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Microstructure characteristics of brass-coated plain carbon steels via spray metal

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Abstract: *Plain carbon steel samples were coated non-reactively with brass by means of spray metal technique. Brass alloys with thicknesses of 0.75 and 1 mm were coated on plain carbon steel. The microscopic properties of the created surfaces and the boundary between the surface and the base steel were studied by optical microscope. In order to study the hardness of the coating, a micro hardness test was used. The results show that in an identical thickness of coating, with the increase in the energy of the device and the increase of the super melting temperature in the coating, the probability of formation of micro-porosity and cavity increased. Metallographic experiments showed that by increasing the thickness (in a constant input energy) of coating, the interface between the coating and the base steel became thicker and less porosity formed , which is one of the reasons for increasing the hardness by increasing the thickness of the coating.*

Keywords: *metal spray, brass coating, micro hardness, characterization.*

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I. INTRODUCTION

Due to the increased demand for new materials for the production of equipment and the high cost of materials with special properties such as high wear resistance and corrosion resistance, coating technologies such as thermal spraying processes have become especially important [1].Thermal spraying is a general term that includes a group of processes in which metals, ceramics, cermet (a mixture of ceramics and metal) and some polymer materials as powder, rod or wire heated to a melting temperature by a torch or gun. Melted particles are covered by a gas stream on the material. These particles thrown into the substrate to form layers on the substrate and depending on the process used by mechanical and metallurgical locks bonded together [2].Thermal spray coating is a kind of thermal coating in which various metals and alloys that are available as powder or wire are sprayed onto a base metal at their melting point. The basis of adhesion in this method is based on thermal energy (heat over 300 ° C to 1500 ° C) and kinetic energy (150 to 750 Jules) [3-6].

Berget [7], examines microstructural thermal spray coating method. Sample preparation before research is very necessary. He showed that porosity occurs more or less over the coating, and by increasing the thickness of the coating, the residual stress is reduced. When the coating turns from molten to solid state, the heterogeneous accumulation of porosity occurs in the surface [7]. Liu et al. [8] used aluminum phosphate to seal the structures of Cr_2O_3 and Al_2O_3 coatings. In this study, the shear wear resistance of the coating after a 30-day immersion test was not reduced in a solution with a pH of about 10 to 0 for Al_2O_3, which was corroded at pH 14-0. A. Moridi [9] studied the cold spraying of metals on different surfaces and examined their microscopic defects and properties. The cross-sectional levels of different surfaces created by cold sprays vary in different cases, but are generally achieved by cold spraying, dense coatings with low porosity is obtained. Kang [34] used the combination of thermal plasma spraying with cold spraying. A good proportion of tungsten powder and copper powder is first melt in a stainless steel chamber with tungsten carbide balls. Microstructural observations show that more cavities are found in the vicinity of tungsten-rich regions. The porosity levels vary with the change in tungsten content. However, copper oxide has been found abundantly in coating by plasma spraying. In this paper, the microstructures of brass coating were investigated and coatings with thickness of 0.75 mm and 1 mm were used. In the following, the microstructural results and microhardness test are described in detail.

II. EXPERIMENTAL

For this study, industrially produced plain carbon steel bars with an average roughness of 23 mm and flat type with dimension of 20 × 10 cm were used. The plain carbon steel contains 0.64% Mn, 98.68% Fe, 0.03% C and coated layer contains of 60.0% Cu, 38% Zn and 2.0% Pb by weight. To ensure are producible preparation all samples were cleaned in an automatic cleaning system to eliminate organic and inorganic residues on the surface. The procedure contains following steps:

A) Sample preparation include one side of the specimen was machining and reached the same thickness. In addition to flat samples, the shaft samples were threaded at a depth of 0.5 mm to improve adhesion of the coatings.
B) The preheating was carried out up 100 ° C on the samples to increase the adhesion properties of the brass coating.
C) In order to reach the 0.7 mm thick coating, about 5 layers were consecutively given, and to achieve a 1 mm coating, approximately 8 layers were sequentially sprayed.
D) Two pieces of bar sample with coated thicknesses of 0.75 and 1 mm and two pieces of flat type with thicknesses of 0.75 and 1 mm were polished with laser stones for additional experiments.

Figure (1) show the equipment used in the metal spraying process.

Figure 1: Equipment used in the process of brass metal spraying on plain carbon steel

To study the microstructure of coated areas, the uncoated area, the interface area of the coated and uncoated area, as well as the microstructure developments, metallography was used according to ASM Vol.9.For the preparation of metallographic samples, 1000 to 2500 grinding papers were used and then polished with alumina powder in order to prevent the surface of the coating from dying. Samples were immediately etched with methanol solution 5% and nitric acid 65% molar for 10 seconds after polishing. The microstructures of different regions were determined by optical microscope at 400 magnifications.

Hardness test was carried out with 200g load for 15 seconds according to E-384 ASTM standard at Shiraz Azad University. The mean hardness measurements were considered on the cross-sectional area.to perform the micro hardness test, 10 dots at a distance of three millimeters apart, at a distance of one millimeter, were read from the surface of the diamond impregnation point by a 400-fold lens, and the hardness of that point was calculated. To perform the micro hardness test, 10 points within three millimeters apart and within a millimeter of the point of a diamond indenter was read by the lens of 400X and the hardness of that point was calculated. The diagram of Vickers hardness variation was plotted on the cross-sectional area of the coating.

III. RESULTS AND DISCUSSION

In this research, plain carbon steel is used as a base metal. Figure (2) shows the microstructure of plain carbon steel after the etching at a magnification of 400X.This alloy has a perlite (ferrite and cementite) matrix. Generally, plain carbon steel is preheated at temperatures below the eutectic temperature inside the ferrite and cementite phase.

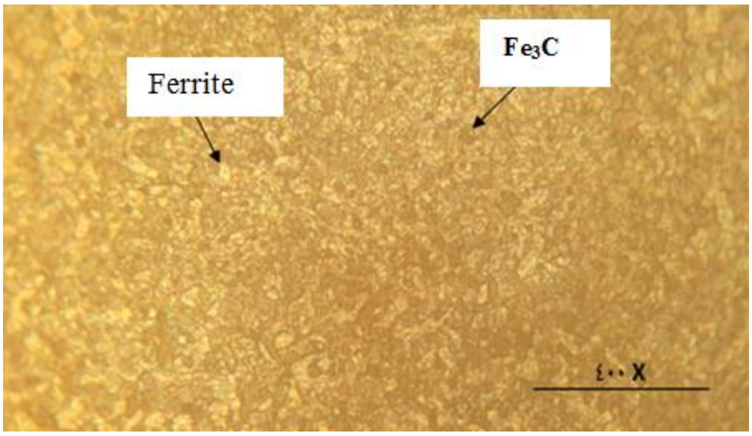

Figure.2 the metallurgical structure of plain carbon steel (base metal) with a magnification of 400 X

Figure (3) shows the microstructure of brass coating after etching. The microstructure of alpha-beta brass contains two phases β and α, which is essentially the ratio of copper to zinc is 40: 60. In fact, when the zinc content in copper alloys is about 40%, these alloys have a two-phase structure. The presence of β-phase causes this alloy to be heat-treated, but reduces its ductility [10,11].If Cu-Zn alloys with 40 to 45% Zn are heated to a temperature of 830 ° C, the beta phase will be decomposed (Fig. 3) [12].

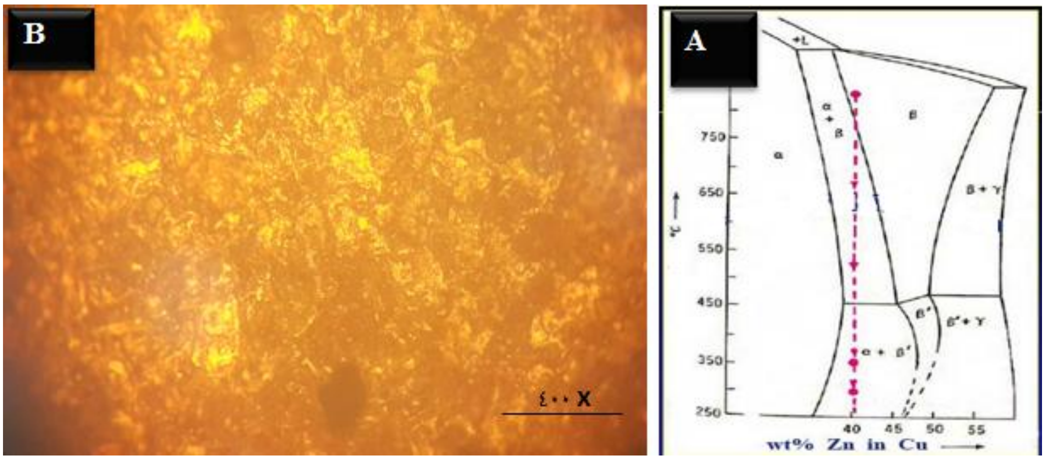

Fig. 3 a) Zinc – Copper phase diagram b) Metallographic structure of yellow brass at 400X.

Figures (4) and (5) indicate brass coated with thicknesses of 1 and 0.75 mm on a plain carbon steel base. The efficiency of the spray coating device depends on many factors, such as the melting point of the spray, the elemental heat capacity, and the size of the sprayed particles [13,14]. In this study, the particle size was kept constant and due to the constant heat capacity for all coated samples, only the spray temperature was changed. The specimen presented in Fig. 4 is coated with a temperature slightly higher than that of brass melting point, which during the cooling process, the uniform distribution of particles and melt materials caused the formation of cavities and dispersed and non-uniform Porosity. In the Figure (5), the particles are sprayed with temperatures closer to the melting temperature, the uniformity of the coating, cavities and imperfections were reduction. Also, with increasing temperature to more than the melting temperature of brass alloys, the amount of energy consumed has also increased (the power of the device has increased by increasing the coating temperature from 10kW to 20kW).Considering the same distance of the torch from the surface of the samples, decreasing the power of the device (not as much as the torch temperature reaches below the melting temperature), a more uniform distribution of particles has been observed.

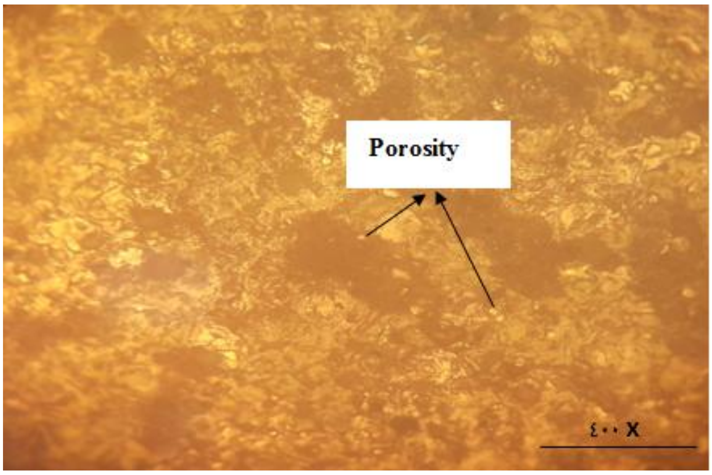

Figure 4: Metallographic structure of the surface of a 1 mm thick brass coating on plain carbon steel with 400 X magnification in thermal spraying.

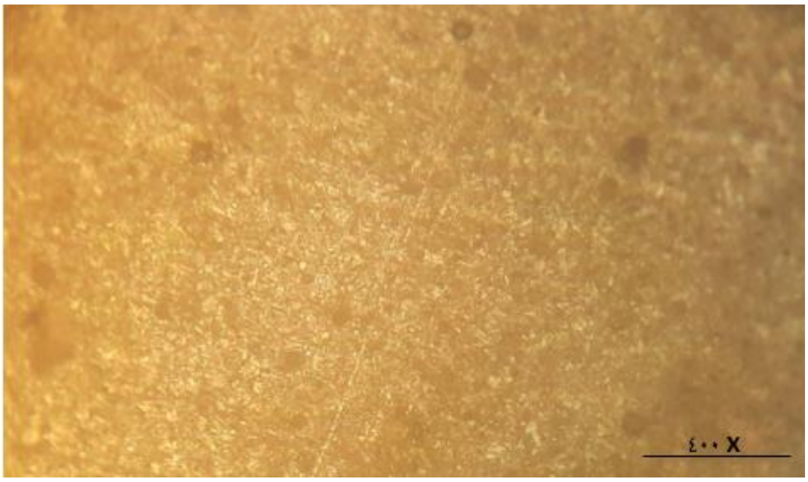

Figure 5: Metallurgical structure of brass coating surface with a thickness of 1 mm on plain carbon steel by spraying Thermal.

Fig.(6) and (7) respectively indicate the interface between brass and base metal in the flat and cylindrical sample. In the case of bars sample due to the thread on the surface, adhesion of the surface rather than the flat samples increased, thus the interface between the coated surfaces and the base metal became thinner, indicating a lower distance for the diffusion of atoms in the surface layer of the base steel. But in flat samples, this interface is thicker and atoms have more distance to penetrate the surface of the base metal. This type of interface can be caused by the heat transfer rate of the base steel during thermal spraying process [15,16].Since the copper heat transfer rate is much higher than that of steel, copper particles in the coating are cooled much faster and may cause grain to become finer at the surface. By increasing the thickness of the coating in both flat and cylindrical samples, the density of the coating is increased and the formation of the cavity and porosity in the surface is reduced. Studies show that surface roughness affects the amount of cavities and porosity. With increasing surface roughness, the possibility of formation of cavities and the possibility that some spray particles may melt later also increase [17,18]. In cylindrical samples with roughness of surfaces, cavities with a thickness of less than 0.75 mm were formed (Figure 6).

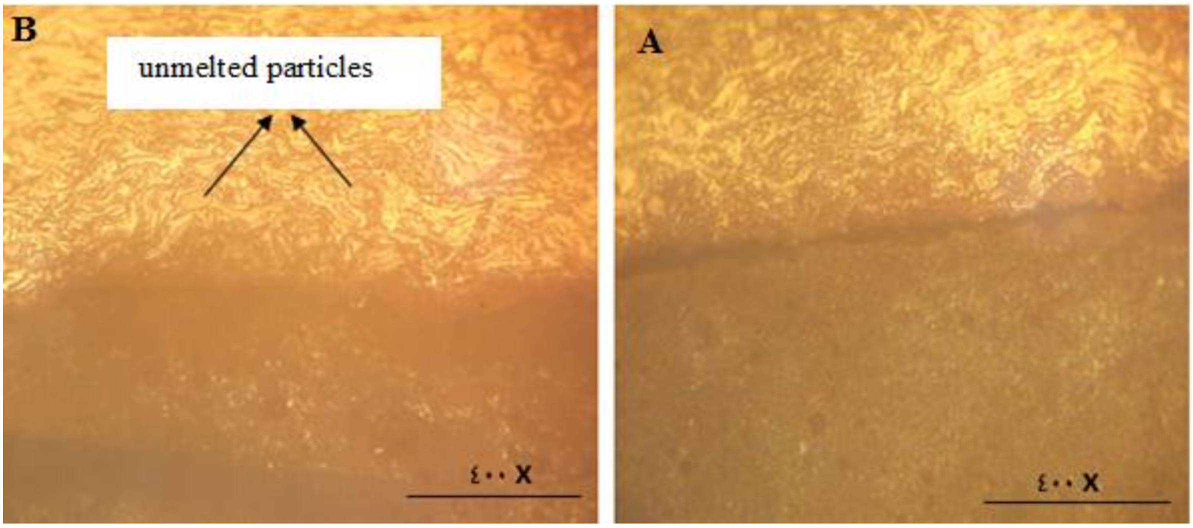

Figure 6 - a) brass-steel with 1 mm Coating (cylindrical sample); and (b) brass-steel with 1 mm Coating 0.75 mm Coated Cylindrical Sample) at 400X .

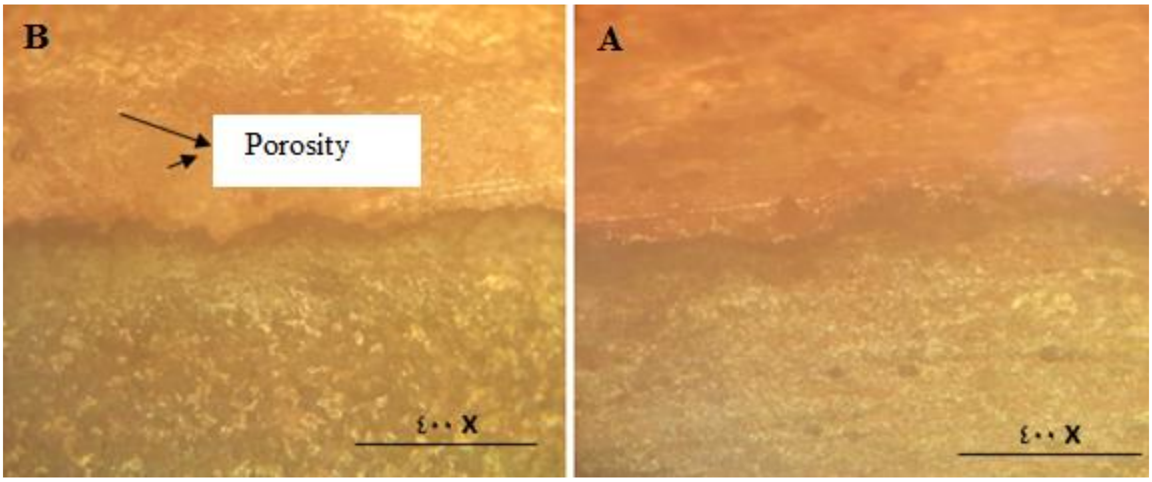

Figure 7 a) brass-steel with 1 mm Coating (flat sample); and (b) brass-steel with 1 mm Coating 0.75 mm Coated (flat Sample) at 400X .

In the coating process, the hardness of the coating reflects the quality of the coating. In this research, the micro hardness test was performed on different phases with polished cross section and the results are presented in the Fig (8) for coating with thicknesses of 0.75 and 1 mm. For all samples, the hardness varies from 50 to 230 Vickers. According to Fig. 8, the peaks are related to the hardness number in the boundaries, which results from the formation of different phases or the presence of non-melted particles in the boundaries.

The hardness of the base steel is typically 240 Vickers which, it is more than the average hardness of the coating. The presence of cavities and porosity and non-melted particles can change the hardness in some places [19,20].In brass alloys, the amount of zinc up to 40% (zinc content in the current study is 38%), the beta phase is formed, which is a hard phase and has a high abrasion resistance, which increases the strength and hardness of the alloy. The increase of zinc in the brass alloys results in the formation of a gamma phase (Cu_5ZnS), which is an extremely hard phase and reduces the mechanical properties of the coating [19]. The formation of carbides (including zinc carbide) in the boundary layer of the coating with a base metal surface causes increase hardness. The high temperature of the flame and the high velocity of coating contribute to the faster formation of this carbide. The high speed of the coating reduces the reaction time between the particles and the flame, which itself keeps the carbides in the molten metal and the matrix. When the particles in the melt field are solid, the coating is well bonded and hardened.

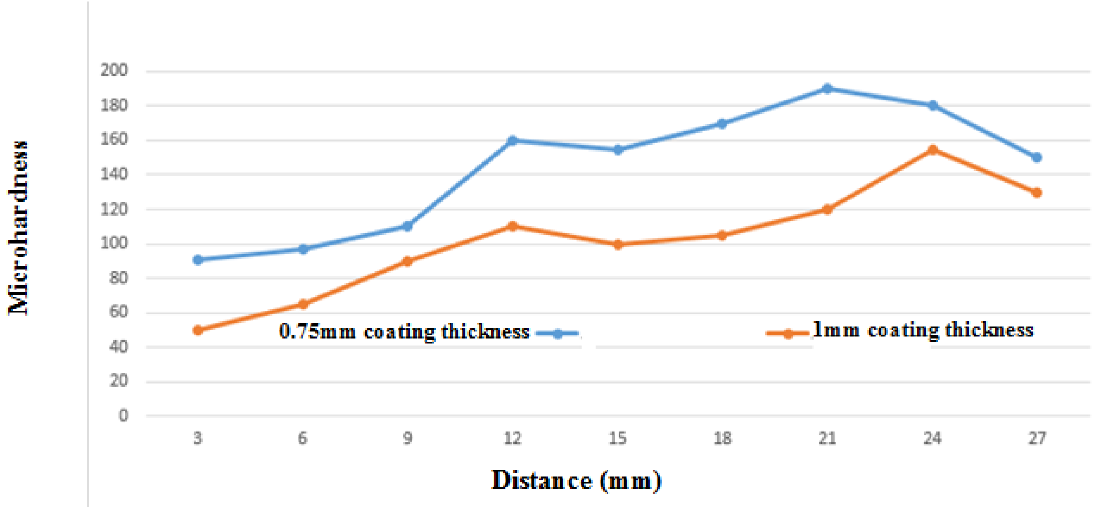

Fig. 8 shows the Vickers hardness graph VS the distance for brass coating on plain carbon steel with thicknesses of 1 and 0.75 mm.

IV. CONCLUSION

In this research, plain carbon steel was coated with thickness of 0.75 and 1 mm brass via metal spraying method. Tests such as metallography and microhardness for more analysis of microstructure were done.in this research concluded that:Considering the same coat thickness, with increasing flame temperature, the thermal spraying system has risen above the melting point of brass alloys, pore formation and porosity have increased, and thus it is better to coating near the melting temperature of the coated alloy. This also increases the efficiency of the device.By increasing the thickness of the base steel coating, the coating density has improved and porosity has been reduced.Increasing the thickness of the coating cause The interface between brass and base metal has also been increased , which has the potential to penetrate the atoms during cooling reduce and metallurgical changes less occurs.By increasing the thickness of the coating, the hardness of the coating has increased, which results in a higher density and decreasing of cavities and porosity. In some places, the results of the hardening data are significantly increased, which may be due to the presence of non-melted particles at the boundaries or the formation of intermetallic compounds and carbides.

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