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Metal Spray Deposition and Corrosion Properties of Brass Coatings on Plain Carbon Steel Substrates

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Abstract: *Coating is a process that is partially or completely applied on the surface of the elements and alloys in different ways to prevent the base metal from corrosion, wear and failure at high temperatures. Thermal spray coating is one of the most effective coating methods to protect surfaces. In this process, relatively thick coatings layer is deposited. Optimum coverage conditions are selected based on the desired requirements. In this research, brass alloys with thicknesses of 0.75 and 1 mm were coated on plain carbon steel via metal spray coating method. In order to study the surface behavior, corrosion testing was performed to determine corrosion conditions. Salt spraying was also performed to determine the lifetime of the coating, and finally a pin to disk wear test was performed. The corrosion test indicated that the improved corrosion conditions of the coating by increasing the thickness of the coated layer. Salt spray tests showed that the sample is resistant to corrosion up to 48 hours at laboratory condition, which is equivalent to 1000 hours of work in real saline environments. Also, the results of the test of the pin on the disk indicate irregular changes in friction over time, and more indicative of the shearing mechanism of the laminate surface with fatigue.*

Keywords: *thermal spray, brass alloys, corrosion, wear.*

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I. INTRODUCTION

Steel alloy is widely used to build power transmission equipment such as shaft, gear, rims and so on. Despite its favorable mechanical properties, this alloy does not exhibit a proper tribological and corrosion behavior. Therefore, surface engineering processes are used to improve its surface behavior. Recently, diffusion coatings have been used to improve the surface properties of steel. However, metal spray coatings have been widely used in the automotive industry due to their good properties, such as wear resistance, low friction coefficient, bearing properties and bonding properties. Metal spray is one of the most advanced methods for the reconstruction, repair and protection of engineering tools and systems. In this method, the metal coating is fed by an automatic mechanism into the flame created by the spray nozzle. The unique properties of metal spray are perhaps due to the variety of applications. The methods and systems of metal spray used in huge industrial production such as automotive, shipbuilding, aerospace and construction equipment manufacturing as a process in the main production line or as a separate unit . Taranen et al. [1] examined the coating of Al_2O_3-5% SiC ceramic nanoparticles by high-speed oxygen fuel spray application. In this work, the hardness and abrasive wear of all coatings were investigated. Ramysh et al. [2] investigated the oxidation resistance of 25% (Cr_3C_2-25 ($Ni_{20}cr$) + 75% NiCrAlY) metal coating on titanium alloys. The results show that the coating on titanium alloys has improved the oxidation and hot corrosion resistance and increased its toughness. Al-Fadhli et al. [3] coated Inconel 625 by the high-oxygen thermal spraying method on stainless steel used in oil and gas industries. Coating on three different levels includes carbon stainless steel, spotted stainless steel and a surface composition of stainless steel and carbon steel welded together. The coating covered in this study is sensitive to the presence of sand particles in the fluid. The time that the period of exposure to fluids increases in the surface of the coating increases the weight loss. A review of the literature indicates that low attention has been paid to the influence of brass on the corrosion behavior of plain carbon steels. Brass can be used as coatings on steels to improve their corrosion resistance while maintaining all usable advantages offered by steels. Brass coated steels are used in several industrial sectors to produce springs, brushes, hose reinforcement, tires, and electrical cables. In this study, the effect of thickness of brass coating on the surface of carbon plain steel by thermal spraying method has been investigated and properties such as corrosion and abrasion have been investigated.

II. EXPERIMENTAL

In this study, plain carbon steel with the chemical composition presented in Table (1), which has been coated with brass(chemical composition shows in the table 2) by thermal spraying method, were used. Four flat plates with dimensions of 20 × 10 cm and 4 shafts with a length of 20 cm and a diameter of 23 mm were prepared. Before covering the flat parts, 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. The preheating was carried out up 100 ° C on the samples to increase the adhesion properties of the brass coating. The thickness of the coated layer is 0.75 mm and 1 mm. Figure (1) shows the coated samples.

Table (1): chemical compositions of the base metal (wt. %)

element	Mn	Fe	C
Wt%	0.64	98.68	0.03

Table 2 Chemical composition of the brass coating (weight percent %wt)

element	Cu	Zn	Pb
Wt%	60.0	38.0	2.0

Fig. 1 Flat and cylindrical samples of plain carbon steel brass coated.

In order to find the maximum time of operation of brass coated parts in salt corrosive environment, the non-polished samples were cut in 2 × 1 cm dimensions under the MIL-STD-810 standard in the Shiraz electronic industry under a salt spray experiment for 48 hours Equivalent to 1000 hours of operation in a salt bath solution, was placed and the test results were extracted. Figure (2) shows the salt spray test samples. Corrosion testing was conducted to verify the corrosion resistance of coated steel samples and also to compare the effect of coating thickness on corrosion resistance of plain carbon steel. In this test, coated thickness of 1 mm and 0.75 mm were first placed in 0.035 NaCl solutions for one hour and then using a corrosion test device at Azad University Islamic of Shiraz was tested. In this study, the corrosion rate of the coatings with thicknesses of 1 and 0.75 mm was compared with the uncoated sample of plain carbon steel. Figure (3) shows the corrosion test samples.

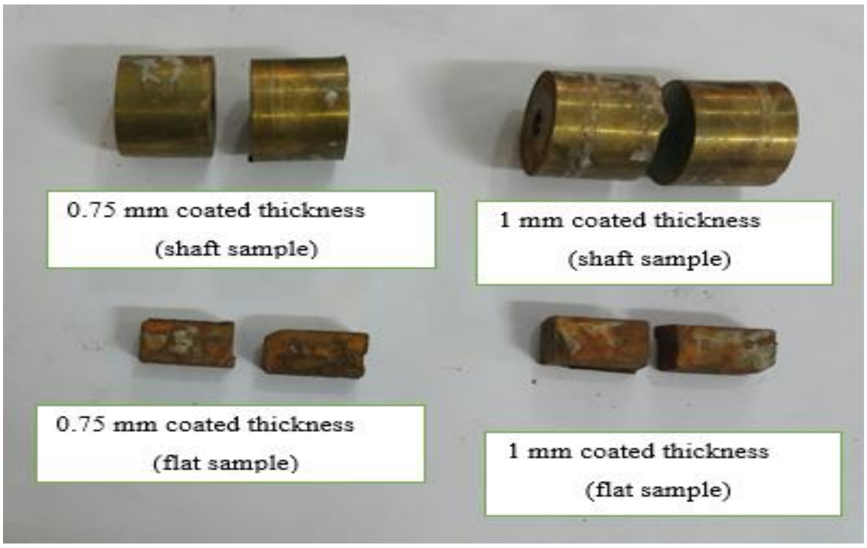

Figure 2 - Classification of salt spray test specimens.

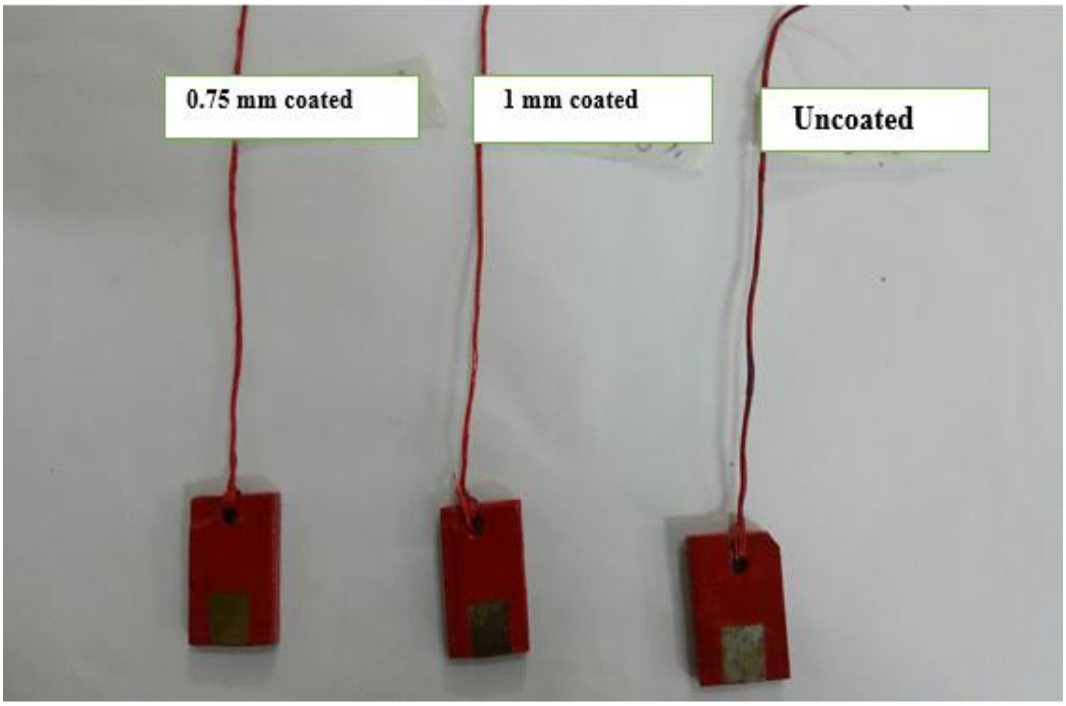

Figure 3 - Corrosion test samples.

The abrasion test was done with a 1mm coated sample and dimensions of 3 × 2 cm under a force of 0.49 kg at a speed of 0.22 m / s by wearing apparatus in at Shiraz University. Data including weight loss due to wear and wear type were extracted.

III. RESULTS AND DISCUSSION

The first approach to determining which material is first solved is to compare the oxidation potential of the elements. As shown in the table (3), metals with an absolute value of a more positive potential are actually noble and soluble in a less positive potential. The corrosion rate is obtained by weight loss of the specimen coated in a corrosive environment divided by the exposure time [4-9].Table 3.shows the oxidation potential of metals according to the hydrogen electrode at 298 ° C. [7]

Table 3. the oxidation potential of metals according to the hydrogen electrode at 298 ° C.

Metal	Reaction	Oxidation potential V
Al	$Al = Al^{3+} + 3\,e^-$	−1.662
Ti	$Ti = Ti^{2+} + 2\,e^-$	−1.630
Zn	$Zn = Zn^{2+} + 2\,e^-$	−0.7618
Cr	$Cr = Cr^{3+} + 3\,e^-$	−0.407
Fe	$Fe = Fe^{2+} + 2\,e^-$	−0.447
Ni	$Ni = Ni^{2+} + 2\,e^-$	−0.257
Mo	$Mo = Mo^{3+} + 3\,e^-$	−0.200
Cu	$Cu = Cu^{2+} + 2\,e^-$	+0.3419
Au	$Au = Au^{+} + e^-$	+1.692

Fig (4) and Table (4) show pentosiodynamics corrosion test for 0.75 mm of brass coated and compare their corrosion with plain carbon steel respectively.

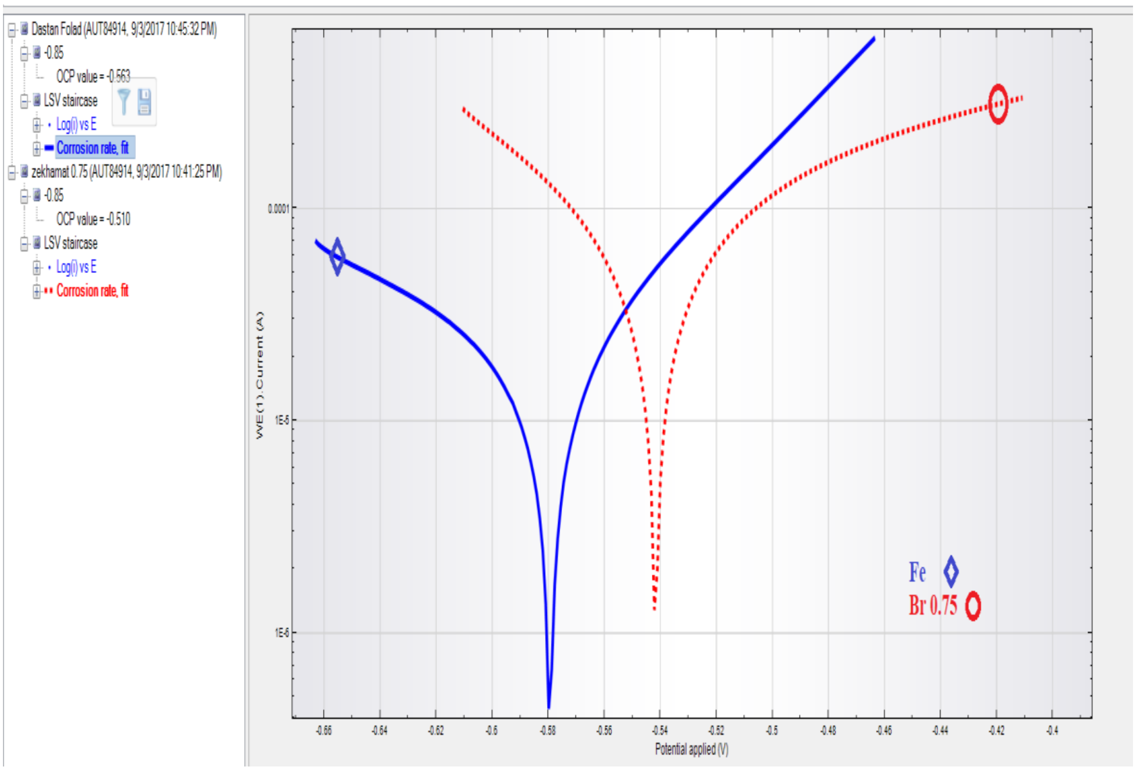

Figure (4) shows the results of corrosion test of 0.75 brass coated.

Table (4) Compare of the flow and corrosion potential of different brass coatings with an uncoated sample.

Corrosion rate(mm/year)	Rp(Ω)	Ba(mv/dec)	bc(mv/dec)	Icorr (ma/cm^2)	Ecorr (mv)	Coated thickness
0.208	200.7	95.03	203.770	140.230	-458.310	1mm
0.210	330.420	171.900	287.550	141.410	-541.780	0.75 mm
0.024	101.3	104.860	60.05	16.372	-579.400	Non coated

The test results are as follows:

A) The anode part of the graphs is similar, and it can be said that none of them shows the behavior of passivation.

B) There is a linear relationship between potential and density.

c) The cathode part of the three samples is similar, and in sea water or sodium chloride solution, it is the dominant reaction of oxygen recovery, and the reaction is under diffusion polarization.

d) Increasing the thickness of the coating improves corrosion resistance.

Salt spray test is a quick way to test the corrosion resistance of galvanized products [10-12]. The purpose of this test is to investigate the corrosion properties of galvanized metal under laboratory conditions and estimate the life of the sample in the actual condition. Because the salt spray test is a fast test method, it must be designed in such a way that it conforms to the actual working condition. But the compatibility of this test with the actual operating conditions of the parts has not yet been proven[13,14].However, this method is accepted as a common test of the corrosion performance of coated parts and has been approved in many qualitative control characteristics that the salt spray test has been carried out and the results reported. Rusting the red rust on the steel surface indicates that the protective layer has been removed and the base metal is exposed to corrosion. Figure (5 a and b) represent the brass coated sample before and after the salt spray test, which is shown in Figure (5b) of the coating loss after exposure to the saline solution for 48 hours, which is the equivalent test With 1000 hours of operation in real life.

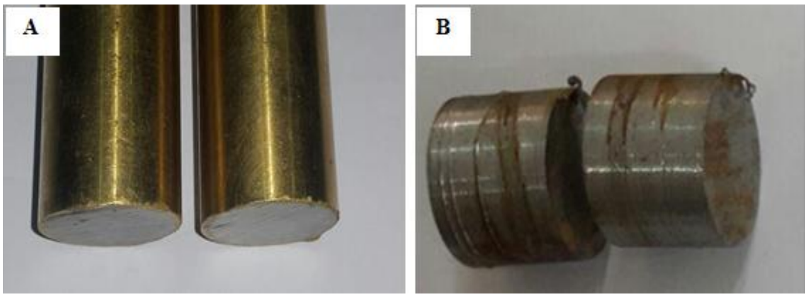

Figure 5. Shows the surface of the galvanized steel before (A) and after the salt spray test (B)

Although the corrosion performance of the coatings is not comparable to the actual yield of the product using the salt spray test, it can be effectively evaluated by comparing the results of this test with the data available in their sources. It should be noted that the salt spray test is a qualitative test, and if the comparison of the performance of the two components is performed by this test, their differences are not necessarily equal to the difference in actual user conditions.Abrasion phenomenon is one of the most important factors in the destruction of industrial parts. To reduce this phenomenon, proper material selection and proper surface coating are very important [15-17]. The results of wear on the coated sample indicate that the weight loss of the piece is from 21.341 to 21.330 grams at a load of 400 grams, with a distance of 30 meter, which show a high wear rate and low abrasion resistance. The range of friction variations in this experiment is irregular. Figure (6) shows friction variations in the wear test.

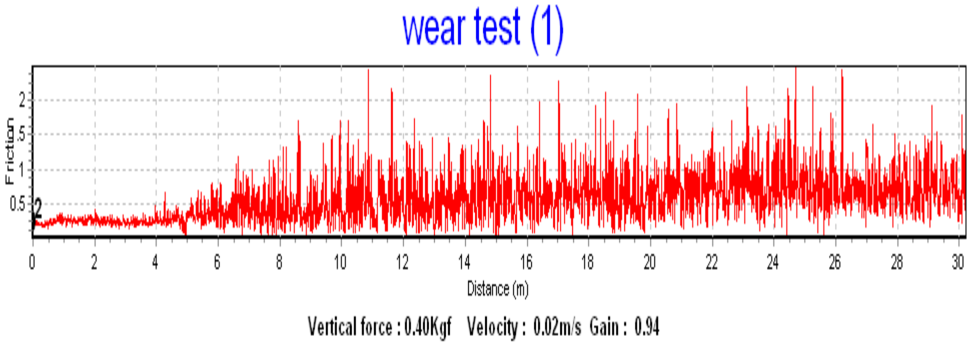

Figure (6) Friction variations of coated specimen in the wear test.

Abrasive surface analysis of the steel (Fig. 7) shows the grooves and buckling of the material those are parallel to the abrasion. There are also relatively small cracks and holes in the surface of the sheets separated by edges and sheets that are detached from the surface. The conclusion of the above observations suggests that the prevailing mechanism is laminar wear.

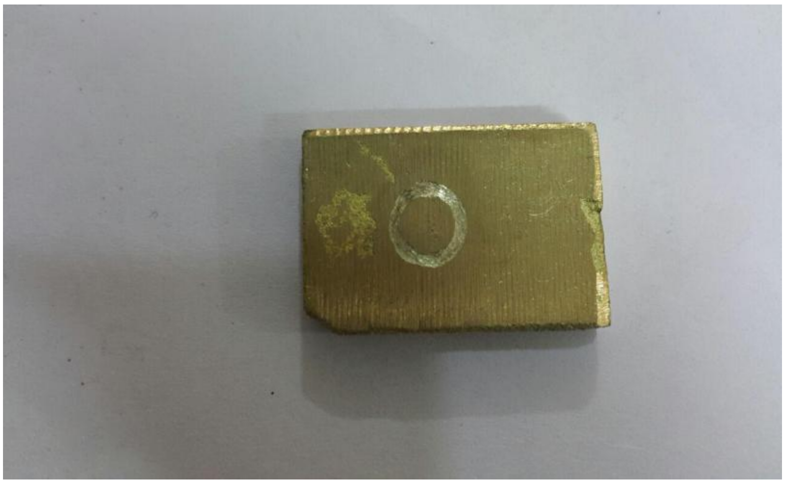

Figure (7) wear test of plain carbon steel with 1 mm brass coated.

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, corrosion testing, , salt spray and wear tests were performed. The following are the results of the experiments.

A) Increasing the thickness of the coating improves corrosion resistance.

B) Salt spray experiments were performed to determine the life of the work pieces. In this experiment, the coating was removed after 48 hours in vitro. This amount of laboratory hours is equivalent to 1000 hours in real condition.

C) The result of the wear test indicates irregular friction variations in the dimension of the distance; the summing up observations suggests that the dominant mechanism is the laminate wear.

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