Journal of Metallurgical and Materials Engineering, Vol.32, No.2, 2021.

The Increase in the Wear Resistance of Copper Substrate Coated by Cu-Al_2O_3 Nanocomposite through Solution Combustion method

Hadi Nasiri[1]* Ehsan Mohammadi[2]

1. Introduction

Copper has different usages in industry. However, the low surface mechanical properties i.e., abrasion resistance and hardness are some of the most important limiting factors of its application. The use of ceramic particles such as: TiO_2, SiC and Al_2O_3 as reinforcing phases of copper matrix is a good way to eliminate mentioned defects. On the other hand, it preserves the inherent properties of the copper phase. Amongst, alumina is the most favorite reinforcing phase due to its cheapness, desirable strength, and stability at high temperatures.

There are many surface engineering methods for the production of the nanocomposite coatings, such as: spraying, sol-gel, co-deposition and milling. Each method has some drawbacks that limit its application. The most important of them are strict control of the coating process, cost, time consuming, the need for sophisticated technology, and complementary operations of these methods. Therefore, the introduce of new methods with high efficiency and low cost is the aim of many researches.

Solution combustion synthesis (SCS) method usually involves the self-propagation reactions in a solution of various metals nitrates and fuels that can be classified according to how the synthesis process is performed. In this research, for the first time, the solution combustion synthesis method was used to produce copper-alumina nanocomposite coatings. In addition, an attempt was made to apply the desired coating on the copper substrate in one step and in the air atmosphere.

2. Materials and Method

To produce copper-alumina nanocomposite coating by the SCS method, copper and aluminum nitrates were used as oxidizers and urea was used as fuel. Graphite was also used as an auxiliary material to prevent the oxidation of metallic copper synthesized in the air.

Graphite was mixed thoroughly with copper, aluminum nitrates, and urea. Water was added to the obtained solid mixture. The prepared solution was placed on a hot plate at the temperature of 300 °C. During heating, the solution was constantly stirred by a magnet at 140 rpm. The copper substrate was placed in the container containing the solution. After the water was evaporated and the gel formed, the combustion took place quickly and after about four minutes, the coating settled on the substrate. Wear resistance values measured for coating produced by different weight percentages of alumina (5, 15, 25, 35 and 45 wt. %) as the reinforcing phase.

In order to synthesize products containing 5, 15, 25, 35 and 45% by weight of alumina reinforcing phase, the amount of copper and aluminum nitrates were calculated according to Equation (1). Table 1 shows the stoichiometric coefficients of Equation (1) for the production of coatings with different ratios of alumina as reinforcement phase.

$$aAl\,(NO_3)_3 + bCu\,(NO_3)_2 + cCO\,(NH_2)_2 = dCu + eAl_2O_3 + fCO_2 + gH_2O + hN_2 \qquad (Eq.1)$$

Table 1. Coefficients related to Equation 1 for producing coatings with different weight percentages of alumina reinforcing phase

Alumina	a	b	c	d	e	f	g	h
5	2	30.3	65.5	30.3	1	65.5	131	97.3
15	2	9	23	9	1	23	46	33.5
25	2	4.8	14.6	4.8	1	14.6	29.3	22.4
35	2	3	11	3	1	11	22	17
45	2	1.9	8.9	1.9	1	8.9	17	13.8

3. Results and Discussion

Figure 1 shows the temperature-time curves of the coatings formed with different ratios of the alumina reinforcing phase.

The abrasion behavior of the coated samples with different percentages of alumina phase was studied and the abrasion rate values in terms of different percentages of alumina reinforcement phase are shown in Figure 2.

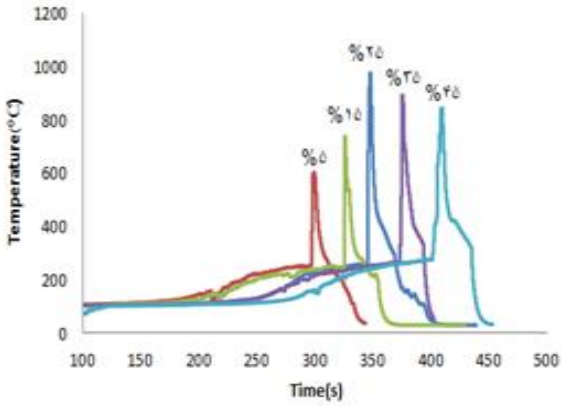

Fig. 1. Temperature curves with time for samples with different ratios of alumina phase.

[1]* Corresponding Author: Assistant Professor, Department of Materials Engineering, Mechanics and Materials Engineering Faculty, Birjand University of Technology, Birjand, Iran. Email: nasiri@birjandut.ac.ir.

[2] MSc of Materials Engineering, Department of Materials Science and Engineering, Engineering Faculty, Ferdowsi University of Mashhad, Mashhad, Iran.

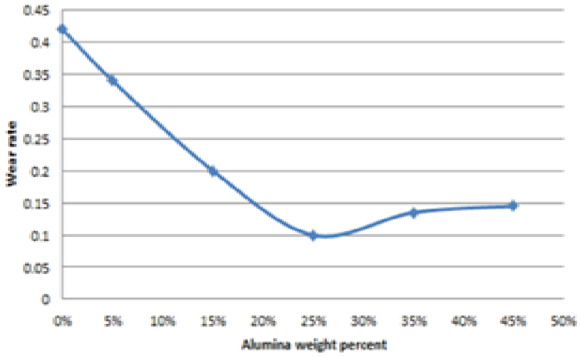

Fig. 2 The changes of wear rate with different weight percentages of alumina reinforcing phase.

The best abrasion properties of the produced coatings are obtained in 25% by weight of alumina reinforcing phase. Figure 3 shows the XRD pattern of the sample coated on a copper substrate with a fuel to oxidizer ratio of 1.25 and the use of 25 wt. % graphite.

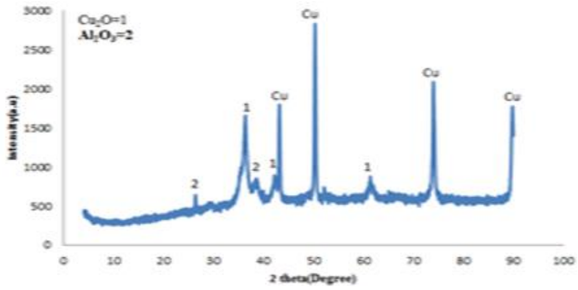

Fig. 3- X-ray scattering pattern for the sample coated with a fuel to oxidizer ratio of 1.25.

4- Conclusion

1- The highest coating temperature and abrasion resistance were obtained in the ratio of 25 wt. % of the alumina reinforcing phase.

2- The wear resistance results showed 400% increase in the wear resistance of the coated surface compared to the base metal.

3- Copper-alumina nanocomposite coating formed by solution combustion synthesis method had high adhesion strength and contained many pores.

4- This coating was synthesized in only one step and was placed on the copper substrate in the air atmosphere.

5- The particle size of the alumina ceramic phase synthesized in this study was less than 20 nm.