composite materials may serve as a way of production a new heterogeneous material with new properties.

2. Experimental

As the subject of studies the waste of the commercially produced Al-W-B composites in the form of pipes, plates and strips, obtained by the method of hot pressing, was taken (fig. 1a-c). For the purposes of comparison, the W-B strips with Al coating at the stage of preliminary manufacturing of composites were used (fig. 1d).

![Fig. 1 Technological wastes of Al-W-B composites: a) pipes (diameter 20...150 mm, length 100...300 mm); b) plates (thickness 1...3 mm, width 100...150 mm); c) strips (thickness 3...6 mm, length 300...800 mm); d) W-B fibers strips after the thermal spraying on of aluminum (thickness 0.5...1.0 mm, width 40 mm and length 200...300 mm)](image)

In the hot-pressed material intended for the crushing, the W-B fiber has unidirectional structure and it is well fixed in the aluminum matrix (fig. 2a). W-B fibers were received by the method of boron tri-chloride deposition onto tungsten fiber base of 10 µm thickness (fig. 2b). This technology is described for example in [2] and Shatta, W. [5]. Dark circles at the fig.2a are the boron fibers, while bright spot inside is the W wire of 10 µm thickness.
Crushing of composites was carried out in several stages using the equipment of the Fritsch Company [8]. During crushing of such composite material the boron fibers was served as additional deforming rigid elements.

For estimation of the mechanical properties of powder particles the Vickers micro hardness method was used. To determine the micro hardness a precision micro hardness tester described in [9] was used. The micro hardness tester is insensitive to the vibrations and suitable for accurate surface hardness measurements with load less than 2N.

3. Results of Al-W-B composite powder properties investigation

Preliminary splitting was carried out in the jaw crusher until particles with the size of not more than 20...25 mm were obtained (fig. 3a). Then grinding in the disk vibrating mill till the size of particles became 0.1...1.5 mm was carried out (fig. 3b). Final crushing was carried out in the planetary ball mill until the size of the particles became not more than 0.1mm (fig. 3c).

Crushing of the hot-pressed composite requires significant expenditures of energy, which is caused by its sufficiently high strength. Axial destruction of fiber and work hardening of aluminum matrix can be also seen.

Research results of some basic properties of Al-W-B composite powders obtained are presented in the table 1.

The micro hardness of boron-tungstic fiber was remained high at all stages of crushing. At the same time the micro hardness of aluminum matrix at the moment of crushing was increasing and reaching 2.0...4.5 GPa, which was much higher than the initial indices of micro hardness.
Table 1 Physic-mechanical properties of the composite powders Al-W-B, obtained by crushing of the hot-pressed composites

<table>
<thead>
<tr>
<th>Nr. of the sample</th>
<th>Bulk density, g/sm³</th>
<th>Size of particles, mm</th>
<th>Micro hardness of particles, GPa</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Al</td>
<td>B</td>
</tr>
<tr>
<td>Al-B (1)</td>
<td>0.60</td>
<td>1.5...2.5</td>
<td>2.5...5.0</td>
</tr>
<tr>
<td>Al-B (2)</td>
<td>0.75</td>
<td>1.0...1.5</td>
<td>2.0</td>
</tr>
<tr>
<td>Al-B (3)</td>
<td>1.0</td>
<td>0.2...0.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Al-B (4)</td>
<td>1.35</td>
<td>0.2...0.5</td>
<td>2.0</td>
</tr>
</tbody>
</table>

The sowing of powder was performed using Fritsh’s vibration screen Analizette 3 in the range of fineness from 5 to 200 μm with further classification (fig. 4).

The microstructure of the particles of the composite powder is represented on fig. 5. Even distribution of short W-B fibers in the aluminum matrix can be observed (fig. 5a) and at the same time clearly expressed ends of the fibers of crystal-like form can be seen (fig. 5b and c).

While crushing of W-B strips with Al coating (fig. 1d) the level of power consumption is significantly lower. It can be described by the absence of the strong joints between its components. It is obvious, that the part of the fibers does not contain matrix environment. Powder after crushing contains a significant amount of free fibers (fig. 6a). At the same time during the sowing it is possible to separate the matrix material easily (fig. 6b).

Fig. 4 Histogram of the sizes of particles of the fibrous composite after its crushing

Fig. 5 Microstructure of Al-W-B composite powder after its crushing: a) x100; b), c) x 250
4. Possibilities of the practical application

Preliminary investigation of a microstructure and properties of a new material allows to make suggestions on some technological opportunities of its application.

One of them is the possibility of using the Al-W-B composite fibrous powder as the boron-containing ligature in the production of aluminum. It is applied for injection of alloying elements into liquid aluminum with the purpose of change of the structure and improvement of metallic melt properties, particularly its fluidity. In this case it is observed increased strength and corrosion stability of the hardened metal. Furthermore, aluminum is processed by boron for neutralizing of harmful effect of titanium, vanadium, chromium and other elements on its electric conductivity. However, adoption of the powder ligature alloying element can be higher, more technological and more uniform by the volume, than during the injection of boron in the pure form.

We have prepared the ligatures of the crushed composite powder in the form of the rings, flat and cylindrical elements, intended for the modification of the aluminum melt (fig. 7).

Al-W-B ligatures were added into the bath with the aluminum melt at a temperature of 700...750°C. A good distribution of powder ligature in the fusion ensured the total sedimentation in the form of the particles of mixed borides. While continuous holding the borides will agglomerate and sediment out in the form of slime of high concentration.

Production of the polishing tool is another direction of the possible application of composite powders. For preparing the samples (fig. 8) crushed Al-W-B composite powders undergone electro sintering in the electric resistance machine under the pressure of 70 MPa. Sintered samples had a density of 2.1...2.3 g/cm³ and compression strength of 70...90 MPa. Testing of cutting properties were performed on friction machine. Tests results confirmed that this application direction is perspective. However further sequential researches of the properties of new material are necessary.
5. Conclusion

In this work the possibility of crushing of the technological wastes of boron-aluminum composites into the powder was shown. At that the size, properties and form of particles are depends on the method and duration of crushing.

It was established that the practical application of obtained powder has wide perspectives. Due to high residual hardness of the crushed fibers and crystal-like shape of particles, there is the possibility of their application for manufacturing of some types of polishing tools. Received ligatures in the form of a powder and powder briquettes can find application for the improvement of the properties of metal and ceramic materials.

Acknowledgement

The authors are grateful to the Ministry of Education of Latvian Republic for financial support of the project 09.1072.

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