EXPERIMENTAL AND ANALYSIS OF NON FERROUS METALS OVER MILD STEEL

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Abstract : According to the present demand for surface engineering technique over the metals in the present industrial application we introduced friction surfacing process. In this process the coating over different metals will takes place by using friction between two metals. It has certain advantages like wear and corrosion resistance, working life times, friction energy losses etc... This process has been for obtaining various hard metal coatings, such as aluminum coatings on mild steel. Friction surfacing process is not only cheaper but also reliable and the properties of the base metal will remain constant after coating. The coating over the metal will take place at recrystalisation temperature of the parent metal only. So that the base metal will not melt as the structure and properties of the base metal will remain constant. The main concept of our project is to know the interface properties of the non ferrous metals after coating over the ferrous metals by using this friction surfacing process.

Key words: Al, Cu, Brass, Mild steel heat-affected zone (HAZ), computer numerical control (CNC), Ansys AND FEM

1 INTRODUCTION 1

The material surfaces are engineered to impart specific properties, which could be different from those of the core material. These surface modifications are generally carried out to impart wear and corrosion resistance to the substrates and yet times these surface modifications enhance esthetic appearance of the substrates. Various surface modifications techniques are adapted for surface modifications which include chemical deposition process, high temperature diffusion related process involving chemical reactions, deposition by fusion routes such as weld overlay, flame spray techniques etc., which are widely employed. Other innovative processes include solid-state process such as roll bonding, explosive cladding and friction surfacing. The proposed study is on solid state deposition of a material on to a substrate employing frictional energy generated between a rotating consumable rod and a linearly moving substrate. Friction surfacing, which is related to friction welding, utilizes the frictional energy dissipated during operation and generates a layer of plasticized metal, the layer of plasticized metal being deposited as a coating without the need for external heat source. The friction surfacing of aluminum presents an inherent problem due to the high thermal conductivity of the metal. With tool steel, the heat generated in the process remains close to the spot due to the low thermal conductivity of these steels. However with aluminum the heat quickly escapes upwards through the rod material. Effectively the cooling rate of the substrate is increased, thus achieving thermal balance between the rod and the substrate to retain more heat in the metal transfer zone. However this means that even greater total energy is lost in the system and so high forces are required to compensate for this by generating more frictional heat.

1.2 PROBLEM DEFINITION 2

1.2.1 Objective

The main aim of our project is to know the interface properties (viz. bond Integrity, hardness distribution and shear strength) of non-ferrous metals (Al, Cu And Brass) over Mild steel using friction surfacing process.

1.1.2 Metals used for coating

Different types of metals can be used for friction surfacing process but as a part of our project we have chosen non ferrous metals like aluminum, copper and brass. And we have continued with aluminum metal over mild steel.

1.1.3 Machines used

For coating process we used BFW vertical milling machine and for good surface finish we used horizontal grinding machine.

2 LITERATURE REVIEWS 2

Surface engineering has gained wide importance owing to the realized advantages in materials technology and an important form of surface engineering is the friction surfacing technique. It has certain advantages like wear& corrosion resistance, working life times, friction energy losses etc.., This process has been for obtaining various hard metal coatings, such as tool steel coatings on mild steel .The frictional heating of the substrate by the consumable material leads to the formation of a heat-affected zone (HAZ) close to the interface between the substrate and the consumable, but this HAZ is smaller than that caused by welding. Dissimilar metal coatings are made possible by the generation of high contact stress and intimate contact between the coating material and substrate, which indicates solid-state adhesion between coating and substrate. Strong bonding is achieved between the coating and the substrate in the friction surfacing process if a high contact pressure is used. Friction surfacing is an effective way of depositing layers of metals on to one another. The technology, classified as a solid state welding process, is derived from friction welding and offers the possibilities of joining materials that are difficult to weld through fusion welding techniques.

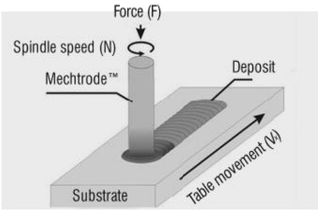

Fig 2.1 the process of friction surfacing is schematically depicted

It uses a combination of heat and deformation to clean surfaces and metallurgical bond metals together. In its simplest arrangement a rotating consumable bar is brought into contact, under low load, with stationary substrate. At initial contact, the rotating bar is preferentially heated to form plasticized layer by the frictional motion. Once this plasticized zone has developed sufficiently (usually in 1-3s), the substrate plate is traversed tangentially to the bar and the plasticized metal is transferred on to the plate. Bonding occurs by the combination of self-cleaning between the two materials and the application of heat and pressure to encourage diffusion across the interface, thereby forming a solid phase metallurgical bond. The process relies on producing precisely the right temperature and shear conditions at the interface between the rotating bar and substrate via the plasticized layer. This leads to the so-called cold lap; an additional factor is the unequal distribution of frictional energy at the free edge of the consumable because this edge is unable to transmit the same degree of pressure.

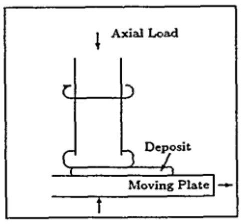

Fig 2.2 Principle mechanism of friction surfacing process

3. PROCEDURAL STEPS FOR FRICTION SURFACING PROCESS 3

A mild steel plate of 250mm length, 120mm width and 10mm thickness plate was taken and for obtaining good friction between two metals i.e., the consumable metal bar and the mild steel plate we roughened the plate over the milling machine. As it was mentioned earlier we have chosen two metals for coating over the mild steel plate they are the aluminium and the copper. Firstly we have coated aluminium over the metal plate. A 19 mm diameter aluminium rod with 75mm length and this rod are held in the collect of the vertical milling machine. The maximum speed of the milling machine is 2500r.p.m. and we coated the aluminium at 2000 to 2500r.p.m. by varying the speed for each pass of the consumable rod over the metal plate.A load of 5kgs is constantly maintained on the spindle head and the table speed is varied accordingly. So that we got varies penetrations at different speeds of the table movement. We got 5mm height of penetration at moderate speed and 2mm height of penetration at high speed of the table. After the coating is completed we used milling cutter for side facing of the metal plate and the coating made so that it is easy to view how much metal has been penetrated over the metal plate and also to see the micro structure and adhesion capacity of the aluminum over the mild steel. The coated aluminum metal is subjected to grinding operation to obtain smooth surface finish as it is uneven before. After the machining operation is completed the metal plate is cut into specimens with 30mm width and 200mm long. So that these specimens are used for testing. Different tests have to be conducted. Over these specimens like shear test, hardness test, micro structure, bending test. And the size of the specimen will vary according to the test. This friction surfacing process is done on conventional vertical milling machine. This friction surfacing process can also be done on CNC machines also but it should be of spring loaded control machine, because in this CNC machines the Z-axis will remain fixed according to the programmed made by the operator. As this machine is not available in our state we preferred conventional milling machine.

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Fig 3.1 25/12mm and 10mm thickness mild steel plate

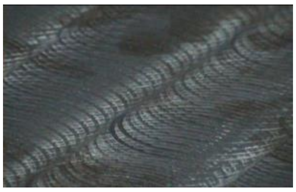

Fig 3.2 the plate is roughened for more friction between two metals.

Fig 3.3 Consumable metal rod held in the machine spindle & the M.S plate in the vice

Fig 3.4 Coating of aluminum over the mild steel plate

Fig 3.5 after coating of aluminum over mild steel the formation of layers along the plate

Fig 3.6 Penetration of aluminum metal over mild steel at various speeds

Fig 3.7 Side facing of the metal plate

Fig 3.8 after facing the adhesiveness and penetration of the metal is clearly seen

We have also made this experiment by using copper as the parent metal to coat over base metal, but the speed is not sufficient so the coating has been not occurred so it was kept as an experimental process.

The process of coating of copper over mild steel is shown in the below figure.

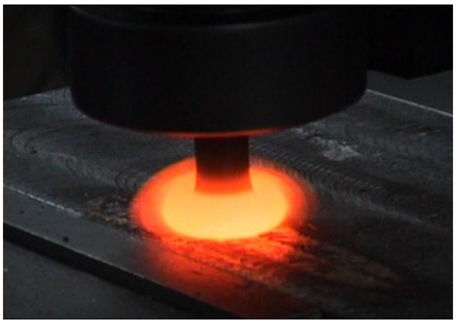

Fig 3.9 a layer of copper coating formed over mild steel

Fig 3.10 Coating of brass over Mild steel

3.1 Properties of Metals Used For This Process 1

3.1.1 Type and Temperature

S.No	Metal	Type	Melting Point	Recrystallization Temperature	Composition
1.	Aluminum	H30	660 °C	160-280 °C	Cu-0.1, Mn-1.2, Mg-0.6.
2.	Copper	C101	1083 °C	120-240 °C	Fe0.25,Cu 99.9
3.	Brass	B45	1050 °C	240-320 °C	Cu-0.7,Zn-0.3

Table-1 Type and Temperature of metals

Different types of metals can be used for this friction surfacing process according to their properties. Among different types of metals we have choosen four metals they are mild steel as the base metal for all and the aluminium, copper, brass to coat over mild steel.

3.2 Properties of aluminum 2

Weight: With a density of 2.7 g/cm3, aluminum is approximately one third as dense as steel.

Strength: Aluminum alloys commonly have tensile strengths of between 70 and 700 Mpa. The range for alloys used in extrusion is 150-300 Mpa.

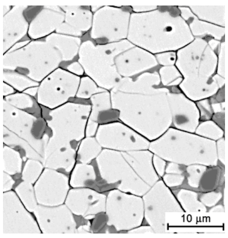

Fig 3.11 Microstructure of aluminum

Linear expansion: Compared with other metals, aluminum has a relatively large coefficient of linear expansion. This must to be taken into account in some designs.

Malleability: Aluminum superior malleability is essential for extrusion. With the metal either hot or cold, this property is also exploited in the rolling of strips and foils, as well as in bending and other forming operations.

Machining: Aluminium is easily worked using most machining methods – milling, drilling, cutting, punching and bending. The energy input during machining is low. Aluminium is easy to machine using most machining methods.

Jointing: Features facilitating easy jointing are often incorporated into profile design. Welding (fusion welding, friction stir welding), bonding and taping are also used for jointing.

Conductivity: Aluminium is an excellent conductor of heat and electricity. An aluminium conductor weighs approximately half as much as a copper conductor having the same conductivity.

Reflectivity: Aluminium is a good reflector of both visible light and radiated heat.

Screening – EMC: Tight aluminium boxes can effectively exclude or screen electromagnetic radiation. The better the conductivity of a material, the better the shielding qualities.

3.3 Properties of Copper 3

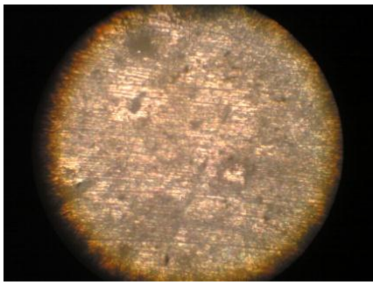

Fig 3.12 Microstructure of copper

Color: Copper's color is a unique softly reflective brown red to deep brick red. Exposure to Oxygen causes Copper to tarnish and turn a Teal Green as is the case with one of America's most famous monuments the Statue of Liberty.

Alloys: The most famous Copper alloy is Bronze, a Copper/Tin alloy, that played a large role in the advancement of ancient cultures. Copper is also often mixed with Zinc to form Brass. Other alloys include Sterling Silver, which is 92.5% Silver (minimum) and 7.5% Copper and lower Karat Gold. Jewelry manufacturers add Copper to Silver and Gold to increase the strength of the items. They also use Copper for the process of Electroplating Gold. In Electroplating, jewelers apply Gold to Copper using electricity and can achieve a very thin product.

4 ADHESIONS AND DIFFUSION 4

Adhesion is defined by the state that two bodies are hold together for an extended period by interfacial forces. The forces range from valance forces to mechanical interactions. The nature of interfacial adhesion ranges from bio adhesion involving cell adhesion to adhesion of heavy construction materials.

4.1 Adhesion Theory 1

Mechanical Theory The Mechanical Theory, also called the Mechanical Interlocking Theory, is the oldest explanation for adhesion. The theory essentially described that mechanical interlocking of the adhesives and the flow into the irregularity of the substrate surface is the source of adhesion. One good example is in the case of dental restoration.

Electrostatic Theory

The Electrostatic Theory describes that an electrical double layer is produced at any interface and the consequence Columbic attraction largely accounts for adhesion and resistance to separation.

$$A_c = \frac{h_c \epsilon_d}{8\pi} \cdot \left(\frac{dV_c}{dh_c} \right)^2$$

Diffusion Theory

The Diffusion Theory states that adhesion occurs through inter-diffusion of the adhesive and adherend across the interface. Adhesion is considered a three-dimensional volume process rather than a two-dimensional surface process.This theory requires that both the adhesive and adherend are polymers, which are capable of movement and are mutually compatible and miscible. To describe the self-diffusion phenomenon of polymers, several theories have been proposed: entanglement coupling, cooperativity, and repetition. The repetition model has been applied to study tack, green strength, healing, and welding of polymers.

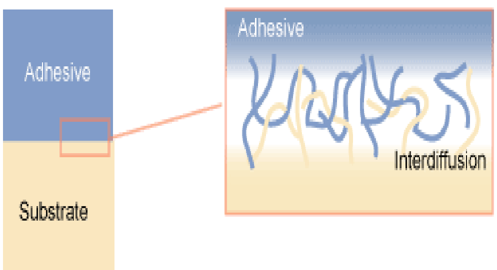

Fig 4.1 Diffusion mechanism

Adsorption Theory

The Adsorption Theory is the most widely applied theory on interfacial adhesion. The theory states that surface forces are involved in adhesion, and that polar molecules are oriented in an ordered way so that surface molecules of adhesive and adhered are in contact. Sufficient intimate molecular contact is achieved at the interface that the materials will adhere because of interatomic and intermolecular forces.

4.2 Hardness Test 2

Hardness is defined as the ability of the material to resist

$$HV = \frac{2F\sin\frac{136^o}{2}}{d^2} \qquad HV = 1.854\frac{F}{d^2} \text{ approximately}$$

indentation or penetration is called hardness.

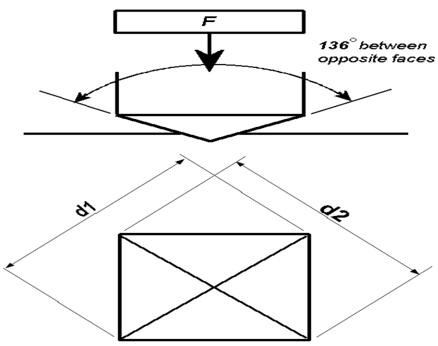

Fig 4.2 Hardness Test

F=Load in kgf, d = Arithmetic mean of the two diagonals, *d1* and *d2* in mm, HV = Vickers hardness

When the mean diagonal of the indentation has been determined the Vickers hardness may be calculated from the formula, but is more convenient to use conversion tables. The Vickers hardness should be reported like 800 HV/10, which means a Vickers hardness of 800, was obtained using a 10 kgf force. Several different loading settings give practically identical hardness numbers on uniform material, which is much better than the arbitrary changing of scale with the other hardness testing methods. The advantages of the Vickers hardness test are that extremely accurate readings can be taken, and just one type of indenter is used for all types of metals and surface treatments. Although thoroughly adaptable and very precise for testing the softest and hardest of materials, under varying loads, the Vickers machine is a floor standing unit that is more expensive than the Brinell or Rockwell machines.

Fig 4.20 Vickers hardness testing machine

Fig 4.21 Specimen used for hardness test

Fig 4.22 the specimen made for the micro structure

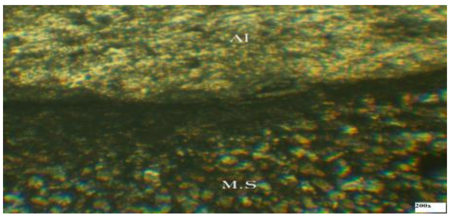

Fig 4.23 the microstructure of the aluminum coating over the mild steel

5 FINITE ELEMENT ANALYSYS 5

Engineers today face increasingly difficult challenges to contend in rapidly changing global market-to-market products in better quality at lowest cost possible, so that the product has a good market in competition. To achieve these goals, one of the powerful tools available for the designer is computer aided finite element analysis. Finite element Analysis is a powerful numerical technique for analysis .FEA is used for stress analysis in that area of solid mechanics.

5.1 Finite Element Method 1

With the advancement of computer technology and CAD systems, complex problems can be modeled with relative ease. Several alternative configurations can be tried out before fabricating the initial prototype.

5.2 Finite Element Procedure 2

Pre-Processing: Define material properties such as Young's Modulus, Poisson's ratio etc.Prepare the sketch of continuum to be analyzed. Mesh generation i.e. dividing the geometry into a number of suitable fine elements, which are interconnected at the nodes.

Processing (solution):

After the model is built in pre processing phase, the solution to the analysis is obtained in the processing phase.

Post Processing:

Post processing deals with the results such as deformed configuration, shapes, and stress distribution, temperature.

5.3 MESHING AND ANALYSIS OF THE MILD STEEL COATED WITH ALUMINIUM3

The following figures are done by taking mild steel properties

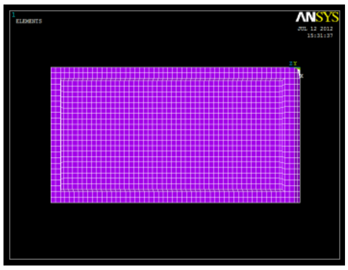

Fig 5.1 Meshing of the mild steel coated with aluminum

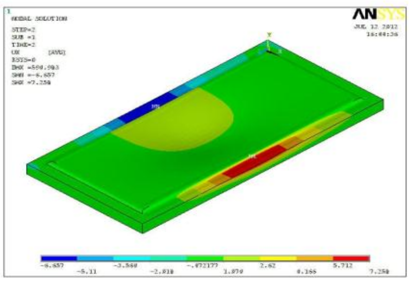

Fig 5.2 Displacement in X-axis for mild steel

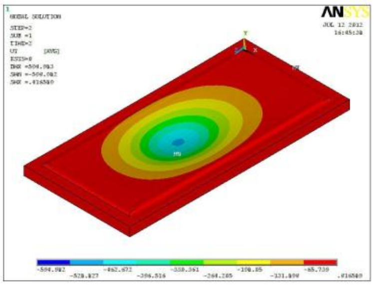

Fig 5.3 Displacement in y axis for mild steel

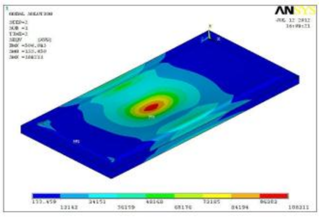

Fig 5.8 Von Misses stress for mild steel

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