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INVESTIGATION OF FRICTION SURFACED PROPERTIES OF AA7075 BY AA6061

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Abstract- Industries are facing problems of corrosion and wear of mechanical components. This problem was reduced by using Friction Surfacing process is most relevant to the Surface Engineering due to changing of surface properties of required Substrate surfaces in Solid State.Friction Surfacing is referred as a Solid State Technology with increasing surface properties of materials. Different types of material combinations have been coated one on another by using Friction Surfacing process. In this process mainly used materials are Aluminum alloys, Magnesium alloys, Titanium alloys, Steels, Copper, Zinc, Chromium, Nickel, and some other materials. This coated materials are exhibit superior wear resistance and corrosion resistance properties. In Friction Surfacing process Heat Affect Zone is less on comparing with fusion based methods. Because the maximum achieved temperature in Friction Surfacing process is below melting temperature and above recrystallization temperature of the materials which are used in this process. And Solidification Shrinkage of materials does not occur due to absence of melting. So Friction Surfacing process is used in many industries like Aerospace, Automotives, Electronics, Petrochemical, Shipbuilding and other manufacturing industries. In this journal paper Friction Surfaced on AA7075 alloy by AA6061 alloy which is used as Mechtrode and AA7075 alloy is used as Substrate material. Coating thickness and width are based on the some Process Parameters. They are Rotational Speed, Traverse Speed, Axial Force, Material properties, Diameter of Mechtrode. In this paper investigate the effect of Process Parameters on coating thickness, width and some other mechanical properties by changing Rotational Speed, Traverse Speed and maintain Axial Force is constant during whole experiment.

Key words: Friction Surfacing, Rotational Speed, Traverse Speed, Mechtrode, Substrate, Material Properties, Deposit

1. INTRODUCTION

Friction Surfacing, Friction Stir welding are related to Friction Welding process. In both Friction Surfacing and Friction Stir Welding the processing temperature is generating by the friction. This friction rises due to contact surfaces of Substrate and tool which is rotated under pressure. Friction Stir welding process is used for joining of materials. But Friction Surfacing process is used for producing coatings on different materials which increases wear resistant, corrosion resistant properties of materials [1]. Friction surfacing process is also used for repair of worn or damaged material surfaces through Building Up or Crack Sealing [2]. In friction based processes must need hard tools for machining operations such as tool Steels, Co –basis alloys. But in Friction Surfacing process may not need hard tools for producing coatings. This process has less environmental impact because not formed any fumes and poisonous gases during machining operations. The energy efficiency of this process is better due to generating of heat is as needed for coating on materials. In this process coating on materials was guided by Process Parameters they are Axial Force, Rotational Speed, and Traverse Speed [3]. Our work is concentrated on Rotational Speed along with Traverse Speed and Axial Force is maintained at constant load during whole experiment. Coating width and thickness are varied by changing this Process Parameters and also some material properties of coated material.

1.1 Principle and Explanation of Friction Surfacing Process

Materials are coated with same materials or different materials by using Friction Surfacing process. Mainly materials are coated with different materials for increasing wear resistance and corrosion resistance properties. This process is a Solid State coating process which is depending on the plastic deformation of consumable rod [4]. In this process consumable rod called as Mechtrode which is rotated at high speed and pressed against the Substrate under the applied Axial Force as shown in figure Fig. 1. Friction is formed when consumable rod is contact with the Substrate. This friction is generating required heat for depositing rod material on the Substrate. Viscoplastic boundary layer is formed at rod tip due to that frictional heat. This viscoplastic material is depositing on the Substrate when Substrate is moved in horizontal direction with Traverse Speed. This frictional heat does not affect the base material micro structures. So Heat Affect Zone (Fig. 1) is less in Friction Surfacing process. So degradation of material properties was avoided [5]. Third body region concept was explained [6] as in that region low flow stress and temperatures above the recrystallization temperature and below melting temperature of the material. So absence of dilution and lower residual stress levels due to absence of melting. So solidification shrinkage does not occur [7]. Highly plasticized material (Fig. 1) which is formed by frictional heat is pressed against the Substrate at rod tip

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without lateral restraint and flowing outside the rod diameter region. So causes the development of revolving flash and lack of bonding at the coating edges on both the advancing and retreating sides [8] (When the direction of rotation and travel moments are same then called as advancing side and when the direction of rotation and travel moments are opposite then called as retreating side[9]. (Fig. 6b)) So in Friction Surfacing process fully bonded width of deposits is less than the diameter of consumable rod [1].

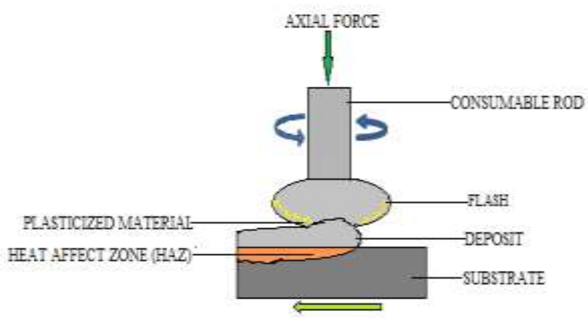

Fig. 1.1 Schematic Explanation of Friction Surfacing

1.2 Material Selection

Service life of mechanical components is based on mechanical properties of materials [10]. Aluminum and its alloys are widely used in different fields after the steels position because they have good physical and mechanical properties [11], and also some other properties like high thermal conductivity high corrosion resistance high electrical conductivity. They have non toxic in nature. The materials which have high strength to weight ration then that materials are used in many industrial applications. AA6061 and AA7075 alloys have good strength to weight ratio. Hence these alloys are used in Aircraft and Aerospace components, Automotives, Break components, Bicycle frames, Valves, Chemical equipments Structural applications, Coupling, etc., AA6061 alloy was low cost on comparing with AA7075 alloy because AA7075 alloy has high strength to weight ration than AA6061 alloy. AA6061 was good Formability, Corrosion Resistance, Weldability and Solderability [12]. So AA6061 (Fig. 2a) has taken as consumable rod and 7075 (Fig. 2b) as substrate in this experiment.

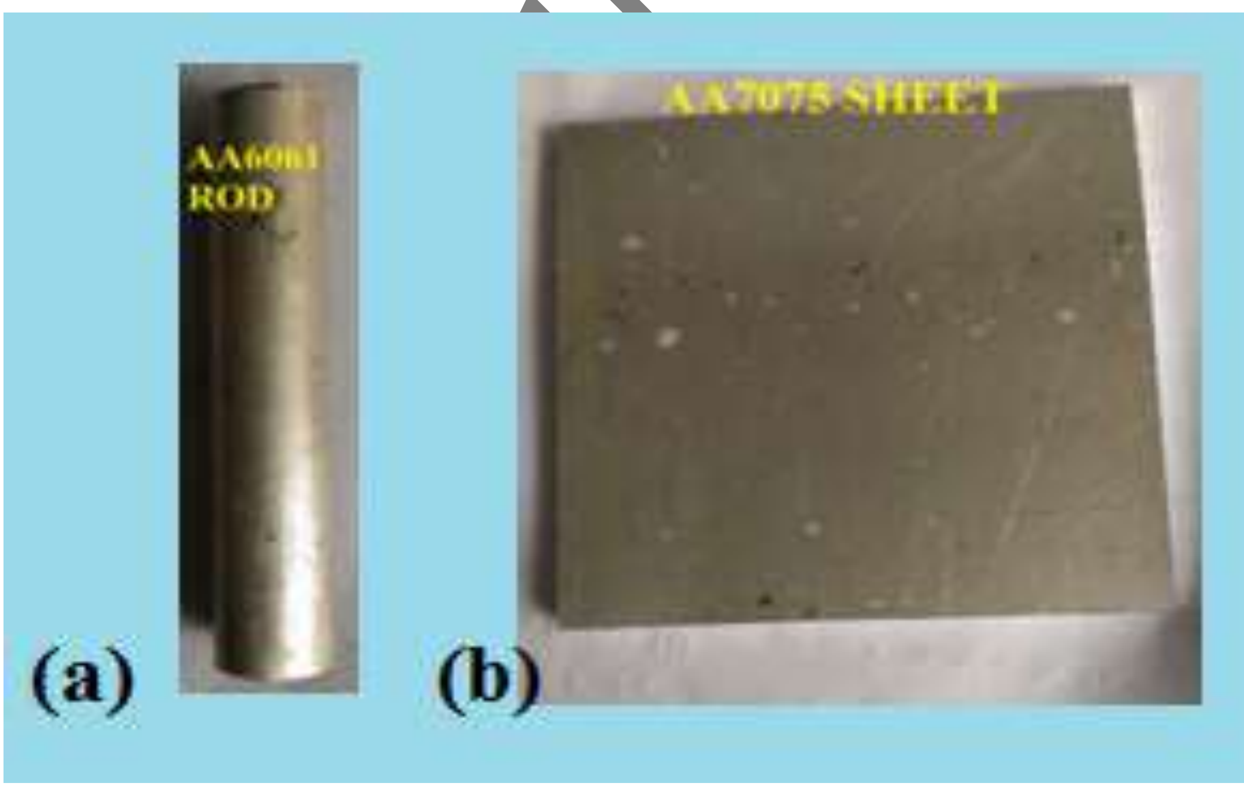

Fig. 1.2 (a) AA6061 rod and (b) AA7075 sheet

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1.3 Material Specification

Specimens used are AA6061 alloy in the form of rod of diameter 20mm length 100mm (Fig. 1.3a) and AA7075 alloy in the form of sheet of thickness 5mm width 100mm length 100mm (Fig. 1.3b). The chemical composition and mechanical properties of the materials are as shown in below tables.

Table-1.1: Chemical Composition of AA6061

ELEMENTS	WEIGHT %
ALUMINUM (Al)	95.9-98.6
MAGNESIUM (Mg)	0.8-1.2
SILICON (Si)	0.4-0.8
IRON (Fe)	0-0.7
COPPER (Cu)	0.15-0.4
CHROMIUM (Cr)	0.040-0.35
ZINC (Zn)	0-0.25
MANGANESE (Mn)	0-0.15
RESIDUALS	0-0.15
TITANIUM (Ti)	0-0.15

Table-1.2 Chemical Composition of AA7075

ELEMENTS	WEIGHT %
ALUMINUM (Al)	86.9-91.4
MAGNESIUM (Mg)	2.1-2.9
SILICON (Si)	0-0.4
IRON (Fe)	0-0.5
COPPER (Cu)	1.2-2.0
CHROMIUM (Cr)	0.18-0.28
ZINC (Zn)	5.1-6.1
MANGANESE (Mn)	0-0.3
RESIDUALS	0-0.15
TITANIUM (Ti)	0-0.2
ZIRCONIUM (Zr)	0-0.25

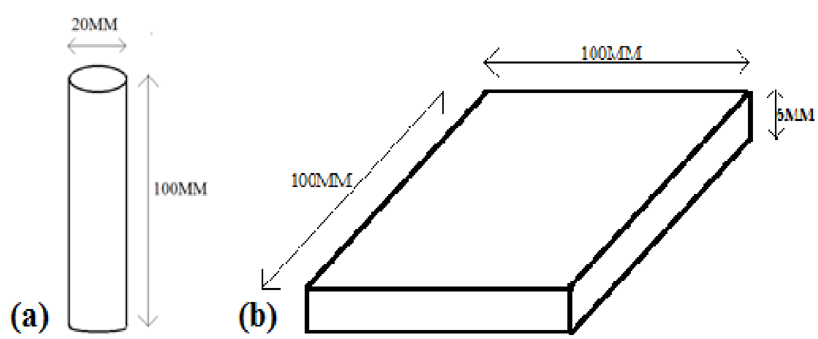

Fig. 1.3 Dimensions of (a) Consumable Rod and (b) Substrate

Table-1.3Material Properties of AA6061 and AA7075

PROPERTIES	AA6061	AA7075
DENSITY (g/cm^3)	2.7	3.1
MELTING POINT (^{0}C)	580	480
MODULUS OF ELASTICITY (GPa)	69	72
POISSON'S RATIO	0.33	0.32
ULTIMATE TENSILE STRENGTH (MPa)	130	540
YIELD STRENGTH (MPa)	77	450
ELONGATION (%)	19	6.2
HARDNESS (BHN)	30	150
STRENGTH TO WEIGHT RATIO (KN-m/kg)	48	170
THERMAL CONDUCTIVITY (W/m-K)	170	130

2. EXPERIMENTAL SETUP

Friction surfacing experiment was carried out on HMT FN 2V Milling Machine (Fig. 2.2a). AA6061 alloy rod was fixed in the tool holder and AA7075 alloy sheet was fixed tightly on work bench of that milling machine as shown in Fig. 2.2b. Consumable rod is rotated at high speed with the help of tool holder when electrical power was supplied to milling machine. The consumable rod was moved closer to the Substrate then deposition of material starts when the rod and Substrate surfaces are in contact and pressed against the substrate as shown in Fig. 2.2c.Then Substrate was moved in horizontal direction. Coating was obtained as shown in Fig. 2.1. Applied Axial Force on the rod is 5KN during the total experiment and changing the vales of Rotational Speed of rod and Traverse Speed of Substrate are as shown in Table 2.1. Then the coated samples were tested for determining the material properties.

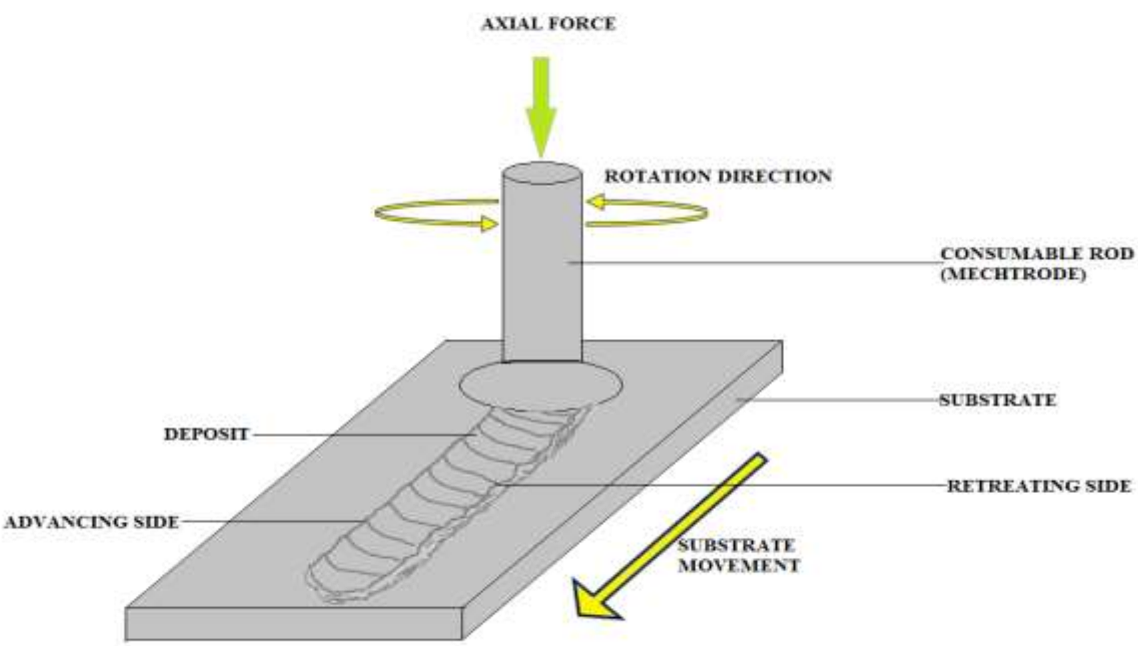

Fig. 2.1 Principle of Friction Surfacing Process

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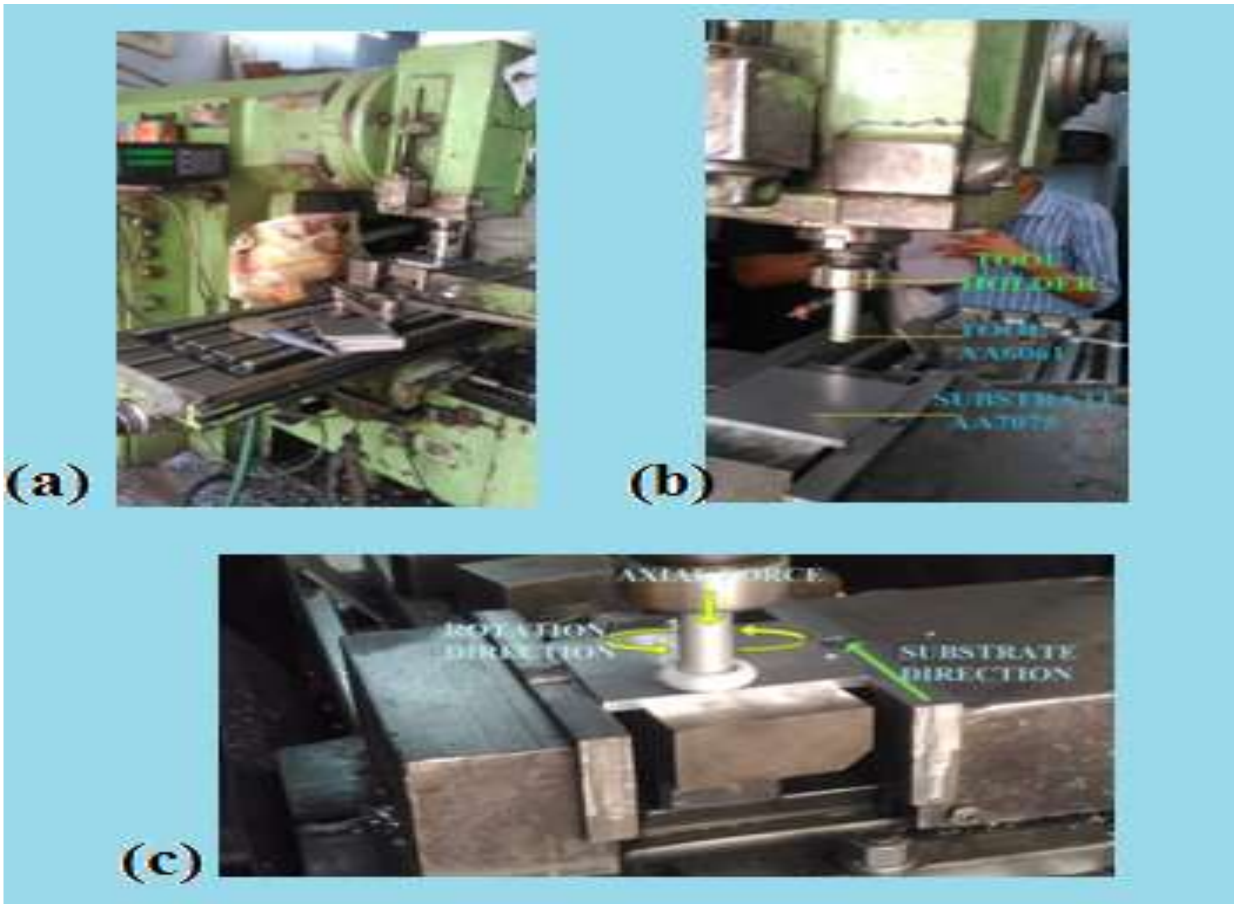

Fig. 2.2 (a) HMT FN 2V Milling Machine (b) Arrangement of Rod and Substrate and (c) During Coating Process

Table-2.1 Range of Process Parameters

SERIAL NUMBER	ROTATION SPEED (in rpm)	TRAVERSE SPEED (in mm/min)
1	560	250
2	710	500
3	900	250
4	1120	400
5	1400	600
6	1800	800

3. RESULTS AND DECISION

3.1 Influence of Process Parameters

Coating width was increased with increasing of Rotational Speed of rod and Traverse Speed of Substrate (Fig. 3.3) but coating thickness was decreased. The quality of coating is better at higher Rotational Speeds of rod than at lower speeds due to regular deposition of rod material on the Substrate. Coating thickness was decreased with increasing of Traverse speed and Rotational speed (Fig. 3.2) due to controlling of plasticized material deposition. These coated substrates are as shown in Fig. 3.1a. The obtained coating thickness and width values are as shown in Table 3.1. Uniform coating was formed at advancing side and non-uniform coating was formed at retreating side (Fig. 3.1b).

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Fig. 3.1 (a) Friction Surfaced (Coated) Materials and (b) Advancing and Retreating Side

Table-3.1 Coating Thickness and Width

SAMPLE NUMBER	THICKNESS	WIDTH
1	3.68	20.88
2	3.45	21.30
3	3.36	21.42
4	3.14	21.76
5	2.85	22.12
6	2.52	23.24

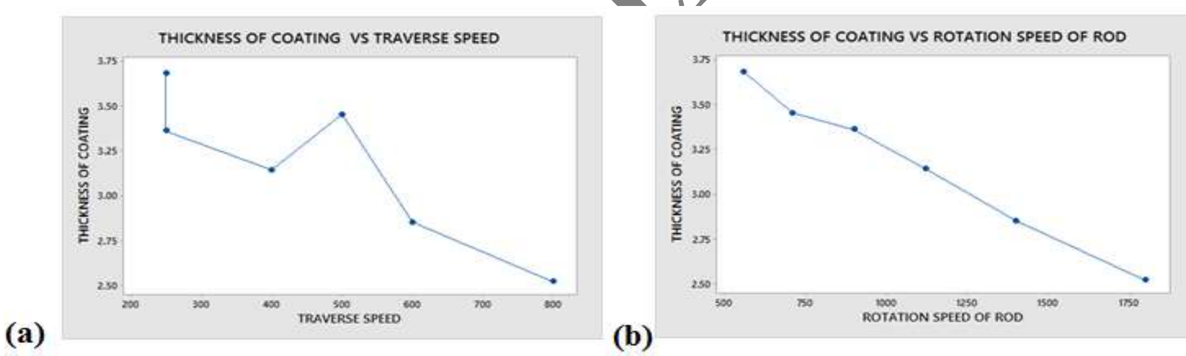

Fig. 3.2 (a) Thickness Vs Traverse Speed (b) Thickness Vs Rotation Speed

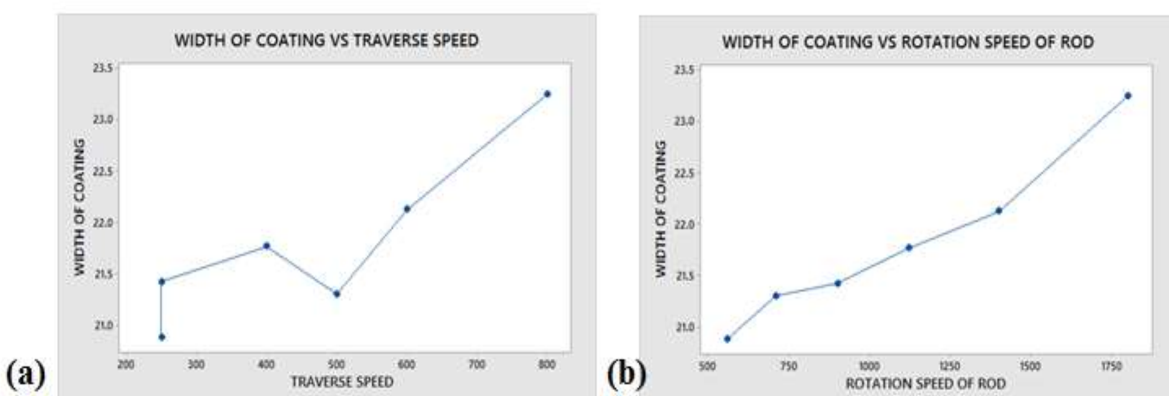

Fig. 3.3 (a) Width Vs Traverse Speed (b)Width Vs Rotation Speed

3.1.1 Corrosion Test

Several modified Salt Spray tests are used for determining the corrosion resistance of material. ASTM B117 test standard was used for check the corrosion resistance of samples. This test was conducted in closed Salt Spray chamber where samples were fixed in sample holder. Salt solution is a mixture of 5% NaCl (AR Grade) and DM (DeMinaralized) water and ph value is 7.1. This salt solution was sprayed on the samples by using pressurized air inside the closed chamber. And maintain pressure at 1atm and temperature at 35^0c during the experiment. Then corrosion environment was formed on the samples. Duration of test is depending on the corrosion resistance of the materials. So the materials which have higher corrosion resistance then taken much time for testing. On observing twelve hours' time period no rust was formed on the coated samples.

3.1.2 Tensile Test

Tensile strength of coated material samples can be determined by using tensile test. This test was conducted on Universal Testing Machine. The values of Ultimate Tensile Strength, Elongation and Yield Stress of coated materials are observed from the tensile test. These values are as shown in Table 3.2. From the Fig. 3.4a and Fig. 3.5a Ultimate Tensile Strength values of coated material are varied with transverse speed and rotation speed. Elongation of coated materials is increasing with increasing of Traverse speed and Rotation speed as shown in Fig. 3.4b and 3.5b. The maximum tensile strength is 470.33 N/mm^2 obtained at 1800rpm and 800mm/min. This tensile strength is 87.18% lower than the Substrate material. Maximum elongation value of coated material is 12% higher than the Substrate elongation value.

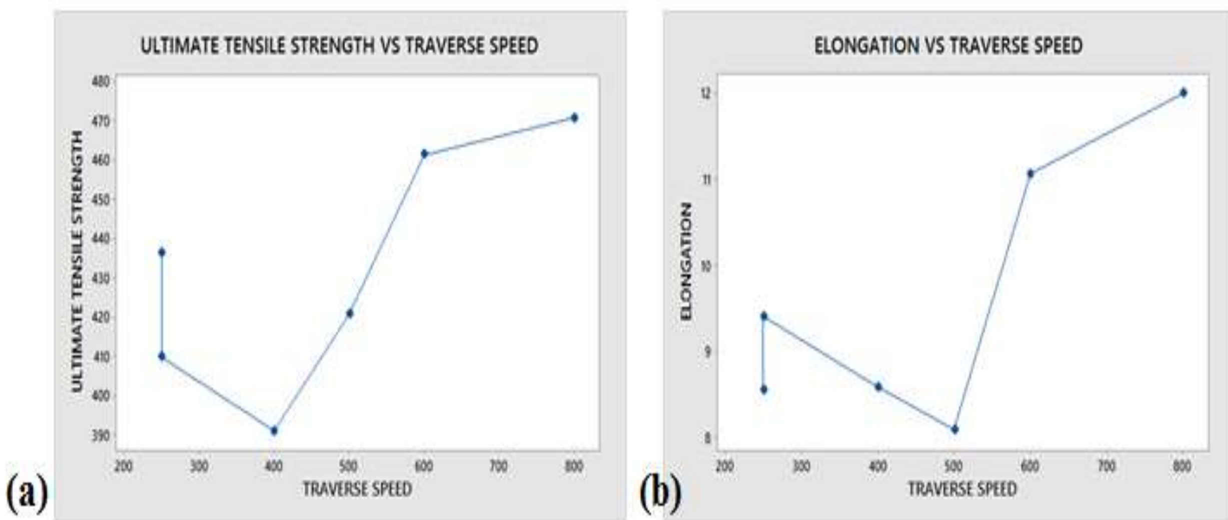

Fig. 3.4 (a) Ultimate Tensile Strength Vs Traverse Speed and (b) Elongation Vs Traverse Speed

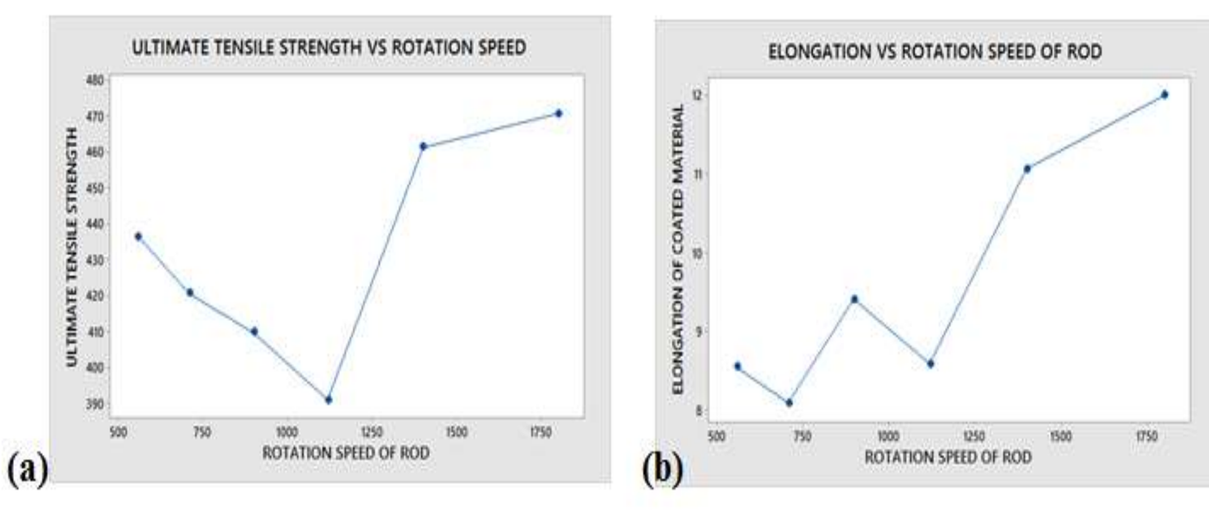

Fig. 3.5 (a) Ultimate Tensile Strength Vs Rotation Speed and (b) Elongation Vs Rotation Speed

Table-3.2 Values of Various Output Parameters Obtained from Tensile Test

SAMPLE NUMBER	ROTATION SPEED (rpm)	TRAVERSE SPEED (mm/min)	ULTIMATE LOAD (KN)	ULTIMATE TENSILE STRENGTH (N/mm^2)	ELONGATION (%)	YIELD LOAD (KN)	YIELD STRESS (N/mm^2)
1	560	250	49.880	436.472	8.540	39.440	345.117
2	710	500	48.920	420.709	8.080	36.320	312.350
3	900	250	48.840	409.835	9.400	39.240	329.278
4	1120	400	45.640	390.854	8.580	30.520	261.369
5	1400	600	54.560	461.434	11.060	35.880	303.451
6	1800	800	56.960	470.783	12.000	37.000	305.810

3.1.3Bend Test

Strength or ductility of coated materials is determined by using Bend test. This test was conducted on Universal Testing Machine. Coated material is fixed by the help of two supporting blocks. Then load was applied on the sample and increased that load gradually till the breakage of sample occurs. Applied load was decreased with increasing of Traverse speed and Rotation speed (Fig. 3.6). The bend test values of coated materials are as shown in Table 3.3.

Table-3.3 Bend Test Results

SAMPLE NUMBER	APPLIED LOAD (KN)	MANDREL SIZE (mm)
1	4.54	10
2	4.84	10
3	4.76	10
4	4.36	10
5	4.36	10
6	3.20	10

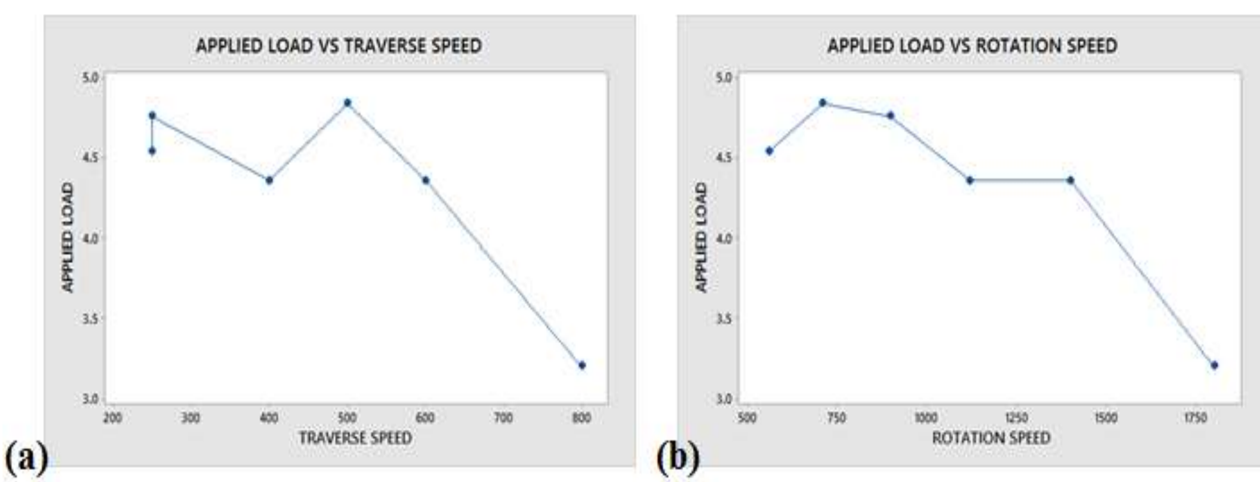

Fig. 3.6 (a) Applied Load Vs Traverse Speed and (b) Applied Load Vs Rotation Speed

3.1.4 Vickers Hardness Test

Vickers hardness test was operated easily than other hardness tests and independent of size of the indenter. This test was conducted on the Vickers Hardness testing machine. Applied load on the sample is 5kg. Hardness of coated materials is increasing with increasing of Traverse Speed of rod and Rotation Speed of Substrate as shown in Fig. 3.7. Hardness values of coated materials are shown in Table 3.4. Highest hardness value is 73.23 HV obtained at 1800 rpm and 800mm/min. This hardness value is higher than rod material.

Table-3.4 Hardness Values of Samples After Friction Surfacing

SAMPLE NUMBER	HARDNESS (HV)
1	65.97
2	71.20
3	70.40
4	68.97
5	71.07
6	73.23

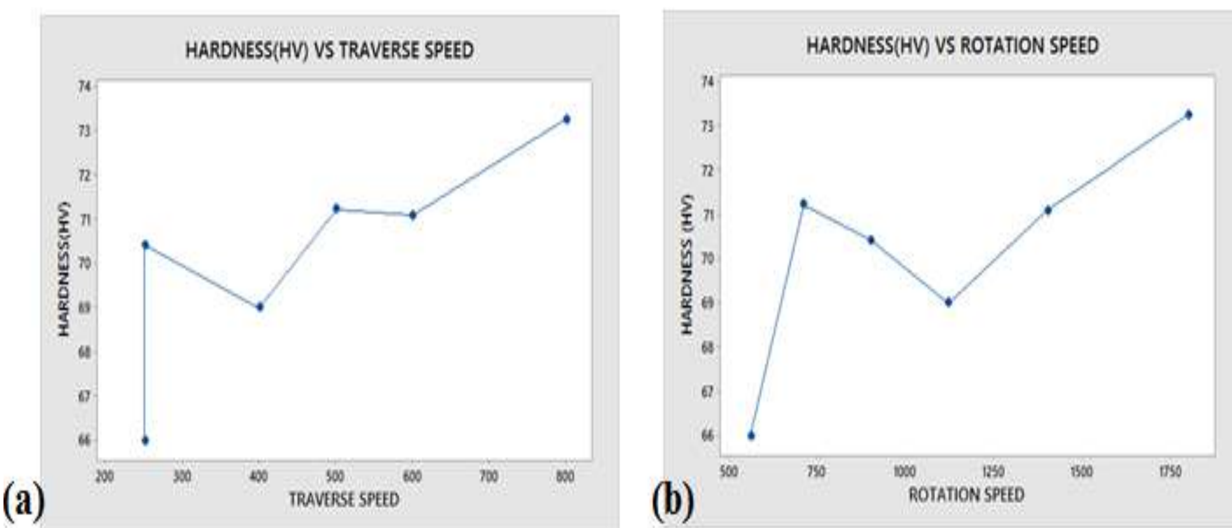

Fig. 3.7 (a) Hardness Vs Traverse Speed (b) Hardness Vs Rotation Speed

CONCLUSIONS

- Successfully deposited AA6061 alloy over AA7075 by using Friction Surfacing process. Better quality coatings are obtained at 740rpm & 500mm/min ,
  - 1400rpm & 600mm/min,
  - 1800rpm & 800mm/min.
- Coating thickness and width are changing with changing the Rotational Speed and Traverse Speed.
- Maximum Tensile strength (470.783 N/mm^2), maximum Elongation (12%), maximum hardness (73.23 HV) values are obtained at higher rotation speed and Traverse Speed.
- Corrosion resistance of coated materials is good observed from Salt Spray test of duration 12hrs.

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