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A STUDY ON ANALYSIS OF XRD, *SEM IMAGES* AND SEM (EDX) FOR THE FORMATION OF A COMPOSITE LAYER ON ALUMINIUM PIPE

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Abstract—Aluminium is widely used for Aerospace,Automotive, Marine, Rail, Building, Packaging and Mechanical industry and engineering applications because of its ease in fabrication and the moderate strength it posses. Comprising a little over 8% of the earth's crust, aluminium is the most abundant metal on the planet. It is the third most common element after oxygen and silicon. In our lifestyles and built environment, aluminium products are just as abundant. Since its commercial production began little more than a century ago, aluminium has become the material of choice for a diverse range of application and utilities. The natural qualities of aluminium and its alloy are positive deciding factors for designers, manufacturers and industrial users who are always on the lookout for better- performing materials and innovative processes. However, its pure corrosion resistance at normal atmosphere is a matter of serious concern. Friction surfacing is a relatively new technology which is capable of producing coatings with zero dilution and good metallurgical bonding. This is attained because no melting is involved in this process. The study reveals it is a technique to improve the properties at the interface between aluminium and zinc.
Keywords-Friction surfacing, zero dilution,metallurigical bonding, properties of inter surface.

I. INTRODUCTION

Fusion welding based coating techniques generally suffers from dilution and thermal spraying results in mechanical bonding rather than metallurgical bonding. Friction surfacing is a relatively new technology which is capable of producing coatings with zero dilution and good metallurgical bonding. This is attained because no melting is involved in this process.[2] Research so far has revealed that in friction surfacing the Rotation Speed N(rpm),Feed (mm/rev) and substrate Forward time,FT (min) are of critical importance for the final quality of the coating and bond. Development of a methodology for in-process precision measurement of coating thickness, surface roughness, micro-structural analysis and , mechanical property. Development of an empirical model involving process parameters N, Feed F, FT and coating quality .

II. COATING APPLICATIONS

Use of thin coatings in automotive industry, Aerospace, Marine, Rail, Building, Packaging, Mechanical industry and engineering, Energy distribution and sports gives economic and ecological savings. This is evoking by reducing of weight of used construction elements and currently by increasing of their service life and with that connected elevating of nano materials manufacturing qualities.

III.FUNCTIONAL COATINGS

A. CORROSION RESISTANCE (Zinc Coating)

As finctional coatings corrosion protection coatings for a global industry with high environmental demands are used. Corrosion protection coatings concerned with zinc coatings.Due to the increasing expectations of consumers, the international automotive industry is required to extend vehicle warranties. Thus improvements in corrosion protection are becoming increasingly important. E.g. zinc- aluminium processes provide superior corrosion resistance even for complex shaped parts through uniform thickness distribution, and these highly bendable layers also allow machining. Zinc coatings enhance performance and extend component service life through improved corrosion resistance.[2]

B.APPLICATIONS

- Aerospace and Aviation
- Automotive Industry
- Rail Transport
- Ship Building
- Construction
- Electrical Engineering
- Consumer Goods
- Packaging

IV. FRICTION SURFACING

A. PROCESS DEFINITION

- It is defined as the solid state deposition process which involves rotating circular zinc rod internally in a fixed pipe.
- It is used for corrosion resistance coating and for reclamation of worn engineering components.
- Rotating speed, Feed and Forward time are the process parameters involved in this coating process.

B.MATERIALS USED

The material is selected based on mechanical, thermal and physical properties of metals. The intension of this process is to select the tool as low melting point material compared to pipe material and the tool is low hardness material where as pipe material is high hard material. The deposited material on internal surface of the pipe material is selected as zinc (Pure Zinc) where as pipe material is selected as Aluminium (AL) as shown in table 1. The following table summarizes the details of the materials which were used during friction surfacing process.

Table 1: Composition of Tool material and pipe material

Sl.No	Composition of parent metals	
	Tool material (Zinc)	Pipe material (Aluminium)
1	99.9% Zn, 0.06P, 0.04S	99.9%AL, 0.05P,0.05S

C.PROCEDURE

Step 1: Experimental work:

The proper tool is selected according to pipe material and fixed in continuous drive friction stir processing machine. The tool is fixed in a stationary member while pipe is fixed in a rotary member. A tool material is inserted into the pipe and rotated inside the pipe to get sufficient temperature due to friction. So that a thin layer is formed between tool and pipe. Then the tool is slowly removed from the pipe. This thin layer (intermetallics) is formed inside the pipe material. This intermetallics act as anti-corrosion material. The friction factor and viscosity of the fluid inside the pipe/tube depends on surface roughness.[1,3]

Step 2: Tool Design

The tool is made up with zinc material and designed according to dimensions required for fitting inside the pipe material to deposit

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the zinc as coating inside the mild steel pipe. The tool is prepared from zinc billet is converted into required tool shape .
The Auto CAD model of pipe material dimensions, tool material dimensions and tool supported material are prepared prior to design the actual dimensions of the tool and pipe as shown in Fig. 1.

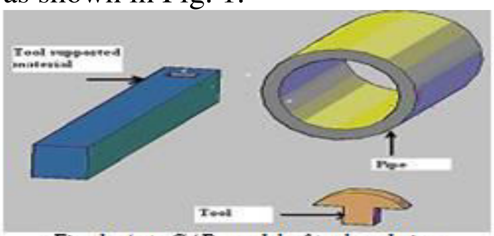

Fig. 1: Auto CAD model of tool and pipe

The CNC machine is selected to do the operation for coating by friction technique. The mild steel pipe is fixed in rotating member (i.e. chuck) while tool is fixed in stationary member (Tool is fixed in horizontal rectangular rod which is fixed in tool post). The tool is adjusted to the center of the pipe with the adjusting of tool post and set the external curvature of tool matches with internal curvature of the pipe. The tool always contacts with the pipe and start the rotation with given speed to the pipe. The tool is feeding slowly according to the selected parameters in forward direction after some time then the tool is slowly in reverse direction. The following parameters are selected and list of parameters are shown in Table 2.

1. Speed(N) in rpm
2. Forward time(FT) in min
3. Feed in mm/rev

Sl. No.	Speed, N (rpm)	Feed (mm/rev)	Forward time, F_T (min)
1	600	0.045	5
2	600	0.045	8
3	800	0.045	5
4	800	0.045	8
5	600	0.05	5
6	600	0.05	8
7	800	0.05	5
8	800	0.05	8

Table 2: Processing Parameters are used in this process

In forward direction, the tool touches with the internal surface of the pipe and the friction generated between tool and pipe. This friction is enough to soften the tool surface and wear of the tool. The deposition is taking place on internal surface of the pipe. In reverse direction, the tool moves with less time improves the surface finish of the pipe, tool moves with less time improves the surface finish of the pipe.[1,3]

Step 4: CNC Part Programming:

The introduction of CNC machines radically changed the manufacturing industry. Curves are as easy to cut as straight lines, complex 3-D structures are relatively easy to produce, and the number of machining steps that required human action has been dramatically reduced.With the increased automation of manufacturing processes with CNC machining, considerable improvements in consistency and quality have been achieved with no strain on the operator. CNC automation reduced the frequency of errors and provided CNC operators with time to perform additional tasks. CNC automation also allows for more flexibility in the way parts are held in the manufacturing process and the time required to change the machine to produce different components.[1,3] The various types of parameters that generally used in CNC part programming .

V. Results and Discussions

A. XRD Pattern of Zinc deposited on Aluminium

In the XRD pattern of Zinc deposited on Aluminium, the peaks are observed at 36.290 and 38.43 with (h k l) values of (0 0 2) and (1 1 1). These results are coinciding with JCPDS card number of 87-0713 for Zinc at 36.290 and it shows hexagonal structure with the crystal size of 10.35nm, the peaks which are coinciding with JCPDS card number of 44.67-for Al at 44.67 and it

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shows cubic structure with the crystal size of 15.05nm

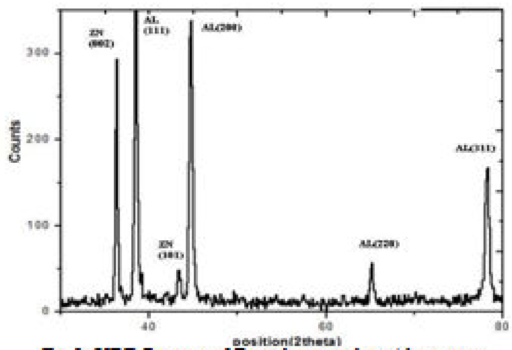

Fig 2: XRD Pattern of Zinc deposited on Aluminium

According to the Debye-Scherer's equation:

$$D = \frac{0.9\lambda}{\beta cos\theta} nm \quad (1)$$

Where D – Average size of the particle (nm)

--Wavelength of the radiation (A°) θ –Diffraction angle (degree)

B – Full width half maximum (FWHM) of the peak (radians)

From the above equation, the obtained average crystalline size is 15.8nm.

B.SEM images of Zinc deposited on mild steel:

SEM images of zinc deposited on Aluminium, it shows fine surface finish after deposition of Zinc on Aluminium by friction surfacing. Due to some alloys present in Aluminium the deposition of zinc is uniform.

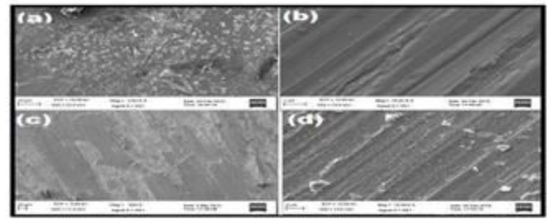

Fig 3(a) (b) (c) & (d) SEM images of Zinc deposited on Aluminium by friction surfacing

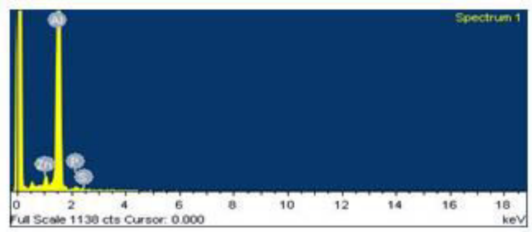

Fig 4: EDX of Zinc deposited on Aluminium by friction surfacing

C. Formation of Composite Layer during Friction Surfacing:

From XRD and SEM (EDX) study we can conclude that the deposit is a mechanical mixture of zinc and Aluminium. Since, the consumable tool was pure ZINC, during friction surfacing, Aluminium particles must have formed and got mixed with zinc. This has resulted in the deposition of a composite layer of zinc and Aluminium. Formation of a composite layer is similar to material transfer during friction conditions and can be explained as follows

In the beginning of friction surfacing both surfaces has asperities. These asperities have various dimensional scales. This means that only few asperities are in contact with each other forming a contact pair . The effective stress at the contact point may be very high compared to the average stress estimated using normal load and initial section diameter. When there is a relative sliding between two surfaces, the asperities will undergo deformation. Being a weaker material, the plastic deformation will be much more towards zinc side than AL side.

Actual strain value will be very high, and it will vary depending on the morphologies of the asperities. zinc, though more ductile, may get fractured easily, because of poor strength value. But being fresh surfaces, two Zinc surfaces have a chance to get re welded. On the other hand, AL is a strain hard enable material and at the asperity contact they will become hard, brittle, and get sheared during sliding. The AL-Zn interface shown in Figure 3(b) shows reduced grove depth (less than 5 µm) compared to initial grove depth (25–32 µm). This supports the argument that the asperity hills on hard Fe surface get broken during shearing. Broken Fe particles get mixed up in soft Zinc layer and the mixture gets deposited during friction surfacing.

D.Cross-Sectional Microscopy:

Deposition thickness is fairly uniform, and measurement over 1 mm length gave thickness in the range of 90 to 106 um. Interface is macroscopically smooth, without any profiles created during surface milling. This is more clearly visible in the Figure 6. It presents the interface between substrate and the material-deposited. The interface is relatively smooth and small. The composition profile across the interface (Figure 3(c)) shows minimum (almost zero) level of mixing of species on either side of the interface. This statement is without considering the material transfer in the form of particles which are visible as white particles (iron) particles of nanometer scale (interface) embedded in zinc matrix. The average spacing between the particles is also very small, indicating that they would contribute for particle strengthening . Strong Al particles are expected to strengthen soft Zn matrix.

From the figure 5 it shows the deposition of zinc metal inside the Aluminium pipe by mechanical action. The microstructure shows interface of zinc deposited inside the Aluminium pipe.

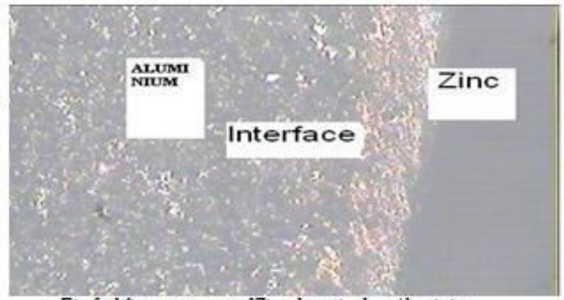

Fig 5: Microstructure of Zinc deposited on Aluminium

VI. CONCLUSIONS

XRD pattern of Zinc deposited on Aluminium by friction surfacing shows, the average crystalline size is 15.8nm. Due to proper deposition of zinc, it shows fine surface finish by scanning Electron Microscopy (SEM). Deposited Zinc consisted of small Al particles dispersed in it. The interface between substrate material and deposited material is smooth and relatively sharp. A mechanism for the formation of a composite layer is presented using shearing, mixing, and deposition of plastic material during surfacing..For friction surfacing three different set of parameters were applied to get the minimum thickness.Hence it does not cause weight increase in coated substances. On aluminium pipe zinc has given a proper coating

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