Plasma Recycling of Mechanical Processing Wastes from Titanium Alloys Stock Materials

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Abstract. The article shows the possibility of processing and involving in production of a powder, made from wastes of the VT-22 alloy ingots mechanical processing. These powders are applied as protective coatings by plasma spraying method. From VT-22 powder there were obtained protective coatings on a steel substrate by plasma spraying method. Coating samples were tested for adhesion with the substrate by the three-point bending method and on the corrosion resistance in a salt mist chamber (combined coatings: metallic + paintwork material). When tested in a salt mist chamber, pitting corrosion was quickly detected on the combined coatings, which indicates low protective properties. Three-point bending tests showed that coatings have a good adhesion to the substrate. After the work on the application of plasma coatings, a powder passed through the argon plasma was collected to study the effect of the plasma-forming gas on the properties of the VT-22 powder. Research have shown that even after passing through the plasma, the powder practically does not change physical-processing properties, chemical composition, or morphology of the particles. Based on the data obtained, it can be concluded that it is possible to reuse the powder.

1. Introduction

During mechanical treatment of metal stock materials (shaping, slotting, milling, drilling, etc.) and parts manufacturing by traditional methods (casting, forging, stamping, etc.) [1] a large amount of man-made waste is produced, which must be disposed of and used in production [2 -4]. Powder metallurgy methods make it possible to reduce the material consumption and the volume of products mechanical treatment, as well as the amount of wastes in the production of the final product [5-7]. With the development of additive technologies (AT) appeared additional methods of obtaining details from powders [8-11].

Powders of titanium and its alloys can be obtained by various methods from ingots, by HDH method from standard waste and titanium sponge, and others [6,7,9,12]. AT methods based on two main requirements for powder materials: sphericity (for better fluidity) and particle size (20 to 100 μm). To obtain such powders, a number of methods have been developed [8, 9, 12], among them the most frequent arc: atomization of liquid metal by an inert gas jet under pressure (gas atomization) and plasma sputtering of a metal electrode. The first method is considered quite costly, and is acceptable for obtaining powders from metals having a not too high melting point. The second one is more technological for a wide range of metals, including refractory metals, and is more effective in industrial applications. This way was obtained the powder material corresponding to GOST 19807-91
from the mechanical treatment wastes of VT-22 alloy ingots at OJSC “Composite” (Korolev, Moscow Region).

The aim of this work is to investigate the possibility of processing and involving in the production of powder made from the mechanical treatment wastes of the alloy VT-22 ingots.

2. Methods and materials

Powder VT-22 was applied to create combined protective coatings (metal, metallic + paintwork material) using the technology developed by authors [13]. The application of powder to steel substrates (Steel. 3) was carried out with the help of the "Corvette-4" plasma spraying installation in a protective atmosphere of argon. Some of the samples with metallic coating were sent to determine the adhesion properties by the three-point bending method on the universal testing machine ZWICK BT1-FR050THW / A1K. Combined coatings (metal + paintwork material) were tested for corrosion resistance in a salt mist chamber Q-FOG / SSP / 600 according to GOST R52763-2007.

After the application of plasma coatings, the powder, passed through the plasma, was collected. Scanning Electron microscope Carl Zeiss EVO 40 was used to study the morphology of the VT-22 powder particles before passing through the plasma and after. Chemical analysis of the powder was carried out using S4 X-ray fluorescence spectrometer (Bruker-AXS, Germany), X-ray diffraction analysis using XRD- 7000 (Shimadzu Corp., Japan).

Bulk density, fluidity and tap density were determined according to the corresponding GOSTs (GOST 19440-94, GOST 20899-98, GOST 25279-93).

The average size, the degree of sphericity (characterizes the degree of proximity of the particle shape to the sphere) and the degree of symmetry (characterizing the degree of deviation of the particle shape from the centrally symmetric) of powder were measured on the CAMSIZER-XT by dynamic image analysis (according to ISO 13322-2: 2006).

3. Results and discussion

The powder material VT-22 was applied to the steel substrate by plasma spraying method. Studies of the obtained samples on a three-point bend showed that plastic deformation of the coating starts at 391-460 N / mm². Coatings have good adhesive properties, are strong enough and withstand the bending test. On the other part of the samples, a paintwork material coating of the CINEP brand was applied according to [13,14]. Samples survived the test in a salt mist chamber for 580 hours and showed the presence of pitting corrosion, which began to appear after 197 hours of testing, which indicates their low corrosion resistance.

Studying the powder collected after passing through the plasma, it was established that particles shape does not change (Fig. 1) [15].

![Fig. 1. Morphology of VT-22 powder: before passing through the plasma (a), magnification - 500; after passing through the plasma (b), magnification - 500.](image)
Conducted chemical and X-ray phase analysis of powders before and after plasma treatment did not reveal any significant changes. Data on chemical composition of the VT-22 alloy in accordance with GOST 19807-91, as well as before and after plasma treatment of powder from this material, are given in Table 1.

Table 1. Chemical composition of VT-22 powder before and after plasma spraying

|                | Ti  | Al  | V   | Mo  | Fe  | Cr  | Zr  | Si  | C   | O   | N   | H   | Other |
|----------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-------|
| VT-22 alloy    |     |     |     |     |     |     |     |     |     |     |     |     | Basis |
| GOST 19807-91  | 4.4 | 4.0 | 0.5 | 0.5 | Up  | Up  | Up  | Up  | Up  | Up  | 0.3 |
| Powder before plasma spraying | 82.50 | 5.75 | 4.8 | 4.0 | 0.85 | 0.9 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.137 |
| Powder after plasma spraying | 82.64 | 5.54 | 4.7 | 4.4 | 1.04 | 0.9 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.129 |

Physical-processing properties of the collected powder were determined and compared to the similar properties of the original powder (Table 2).

Table 2. Physical-processing properties of powders before and after passing through the plasma

|                  | Bulk density, g/sm³ | Fluidity, g/s | Tap density, g/sm³ | Sphericity degree | Symmetry degree |
|------------------|---------------------|---------------|--------------------|------------------|-----------------|
| Before plasma, fraction (-100) | 2.72 | 2.94 | 3.02 | 0.722 | 0.904 |
| After plasma, fraction (-100) | 2.70 | 2.91 | 3.07 | 0.754 | 0.916 |

As follows from the table, physical-processing properties remained practically unchanged, which indicates the possibility of powder material further use not only for plasma spraying of coatings, but also for other additive technologies.

4. Conclusion
Tests of plasma sprayed coatings samples on a three-point bend showed that obtained coatings are strong enough and have good adhesion with the substrate.

When testing in a salt mist chamber, pitting corrosion was quickly detected on combined coatings (with paintwork material), which indicates low protective properties.

Investigation of the VT-22 powder before and after passing through the plasma showed that in the protective atmosphere of argon, using it as a plasma-forming gas, physical-processing properties, chemical composition, and morphology of the particles practically do not change. This indicates that this powder can be reused.

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