Structure and Properties of Detonation Coatings of Mechanocomposite Based on Bazalt-NiAl

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Abstract. The chemical composition, structure and microhardness of detonation coatings based on mechanically activated mixture of basalt powder and NiAl have been studied. It has been shown that the application of mechanomixture by detonation method results in the formation of composite coating similar to the composition of starting mixture. It has high microhardness and temperature resistance that will increase the wear resistance of parts coated with basalt at elevated temperatures.

Introduction.

Basalt is a natural material of volcanic origin, is increasingly used in construction, composite materials manufacture, as protective coatings, thin fibers, special fabrics, etc. The following fact is important: rocks-basalts make up about 30% of the Earth's crust that makes it virtually unlimited source of raw materials for the manufacture of products with the use of mineral resources. Only in Russia there are more than 150 explored and nearly 70 mastered fields. Because of its availability and therefore cheapness, it is used as crushed stone in gravel roads construction and dumping in the form of crushed stone of various fractions. Material, which are cheaper than basalt don’t exist in principle. If we compare it with the other plate-fillers used for the production of protective coatings and having comparable properties, basalt is 10 times as cheap as they.

The simplicity of manufacture, availability and raw materials cheapness, as well as valuable functional characteristics of basalt fiber - all of this cause an increased interest to coatings, basalt fiber, wool, scales and other materials on its basis.

Today we can distinguish some of the valuable characteristics of composites and coatings made of basalt, such as for example:

- the strength of basalt fiber is 15 times as high as the strength of steel one of the same section and material density is 4 times less [1,2].
- Amazing corrosion resistance allows manufacturers to provide a guarantee on the basalt coated pipe, reinforcement, and other products - up to 50 years or more, they do not rust, as basalt products are totally inert to acidic and alkaline conditions [5].
- In basalt coated pipes and boilers scum and precipitation are hardly deposited [6].
- basalt coated products can "breathe" and maintain thermal cycles at temperatures from -200 °C to +200 °C [3].

The chemical composition of gabbro-basalt group rocks is shown in Table 1.
Materials and methods.

The methodology of the study the process of basalt cover applying by detonation-gas method. At Problematic Research Laboratory (PRL) SHS Materials ASTU for spraying coatings detonation spraying installation "Katun-M" has been used.

Basalt grit with particles of 3-4 mm. size was subjected to treatment in a planetary ball mill AGO-2C for 10 minutes and sieved into 3 fractions (<63 microns 63 microns 100..200 mm). Then, obtained powder was dried for one hour and a half at 200 °C temperature. Mehanokompozit composition of basalt powder with additions of 30% intermetalida NiAl was used as sprayed powder.

Table 1 - Chemical composition of basalt

|          | Mass fraction of elements, % |
|----------|------------------------------|
|          | SiO2 | Al2O3 | FeO | Fe2O3 | CaO | MgO | K2O | Na2O | TiO2 | MnO | P2O5 | unavoidable impurities |
| from     | from | from | from | from | from | from | from | from | from | not more than | not more than | not more than |
| 39 to    | 10   | 10   | 8    | 4    | 2    | 0.2  | 0.2  | 0.2  | 0.2  | 2.5           | 5             | 0.4       |
| 51 to    | 19   | 18   | 13   | 12   | 12   | 12   | 12   | 12   | 12   | 12            | 12            | 12        |

Detonation spraying is made on the surface of the part - a steel plate of 50×40 mm, which was subjected to sandblasting.

Studies of the chemical composition of basalt powder with NiAl addition was conducted with the help of Carl Zeiss EVO 50 scanning electron microscope with console for energy-dispersive chemical analysis EDS «INCA X-ACT» made by «Oxford Instruments».

The chemical analysis held during the study of powder particle (Figure 1) showed the content of elements that is presented in Table 2.

The studies of the chemical composition of the coating on the basis of basalt powder (Figure 2) of the region "Spectrum 1" showed the presence of elements of the proportions indicated in Table 3.

The coating chemical composition showed that weight and atomic ratio changes unlike the powder chemical composition practically didn’t happen.

Table 2 – The chemical analysis of elements contained in the basalt powder particle

| An element | Weight, % | Atomic, % |
|------------|-----------|-----------|
| O          | 55.53     | 71.34     |
| Mg         | 3.88      | 3.66      |
| Al         | 7.06      | 5.38      |
| Si         | 16.63     | 12.17     |
| Ca         | 2.74      | 1.43      |
| Fe         | 8.22      | 3.03      |
| Ni         | 6.01      | 4.11      |
Figure 1 - Basalt powder particle. Spectrum 1 - the study area of chemical composition

Table 3 - Chemical composition of the coating

| Element | Weight, % | Atomic, % |
|---------|-----------|-----------|
| O       | 52.26     | 68.28     |
| Mg      | 6.08      | 5.23      |
| Al      | 7.27      | 5.63      |
| Si      | 17.27     | 12.86     |
| Ca      | 5.68      | 2.96      |
| Fe      | 9.04      | 3.38      |
| Ni      | 3.4       | 2.7       |

To investigate the general coating structure microsections were prepared. The total structure was observed after etching in 3% alcohol solution of nitric acid, and in a study of fine structure of coating chemical etching with an aqueous solution of 20% red blood salt K3 [Fe (CN) 6], and 20% KOH was used for 5 minutes.

Figure 2 - Basalt coating with the SHS composite NiAl addition. Spectrum 1 - the study area of chemical composition.
The study of overall (Figure 3) and fine (Figure 4) structures were carried out on optical microscope Carl Ziess AxioObserver Z1. The coating is dense with no delaminations. It means a good coating adhesion to the substrate (adhesion). As it is seen from the figure the coating is multilayer without visible pores and cracks.

Micro Durometer 402 MVD was used to measure microhardness and for Vickers testing with the possibility of operating in automatic and manual modes in the load range of 0.01 - 2 kg.

Hardness measurement was carried out on the coating layer, the indenter load was 100 g. 8 injections were made along the entire length of the coating (Table 4).

Figure 3 - The coating general structure
Average coating microhardness value was 473 HV, it is 3.5 times as high as base metal microhardness (134 HV), and in some areas of coating microhardness is up to 600 - 670 HV (Figure 5), it is 4.5 - 5 times as high as base metal microhardness, it will increase the wear resistance of the coated parts.

Table 4 - Tests for microhardness

| Injection № | Vickers indications |
|-------------|---------------------|
| 1           | 393 HV              |
| 2           | 497 HV              |
| 3           | 512 HV              |
| 4           | 428 HV              |
| 5           | 467 HV              |
| 6           | 482 HV              |
| 7           | 404 HV              |
| 8           | 602 HV              |
| Average value | 473 HV           |
Conclusions.
Basalt coating of mechanically activated powder was obtained. It was deposited on the steel plate by detonation-gas method. The structure research showed that the coating is dense and multi-layered. The chemical composition of the coating showed that the weight and an atomic ratio of the elements was practically unchanged with respect to the chemical composition of the powder. Formed coating has high microhardness. This fact allows to assume an increase in wear resistance of basalt coated parts.

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