THE INFLUENCE OF ALUMINA CONTENT IN CU-AL₂O₃ POWDER ON THE PROPERTIES OF COLD SPRAYING COATINGS

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Introduction

The effect of the content of aluminum oxide particles in copper powder on the structure and strength of adhesion of coatings, obtained by the method of cold gas-dynamic spraying, is in the focus of attention in this work.

Experiment content. Coating preparation parameters.

The main factors, influencing the particle velocity, are: gas pressure, gas temperature, feeding speed, spraying particle characteristics and spraying distance, etc. Table 1 displays experimental parameters for this experiment. Figure 1 shows micro morphology of Al₂O₃ and copper powder, mixing according to certain proportion. In this experiment preparation quality of Al₂O₃ content is respectively 5, 10, 15, 20 and 25%, five different ratio, spray in cold spraying equipment to the substrate surface. This experiment selects the copper, aluminum and steel base materials, and sandblasting processing. Table 2 shows the hardness of the base (substrate) materials.

Table 1 – Experimental parameters of cold gas-dynamic spraying

| Experimental parameter     | Numerical values               |
|----------------------------|--------------------------------|
| Gas pressure, MPa          | 0.5-0.8                        |
| Gas temperature, °C        | 300-400                        |
| Spray particle size, μm    | 30-40                          |
| Send the powder gas        | compressed air                 |

Figure 1 – Micro morphology of Al₂O₃ and copper powder

Table 2 – Substrate type and hardness

| Type of the substrate material | copper | aluminum | steel |
|--------------------------------|--------|----------|-------|
| hardness HV                    | 92.4   | 84.3     | 135.5 |
Coating performance testing. The thickness of the coating
The thickness of the sprayed coating, completely determining the strength of its adhesion to the substrate, is due to a number of technological parameters: the type of the powder to be sprayed, the spraying regime, and the number of cycles. In this paper, the influence of the content of aluminum oxide in the deposited copper powder on the thickness of the formed coating is investigated.

![Graph showing the effect of aluminum oxide content on coating thickness](image1)

**Figure 2** – Effect of the content of aluminum oxide in the deposited copper powder on the thickness of the coating, applied to different substrates (copper, aluminum, steel)

The Figure 2 shows, that all kinds of powder are available on copper, aluminum and steel substrate to achieve a good deposit. With the remaining parameters of the deposition process, the maximum coating thickness in one pass is achieved with aluminum oxide content in the range of 10 to 20%.

**Bonding strength.** In all the experiments, a minimum adhesion strength of the coating was found when the content of aluminum oxide additives in the copper powder was about 15% (Figure 3). The destruction occurred at the interface between the coating and the substrate, and not over the coating itself. This shows that the cohesion strength in the coating is large enough, that is, the grasping of the particles with the copper particles of the matrix takes place.

![Graph showing the effect of aluminum oxide content on adhesion strength](image2)

**Figure 3** – Effect of the content of aluminum oxide in the deposited copper powder on the adhesion strength of the coating, applied to different substrates (copper, aluminum, steel)

**The content of aluminum oxide in the copper coating.** During the deposition of the coating, a certain amount of alumina particles is reflected off the surface of the substrate, which explains the decrease in the ceramic content in the formed coating. According to the coating interface microstructure pictures by using ImageJ software can accurately calculate the content of the ceramic phase in the coating (table 3).
Table 3 – the losses of Al₂O₃ during the deposition of the coating

| % of Cu in the powder | 75 | 80  | 85  | 90  | 95  |
|-----------------------|----|-----|-----|-----|-----|
| Cu substrate          | 0.21| 4.94| 10.69| 9.73| 15.58|
| Al substrate          | 2.96| 7.45| 12.02| 15.88| 21.15|
| Fe substrate          | 1.95| 6.11| 10.36| 17.13| 14.61|

**Relationship of coating thickness and bonding strength.** Adhesion strength of the copper coating, applied to different substrates (copper, aluminum, steel), versus different coating thicknesses is shown at figure 4.

![Coating Thickness vs Strength](image)

The thickness of coatings, mm: 0.20 (a), 0.26 (b) and 0.40 (c)

![Microstructure](image)

**Figure 5 –** Microstructure of a copper coating, applied to an aluminum substrate

The microstructure of coatings of various thicknesses has been studied by SEM metallographic analysis and is shown in Figure 5. When the coating thickness for 0.20 mm, almost no pores between coating and substrate. As the thickness of the coating increases, there is a tendency to increase the porosity.

**Conclusions.** The cold gas dynamic spray was used to prepare the Al₂O₃-Cu alloys coating on Al, Cu and steel substrate with the mixture of pure Al₂O₃ powder and pure copper powder. The effect of different contents of ceramics in a powder mixture on properties of the coatings is analyzed. The results showed that at relatively high substrate hardness, different ratios of ceramics did not significantly affect the bond strength.
Al₂O₃-Cu coating on Al substrate can get largest thickness when the mixed powder includes 10% Al₂O₃. Al₂O₃-Cu coating on Cu substrate can get largest thickness when the mixed-powder includes 15% Al₂O₃. Al₂O₃-Cu coating on steel substrate can get largest thickness when the mixed-powder includes 25% Al₂O₃.

Al₂O₃-Cu coating on Al substrate can get maximum bond strength when the mixed-powder includes 10% Al₂O₃. Al₂O₃-Cu coating on Cu substrate can get maximum bond strength when the mixed-powder includes 20% Al₂O₃. Al₂O₃-Cu coating on steel substrate can get maximum bond strength when the mixed-powder includes 25% Al₂O₃.

The more the coating thickness - the lower the bond strength.

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