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Development of New Coating Technology by Friction Technique

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Abstract: *A new approach in development of coating technology by "Friction stir technique". The research goal focuses on the development and application of new technologies in establishing new piping materials and coatings to improve corrosion resistance there by increasing the ease of fluid flow in pipes. Focus is on achieving operating cost reductions in the transport of gas and oil through pipelines. The outcome of the research is a newly developed pipe line system for transportation of gas and oil. This project helps to improve the surface smoothness and anti-corrosion of inside pipe without using the chemicals or coating for the usage in petro chemical industries, marine applications, wear and abrasion resistant ship structures. The proper tool is selected according to pipe material and fixed in continuous drive friction welding machine. The tool is fixed in a rotating member while pipe is fixed in a stationary 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.*

Keywords: Coating, Friction Technique, Zink billet and tool, Coating Thickness and Hardness rate.

I. INTRODUCTION

Coating is a covering that is applied to the surface of an object, usually referred to as the substrate. In many cases coatings are applied to improve surface properties of the substrate, such as appearance, adhesion, wet ability, corrosion resistance, wear resistance, and scratch resistance. In other cases, in particular in printing processes and semiconductor device fabrication (where the substrate is a wafer), the coating forms an essential part of the finished product. The most common use of industrial coatings is for corrosion control of steel structures such as offshore platforms, bridges and underground pipelines. Other functions include intumescing coatings for fire resistance. The most common polymers used in industrial coatings are polyurethane, epoxy and moisture cure urethane. Another highly common polymer used in industrial coating is a fluoropolymer. There are many types of industrial coatings including inorganic zinc, phosphate, and Xylan and PVD coatings. A typical coating system may include a primer, a intermediate coat, and a top-coat. The polymer film acts as a physical barrier between the steel substrate and the corrosive environment such as atmosphere, water and soil. Types of coatings are,

- Chemical vapor deposition
- Physical vapor deposition
- Chemical and electrochemical techniques
- Optical coatings
- Roll-to-roll coatings

II. EXPERIMENTAL WORK

Material Selection: 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 aluminum (Pure Aluminum) as shown in table 1. The following are the composition of tool and pipe materials are:

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Table 1: Composition of Tool material and pipe material

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

Tool Design: The tool is made up with zinc material and designed according to dimensions required for fitting inside the pipe material to deposit the zinc as coating inside the aluminum pipe. The tool is prepared from zinc billet (Fig. 3.1) and is converted into cylindrical rod (Fig. 3.2) then it is prepared into required tool shape as shown in Fig. 3.3.


Fig. 3.1: Zinc billetFig. 3.2: Zinc cylindrical rodFig. 3.3: Zinc tool material

The zinc billet is fixed in vice and cut into rectangular blocks of size 200X50X40 mm. Then the rectangular block is fixed in lathe machine and turning it into cylindrical rods of size length 200mm and 36mm dia. The cylindrical rod is fixed in power hacksaw (Fig. 3.4) machine and cut into tool dimensions and pipe is also cut into required dimensions of 200mm as shown in Fig. 3.5.



Fig. 3.4: Preparation of tool from cylindrical rod Fig. 3.5: Pipe material is cut into required size

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III. Experimental Setup

The All Geared Lathe machine is selected to do the operation for coating by friction technique. The aluminum 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 3.1.

Table 3.2: Parameters are used in this process

Sl. No.	Speed, N (rpm)	Forward time, F_T (min)	Reverse time, R_T (min)
1	1000	20	5
2	1000	20	10
3	1000	30	5
4	1000	30	10
5	1200	20	5
6	1200	20	10
7	1200	30	5
8	1200	30	10

3.4 Corrosion test

The corrosion test is conducted on internal surface of coated aluminum pipe for corrosion. The sample is according to corrosion test dimensions as shown in Fig. 3.7.


Fig. 3.7: Sample prepared for corrosion test Fig. 3.8: Corrosion testing machine

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Fig. 3.8 shows corrosion testing machine used for sample kept inside the machine for long time. The corrosion is observed with respect to time. In the chamber the chemicals (NaCl) are sprayed inside the pipe and external of the pipe is covered as shown in Fig. 3.9.

Fig. 3.9: Corrosion testing chamber

Micro hardness : Vickers hardness test

The Vickers hardness test was developed by Smith and Sandland (1922) at Vickers Ltd. as an alternative to the Brinell method to measure the hardness of materials. The Vickers test is easier to use than other hardness tests since the required calculations are independent of the size of the indenter, and the indenter can be used for all materials irrespective of hardness. In this method, micro indentation is made on the surface of a specimen with the help of diamond pyramidal indenter. It is a square pyramid with an angle of 136°±30′ between the faces as shown in Fig 3.10. The faces meet at a sharp point and the faces of the pyramidal indenter are optically flat. The hardness is calculated from the relation:

$$H_v = 1854.4(P/d^2)$$

where P is the load applied on the indenter in g and d is mean diagonal length of the square impression formed on the sample surface in μm. Hardness is measured in units of kg/mm^2. Figures 3.11 show the photograph and schematic representation of the instrument used in the present studies.

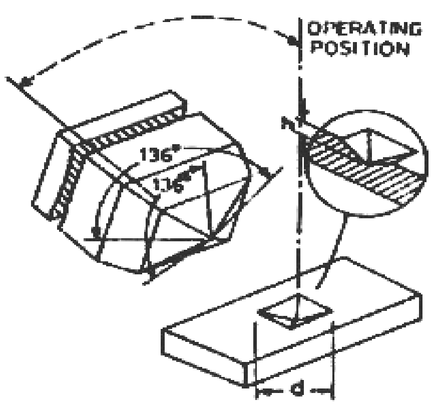

Fig 3.10: Geometry of the Vickers indenter **Fig. 3.11: Photograph of Leitz-Wetzlar (miniload2) microhardness tester.**

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IV. RESULTS AND DISCUSSIONS

Hardness: The parameters are plays a greater role to improve the hardness of coating, which is deposited inside the aluminum pipe. The parameters used in the experimentation are pipe speed, forward time for tool and reverse time for tool as shown in table 4.1.

Pipe speed (N) in rpm – 1000 and 1200
Forward time for tool (F_T) in min – 20 and 30
Reverse time for tool (R_T) in min – 5 and 10
Base metal: Aluminum pipe - 46.812 Hv

Zinc - 57.937 Hv

Table 4.1: Hardness varies with the Parameters

Sample. No.	Parameters			Hardness, Hv
	Speed in rpm	forward time in min	Reverse time in min	
1	1000	20	5	56.515
2	1000	20	10	52.551
3	1000	30	5	106.521
4	1000	30	10	42.872
5	1200	20	5	118.239
6	1200	20	10	302.693
7	1200	30	5	50.135
8	1200	30	10	99.650

<u>At 1000 rpm:</u>

1000	20	5	56.515
1000	20	10	52.551

At the lower speed and lower forward time, the hardness is approximately equal but a slightly difference in hardness with an decreasing order due to low time is not enough to create coating. This leads to lower hardness which is equal to base metals.

1000	30	5	106.521
1000	30	10	42.872

The lower speed and higher forward time, the hardness is higher (Double value) than the base metal with the lower value of reverse time due to higher amount of zinc is deposited inside the internal surface of the aluminum pipe. In reverse time, the deposited zinc redistributed equal into the internal surface due to less time, which leads to more axial compressive forces acting onto the internal surface of the pipe.

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1000	20	5	56.515
1000	30	5	106.521

The hardness is increases with an increase in forward time at low speed and low reverse time. Lower reverse time allowed more axial compressive forces acting inside the surface of pipe. The hardness is higher at higher forward time and lower reverse time due to more amount of zinc deposition due to more axial compressive forces.

1000	20	10	52.551
1000	30	10	42.872

The hardness is decreases with an increase in forward time at higher reverse time and low speed due to higher reverse time results lower deposition of the zinc.

At 1200 rpm:

1200	20	5	118.239
1200	20	10	302.693

The hardness increases with an increase in reverse time at high speed and lower forward time. The maximum hardness is observed at higher speed due to more plastic deformation between tool and pipe. More plastic deformation happens due to higher speed.

1200	30	5	50.135
1200	30	10	99.650

The hardness increases with an increase in reverse time at high speed of the pipe and higher forward time but there is a difference in hardness at lower forward time and higher forward time.

1200	20	5	118.239
1200	30	5	50.135

The hardness is decreases with an increase in forward time at the condition of higher pipe speed and at lower reverse time. The hardness is higher due to lower forward time results higher friction generated between tool and pipe then the more deposition of the zinc sticks with internal surface of the pipe.

1200	20	10	302.693
1200	30	10	99.650

The hardness is decreases with an increase in forward time at the condition of higher pipe speed and at higher reverse time. The hardness is higher due to lower forward time results higher friction generated between tool and pipe due to more deposition of the zinc stick with internal surface of the pipe.

At 1000 &1200 rpm:

1000	20	5	56.515
1200	20	5	118.239

The hardness of the internal surface of the pipe varies with the speed of the pipe at the constant forward time and reverse time. This happens due to higher speed and at lower forward and reverse time results higher friction leads to more deposition.

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1000	20	10	52.551
1200	20	10	302.693

The hardness of the internal surface of the pipe varies with the speed of the pipe at the constant forward time and reverse time. This happens due to higher speed and at lower forward and higher reverse time results to high friction leads to higher deposition.

1000	30	5	106.521
1200	30	5	50.135

The hardness of the internal surface of the pipe varies with the speed of the pipe at the constant forward time and reverse time. These happen due to lower speed and at higher forward and lower reverse time results higher friction leads to more deposition.

1000	30	10	42.872
1200	30	10	99.650

The hardness of the internal surface of the pipe varies with the speed of the pipe at the constant forward time and reverse time. This happens due to higher speed and at higher forward and reverse time results higher friction leads to more deposition. This trend is different from at lower reverse time.

4.1 Coating thickness

The coating is developed due to friction technique during rotation of the tool inside the aluminum pipe. The thickness of the coating is varied with different parameters used in the process as shown in table 4.2.
Table 4.2: Coating thickness varies with the parameters

Sample No.	Parameters			Coating thickness, mm
	Speed in rpm	forward time in min	Reverse time in min	
1	1000	20	5	0.0292
2	1000	20	10	0.0940
3	1000	30	5	0.0430
4	1000	30	10	0.0412
5	1200	20	5	0.0702
6	1200	20	10	0.1054
7	1200	30	5	0.1995
8	1200	30	10	0.0640

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<u>At 1000rpm:</u>

1000	20	5	0.0292
1000	20	10	0.0940

At the lower speed and lower forward time, the coating thickness is increases with an increasing reverse time due to more deposition of zinc in reverse time as shown in Fig. 4.1 and Fig. 4.2.

Fig. 4.1: Sample 1

Fig. 4.2: Sample 2

1000	30	5	0.0430
1000	30	10	0.0412

The lower speed and higher forward time, the coating thickness is approximately equal but a slightly difference with respect to reverse time. The higher forward time and lower reverse time results higher coating thickness due to higher amount of zinc is deposited inside the internal surface of the aluminum pipe.

Fig. 4.3: Sample 3

Fig. 4.4: Sample 4

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1000	20	5	0.0292
1000	30	5	0.0430

The coating thickness is increases with an increase in forward time at low speed and low reverse time. The coating thickness is higher at higher forward time and lower reverse time due to more amount of zinc deposition due to more axial compressive forces.

Fig. 4.5: Sample 5 Fig. 4.6: Sample 6

1000	20	10	0.0940
1000	30	10	0.0412

The coating thickness is decreases with an increase in forward time at higher reverse time and low speed due to higher reverse time results lower deposition of the zinc.

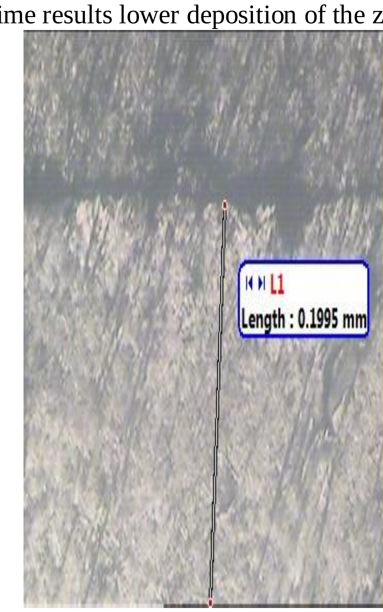

Fig. 4.7: Sample 7 Fig. 4.8: Sample 8

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At 1200 rpm:

1200	20	5	0.0702
1200	20	10	0.1054

The coating thickness increases with an increase in reverse time at high speed and lower forward time. The maximum thickness is observed at higher speed due to more plastic deformation between tool and pipe. More plastic deformation happens due to higher speed.

1200	30	5	0.1995
1200	30	10	0.0640

The coating thickness decreases with an increase in reverse time at high speed of the pipe and higher forward time but there is a difference in hardness at lower forward time and higher forward time.

1200	20	5	0.0702
1200	30	5	0.1995

The coating thickness is increases with an increase in forward time at the condition of higher pipe speed and at lower reverse time due to higher plastic deformation which results coarse grain structure.

1200	20	10	0.1054
1200	30	10	0.0640

The coating thickness is decreases with an increase in forward time at the condition of higher pipe speed and at higher reverse time. The coating thickness is higher due to lower forward time results higher friction generated between tool and pipe due to more deposition of the zinc stick with internal surface of the pipe.

At 1000 &1200 rpm:

1000	20	5	0.0292
1200	20	5	0.0702

The coating thickness of the internal surface of the pipe varies with the speed of the pipe at the constant forward time and reverse time. This happens due to higher speed and at lower forward and reverse time results higher friction leads to more deposition.

1000	20	10	0.0940
1200	20	10	0.1054

The coating thickness of the internal surface of the pipe varies with the speed of the pipe at the constant forward time and reverse time. This happens due to higher speed and at lower forward and higher reverse time results to high friction leads to higher deposition.

1000	30	5	0.0430
1200	30	5	0.1995

The coating thickness of the internal surface of the pipe varies with the speed of the pipe at the constant forward time and reverse time. This happens due to lower speed and at higher forward and lower reverses time results higher friction leads to more deposition.

1000	30	10	0.0412
1200	30	10	0.0640

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The coating thickness of the internal surface of the pipe varies with the speed of the pipe at the constant forward time and reverse time. This happens due to higher speed and at higher forward and reverse time results higher friction leads to more deposition. The similar trend is observed even at lower reverse time also.

Corrosion

White Rust Observed inside the Tube at 12Hours and further intensifies at 24Hours. No damage is observed to the Base Material. The sample 1 and 2 are shown in Fig. 4.9 and Fig.4.10 that the intensity of corrosion increases if the sample kept in chemical for 24 hours.

Fig. 4.9: Coated sample after corrosion test during 24 Hrs Fig. 4.10: Base metal after corrosion test during 24 Hrsl

V. CONCLUSION

- At the lower speed and lower forward time, the hardness is approximately equal but a slightly difference in hardness.
- The hardness increases with an increase in reverse time at high speed of the pipe and higher forward time but there is a difference in hardness at lower forward time and higher forward time.
- The hardness of the internal surface of the pipe varies with the speed of the pipe at the constant forward time and reverse time. This happens due to lower speed and at higher forward and lower reverse time results higher friction leads to more deposition.
- The coating thickness is increases with an increase in forward time at low speed and low reverse time. The coating thickness is higher at higher forward time and lower reverse time due to more amount of zinc deposition due to more axial compressive forces.
- The coating thickness is increases with an increase in forward time at the condition of higher pipe speed and at lower reverse time due to higher plastic deformation which results coarse grain structure.
- The coating thickness of the internal surface of the pipe varies with the speed of the pipe at the constant forward time and reverse time. This happens due to lower speed and at higher forward and lower reverse time results higher friction leads to more deposition.

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