Coating Metal Powders Using Fluidized Bed Cell Technique

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Abstract: It has always been the hope of metallurgists to be able to produces structural materials possessing both great strength and extreme ductility to offer high load carrying capacity and prevent catastrophic failures. This work involves design and construction of a fluidized bed (F.B) system for applying one available method for covering material substrates with a metallic coating. The material studied was cast iron chips machined powder. The study attempt to produce composite powder which could be used in the powder metallurgy industries as cheaper replacement for expensive and unavailable powders particularly. The experimental work involved chemical displacement plating method in which the study of on wet coating technique for the deposition of metals from aqueous solutions on to different size of cast iron chips. A fluidized bed apparatus and stirred bath were used in coating and handling of the powders particles. A comparison of the coating performance between these two handling techniques were investigated and studied. The results showed that the performance of fluidized bed technique had greater influences on the behaviour of the copper metallic coating were controlled as expected by the amount of the metal coating.

Keywords: Composite powders, Displacement coating metals, Fluidized bed cell, Metallurgy.

I. INTRODUCTION

The process of finishing metal surfaces with dry powder coatings is not new. It has been used since the mid 1950$'$s. It began with the coating of pipe, for corrosion protection, and electric motors, for insulation. With the growing need to reduce air pollution, including that associated with thin film liquid coatings, powder coating developed further. Meanwhile powder coating is making a major impact in the finishing industry. By utilizing the natural principle of opposites attract, this finishing technology offers manufacturers increased economic benefits and superior quality. From equipment to surface area covered per dollar of material applied, the costs of powder coating are comparable to those of liquid coating. Powder coating has been referred to as a "dry painting process". That's because powder coating is a modern technology [1]. For the first time, end-use manufacturers are able to engineer their finishing operations to a degree only dreamed of heretofore, while eliminating many of the problems that have been traditional in the finishing operation. There are distinct advantages to powder coating when compared to solvent based liquid coating:

The wide variety of equipment available makes powder coating feasible for the small end-use manufacturer, as well as for the very large user who may require an extensive finishing operation for multiple products. In recent times even the car manufacturing companies in part switch from liquid to powder coating. The charged powder particles will be attracted to the surface of the part whether the part is cold or heated [2], [3].

Besides the choice of the appropriate powder to be used, choosing the method of application is critical to achieve optimum coatings. In general the powder supplied from the manufacturer is placed in a powder feed system which enables it to be delivered, mixed with air (this mixture is called: fluidized powder) [4], to an application device.

Fluidization is one of the most promising techniques for handling fine powders because of its advantages of high heat and mass-transfer rates, temperature homogeneity and high flow ability of particulate materials [5].

The aims of this paper are: 1-) to design and establish fluidized bed system and using it as a technique for coating a gray cast iron chips powders with metallic copper by displacement method; 2-) to compare the performance of copper coating on powder for both fluidized bed system and bath coating techniques; 3-) to achieve different percentage of copper coating on different sizes of iron powder particles; 4-) to produce and investigate these composite powders, that are expected to have new properties which will open up a new field for using these powders as raw materials for powder metallurgy applications, electrical, conductors and porous engineering components.

II. THE COATING MECHANISM

According to the electrochemical or galvanic series as shown in Table I, any metal in that table will replace from solution any metal above it [6]. When iron is immersed in a copper sulphate solution, it becomes coated with metallic copper because the iron atoms have formed ions to replace the copper ions in solution. As result electrons pass from the iron atoms to the copper ions which are then deposited as copper atoms. This happens because of that iron is anodic to copper as indicated by their relative positions in Table I.

It follows that any pair of metals in the table when immersed in an electrolyte and also in electrical contact with each other will form a voltaic cell. The metal which has lower electrode will be anodic to the other and will go into solution as its atoms from ions and release electrons into the external circuit. The further apart these metals are in the table the greater the electrode potential between them and the greater the tendency of the anode to dissolver or corrode.

Table I The electrochemical (Galvanic) series [6].

Metal (ions)		Electrod potential (volts)	
(Noble metals)	Gold (Au^{+++})	+ 1.5	Cathodic
	Silver (Ag^{+})	+0.8	↑
	Copper (Cu^{+})	+0.52	↑
	(Cu^{++})	+0.34	↑
	Hydrogen (H^{+})	0.00	(Reference)
	Iron (Fe^{+++})	-0.05	↓
	Lead (Pb^{++})	-0.13	↓
	Tin (Sn^{++})	-0.14	↓
	Nickel (Ni^{++})	-0.25	↓
	Iron (Fe^{++})	-0.44	↓
	Chromium (Cr^{+++})	-0.74	↓
	Zinc (Zn^{++})	-0.76	↓
	Aluminium (Al^{+++})	-1.66	↓
	Magnesium (Mg^{++})	-2.37	↓
Base Metals	Lithium (Li^{+})	-3.04	Anodic

(Some metals e.g. copper and iron, form more than one type of ion, depending upon the number of electrons lost by the atom under the electrochemical conditions prevailing.)

Fig. 1 describes the mechanism of coating copper on cast iron chips powder using displacement coating approach.

III. Experimental Details

A. Fluidized bed system construction

The fluidized bed vessel consisted of a glass tube with flanges at both ends with an internal diameter of 10 cm and outer diameter of the flange was around 15 cm. The porous polyethylene disc, with 2 mm thickness, was merged between the two flanges. The purpose of this disc was to produce and ensure uniform fluidization. Two semicircular wooden blocks were designed to fit on the top side of the flanges to join them neatly. Fig. 2 illustrates the cell configuration of the fluidized bed system with bath reservoir, variable speed pump and flow pipes.

The joints of the flanges were held together and rested on a flat wooden base, in which six screws and pins were used to bolting the flanges together, three on each semicircular block.

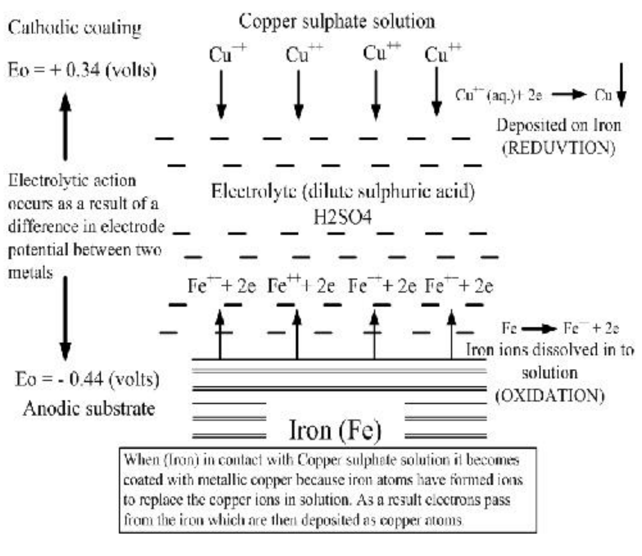

Fig.1 Copper coating mechanism on cast iron powder by displacement coating method.

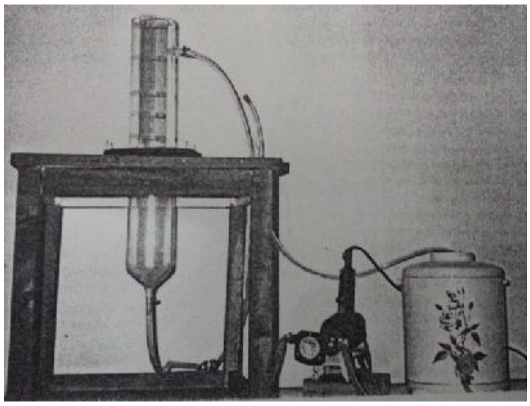

Fig. 2 Assembly of fluidized bed system.

The flexible set up was made in this way for easy assembly and dismantling. An additional O-ring was fitted between the flat wooden base and the bottom flange to reduce the risk of the bottom flange being damaged. In order to avoid the leakage of the fluidizing medium and powder being entrapped between the bed support and the glass flanges, silicon rubber was used and filled the ends of the flange joint neatly. Although this arrangement was very well sealed, the whole assembly had to be taken apart and thoroughly cleaned after each operation, which was a disadvantage. This was always done after each run to prevent subsequent contamination of the batches and also scratching of the glass flanges by powders.

B. Material used

Iron powder is a gray cast iron chips or powder obtained as residual of machining operations such as grinding, milling, etc., this has been used as raw material for copper coating application.

Copper sulphate is electrolyte bath for copper powder and it is represents the ion source of the bath. In order to get ready powder for coating, few processes are done;

i. Grinding the powder by using milling action and this operation is taken by dividing all powder quantity to several batches.
ii. Standard vibratory sieving equipment was used to get finer particles in size. According to that, two sizes of particles are obtained, 75-150 micrometer and 100-200 micrometer.
iii. Cleaning operation was done by which the iron powder was immersed on alcohol bath and then washed by distillate water then followed by drying process using hot air to prevent oxidation. The powder now cleaned from dust and oil or grease.

After the above mentioned operation, the Fe-powder is ready for coating processes.

C. Coating solution preparation

The coating solution consists from a copper sulphate, Iron sulphate as catalytic agent and sulphuric acid to remove oxides forming during deposition, and lowering the ohmic resistance of the solution. The preparation operation of solution is the same for each run or test hence a constant concentration was taken for each iron sulphate $FeSo_4$ and sulphuric acid H_2So_4, which are 5 g/l and 5 ml respectively with different concentrations of copper sulphate Cu So_4, for each run. For the first run, the concentration is 2.5 g/l, while 5 g/l and 10 g/l are used for the second and the third run respectively.

D. Test procedure

1) Displacement plating process in a manual stirred vessel

Coating deposition by the displacement method for a copper on cast iron chips particles was carried out in a manual stirred vessel. A manual stirred was achieved powders were added to the stirred coating solution and in a pyrex glass vessel at room temperature. Table II demonstrated the solution composition for this method of plating in bath.

Table II Composition of solution used for displacement method coating on cast iron chips powders in fluidized bed system and bath techniques.

Copper plating solution		The amount
Copper sulphate heptahydrate	$CuSo_4.5H_2o$	2.5, 5, 10 g/l
Ferrous sulphate septahydrate	$FeSo_4.7H_2o$	5 g/l
Sulphuric acid	H_2So (concentrated)	5 cc/l
Bath temperature	room temperature	20 c°

The basic operation and the apparatus generally is very simple and was used for preparing many samples of coated powders. Any quantity of powder up to 200 g could be coated in quick batches. Agitation was achieved successfully using up 1 litre of coating solution. Different percentages of coating on iron particles were obtained by this method. Fig. 3 illustrates the procedure description for the deposition of copper coating.

2) Fluidized bed method

This method is not different in principle to that described in previous section but it can deals with higher concentration for the same weight of Fe powders. Two sizes of Fe powder were examined by this method. The first size was 75-150 mic and the second size was 100-200 micrometer. The procedure of operation can be described as follows:

1. Fill the plastic container with 5 litres of distillate water.
2. Add 2.5 g/l of $CuSo_4$ to the distillate water and stirring both until the two are solved very well.
3. Add the following constant concentration, 2.5 g and 25 ml for FeSo4 and H_2S0_4 respectively. At this point, the diluted copper solution was become blue in colour and it is ready for coating.
4. Switch on the pump at low speed and then increase the pump speed gradually until the liquid reaches the fluidized.
5. From the upper opening of the glass tube, add the Fe-powder of amount 50 g. This operation is left for a period of 2-3 minute until the colour of solution changed from blue to transparent. Once the colour changed, the coating operation is stopped and then the red powder (coated powder) is obtained.
6. Remove the red powder from F.B system. This powder washed using distillate water and then dries it at room temperature.

All above steps are repeated for second and third run except step number 2 which becomes 25 g and 50 g for the second and third runs respectively.

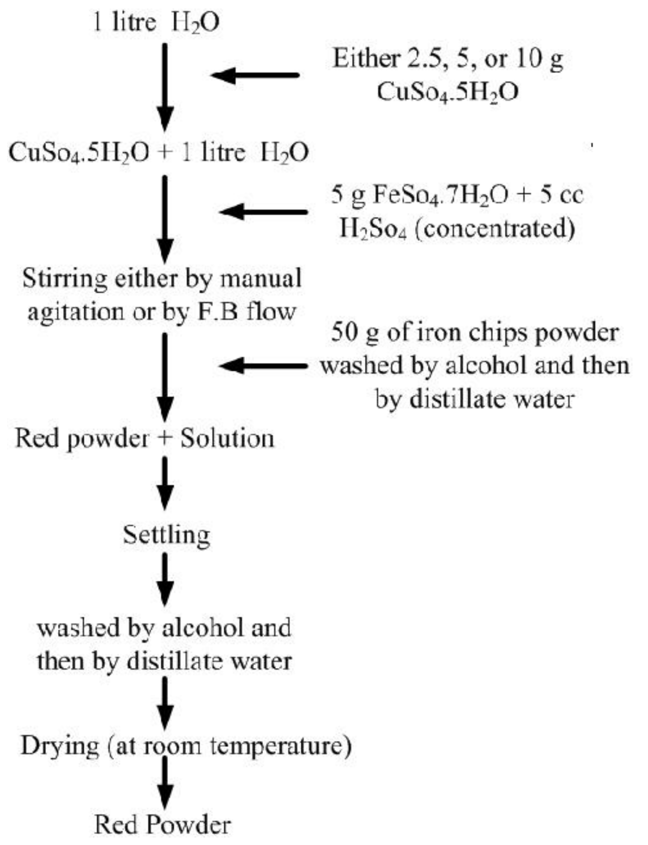

Fig. 3 Procedure for the deposition of coating iron powder using displacement method in either manual stirred vessel or in the F.B system.

E. Determination of the amount of copper deposition on iron particles

The composition of the composite powder was found out by weighting each sample of iron powder before and after copper coating process. All batches of 50 g of Fe particles were weighted on a chemical balance to an accuracy of 0.0001 digit and percentage measurements were taken and recorded for each sample of coated powder.

IV. RESULTS AND DISCUSSION

Table II describes the composition of solution used for displacement method coating on cast iron chips in fluidized bed and bath techniques.

Fig. 4 describes the results of the effect of copper sulphate on the amount of copper deposited on cast iron chips powder by fluidized bed coating technique. These results were obtained using three different solution compositions as illustrated in Table III.

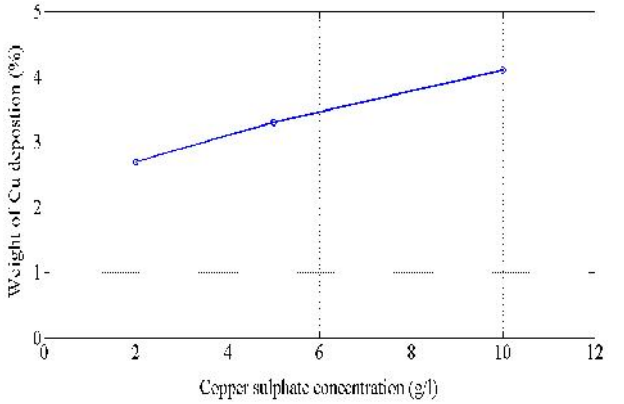

Fig. 4 Effect of copper sulphate amounts on amount of copper deposition on cast iron chips powder by F.B technique.

The results obtained by displacement coating method were shown in Table IV. In which the values of copper coating % on one size of 75-150 micrometer of iron chips powder were obtained as follows: 0.4, 0.9 and 1.4 where these values are plotted versus copper sulphate concentration as shown in Fig. 5. Whereas, the results obtained by fluidized bed technique were also given in the same table. The values of copper deposition % on two different sizes of iron chips powder are founded. The values 2.7, 3.3 and 4.1 are the results of weight of Cu deposition % for iron chips size of 75-150 micrometer while the values 2, 2.9 and 3.6 are the results of weight of Cu deposition % for iron chips size of 100-200 micrometer.

Table III Solution composition used to find effect of copper sulphate amount on amount of copper deposited.

	Coating solution		
	1	2	3
$CuSo_4.5H_2o$ g/l	2.5	5	10
$FeSo_4.7H_2o$ g/l	5	5	5
H_2So (concentrated) cc/l	5	5	5
Total volume	5 Litters		
Temperature	Room temperature 20c°		
Powder charged	50 g of cast iron chips, size range (75 150)mic		

Table IV Copper coating values on different sizes of iron powder obtained by F.B and by Bath techniques.

Powder type	Method of coating	Cu coating weight (%) 50 gr/batch
Fe of size (75-150)mic	1. By bath	0.4
		0.9
		1.4
	2. By fluidized bed System	2.7
		3.3
		4.1
Fe of size (100-200)mic	- By fluidized bed System	2
		2.9
		3.6

Fig 4 and Fig. 5 illustrate that both mechanical method (bath) and F.B method, the weight of Cu deposition is increased with increasing in $CuSo_4$ concentration.

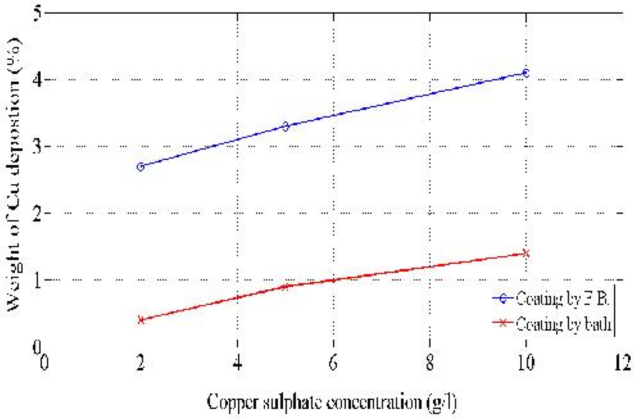

Fig. 5 Methods of coating and its effect on the amount of copper deposition on Fe powders (chips gray cast iron of amount 50 g and size of 75 - 150 micrometer).

Fig. 5 presents the effect of F.B method on coating process compared with traditional or mechanical method (i.e. by bath). There was a significant difference between the results of the two methods, e. g., that when coating an amount of 50 g of Fe-powder for the size of 75-150 micrometer using mechanical method that when CuSo4 concentration is 2.5 g/l, the copper percentage (coating thickness) that formed by this method is 0.4 % while the coating thickness is 2.7 % when using the F.B method. This increasing in coating thickness was obtained where the same amount, size of Fe powder and the CuSo4 concentration as well. The observed increase in coating thickness could be attributed to that in F.B method, the iron particles were steering around itself so all surface subjected to coating. In addition, the continuity of coating operation is another reason to adhere the copper atoms over those copper atoms rounded the iron particles.

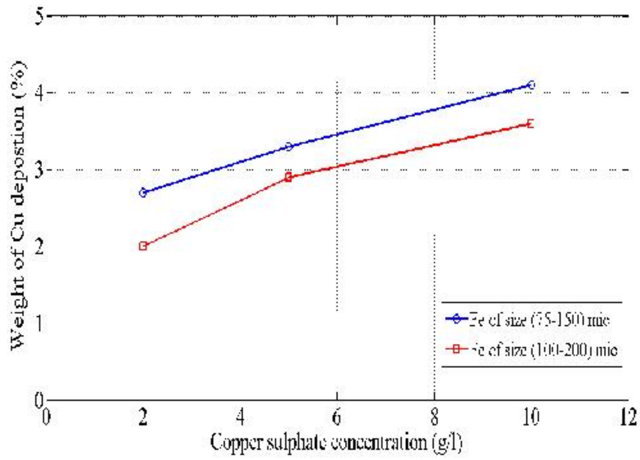

Fig. 6 The effect of particle size of Fe powders on the amount of copper deposition using F.B coating technique.

Fig. 6 presents the effect of particle size of Fe-powders on the amount of copper deposition using F.B coating technique. For the large particle size (i.e. 100-200 micrometer), the copper deposition is less than those for small particle size (i.e.

75-150 micrometer) for the same CuSo4 concentration. This is because of that the total surface area for constant volume for large particles is smaller than the total surface are of smaller particles for that volume. Therefore, the large particles will be coated with less copper deposition than that for small particles.

V. CONCLUSION

A copper coating of cast iron powder chips using fluidized bed cell technique has been presented. The design of fluidized bed system is constructed. Displacement coating using both by bath and F.B methods is experimentally conducted. This paper has given an account of and the reasons for the central importance of use of coating operations, in which composite powder are get successfully either by using mechanical coating method nor by fluidized bed cell system. The coating operation by using fluidized bed technique gives thicker coating than these traditional methods (i.e. by bath method) so that gives an indication to use FB technique rather than the second one. Also it is seems very rapid method and can be used for mass production. Coating solution concentration is very important parameter because when increasing in coating solution concentration the amount of coating deposited will be increased. Moreover, the fluidized bed system which constructed is ready for any other operation for coating another two different metals, such as copper over tin to produce bronze. Different powder sizes can be coated easily by using fluidized bed technique. Also it is known that for relatively large powder particles there is less amount of coating deposited, so the smallest powder particles are favourite. Furthermore, the coated powders which are obtained in this work (iron/copper powder from F.B method) can be considered as a raw material and it is be ready to convert to any engineering form by using powder metallurgy operation.

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