ORIGINAL ARTICLE

Metal Coating by TIG Arc Deposition Method

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ABSTRACT – Metal (Aluminum) coating was prepared on stainless steel substrate by arc deposition method using TIG Welding machine. Plasma spray is a type of metal coating that is widely used in the industry and its preparation cost is expensive. It is also the most flexible method to apply a wide variety of coatings on a substrate. To reduce the cost of the set-up, the plasma will be generated by using a TIG welding machine to replace the plasma spray. The use of powder which is aluminium as a coating raw material causes almost no restrictions on the use of coating materials used in the plasma melting process. The changing parameters in this experiment are the angle nozzle powder and the flow rate of the working gas which is Argon (Ar) gas and the substrate used is SUS304 stainless steel and the feedstock powder used is Aluminium (Al) powder with an average size of 5 μm. Flow rate used in this study was 10,20 and 30 l/min of Ar and the powder nozzle spray angle was 45°, The live image, diameter, thickness, and surface roughness of the coatings were systematically analyzed using LEXT OLS5000 3D Measuring Laser Microscope .

INTRODUCTION

Metal can be coated with a number of coatings, and the type of coating used is determined by the final use of the metal product. Metal can be coated with a variety of coatings, with the type of coating chosen based on the eventual purpose of the metal product. Metal coatings are applied to metal surfaces to protect them from rust, corrosion, dirt, and debris. This is critical for outdoor applications such as boats, heavy machinery, vehicles, trains, and aeroplanes. All of these products are exposed to a range of potentially dangerous chemicals in the workplace, such as fuel, oil, lubricants, and dirt. Metal coatings are protective coatings that are put to metal to prevent wear and tear. Due to environmental exposure and unprotected metal will rust and corrode. An extra layer of protection is supplied by coating the metal.

TIG torches are used to heat the material that has to be heated. Its purpose is similar to that of a heating torch. Aside from that, it is made up of a collet (sleeve to hold the tungsten), a collet body (to retain the collet), tungsten, and a ceramic cup. The tungsten conducts the current, resulting in an arc. Shielding gas flows out of the ceramic cup and surrounds the weld pool through orifices in the collet.

For this project, plasma will be created using TIG welding equipment since it has a lower temperature than other plasmas. The gas working flow rate and powder nozzle angle will be the variables that change in this experiment. Holders will be utilized to check that the head and head are working correctly to generate a good coating.

Coating

A coating is a layer of material applied to the surface of an object, commonly called a substrate. Functional coatings can be used to modify the surface qualities of a substrate, such as adhesion, wettability, corrosion resistance, or wear resistance (Howarth G.A,1997). Service environment, life expectancy, substrate material compatibility, component shape and size, and cost are all factors to consider when selecting a coating. The coatings are fabricated by involving the following mechanisms, which is started by heating and accelerating the spray particle inside the plasma plume, then the melted particles are impinged onto the surface of the substrates, and finally flattened particles are then rapidly solidified to form the coatings (Redza, 2012.). There are a variety of coating technologies available for depositing a wide range of materials at thicknesses ranging from a few microns to several centimetres. Coatings are categorised in a number of ways. One typical technique is based on how the coating material is applied to the surface of the substrate. These include atomic deposition, particle deposition and bulk coating or cladding.

Metal Coating

Metal coating is important in a variety of industrial areas since it protects the surfaces of many of the items we buy. It is used to create a layer that alters the surface qualities of the workpiece to match the metal being applied. The workpiece is transformed into a composite material with qualities that neither material alone can accomplish. The coatings create a long-lasting, corrosion-resistant layer, while the core material bears the strain. The deposition of metal coatings such as nickel, chromium, cadmium, and copper are often deposited using wet chemical methods, which have inherent pollution control issues.

Plasma Spray

In plasma spraying, powders are injected into a direct current plasma jet where they are melted and accelerated, and then the stream of molten particles is directed onto a substrate where they spread and solidify to create a coating. Plasma spraying show in Figure 2-1 has two type of methods Atmospheric plasma spraying (APS) which is carried out in the atmosphere, and Vacuum Plasma Spray (VPS), carried out in the vacuum (Swain et al., 2018). The plasma jet is generated by creating a DC (direct current) arc between the electrode (cathode) and nozzle (anode) and partially or fully ionizing the plasma gas. Plasma spray are probably a flexible method for all expanded spraying processes that are sufficiently energy to dilute any material. (Sagar Amin, 2016). The use of powder as a coating raw material causes almost no restrictions on the use of coating materials used in the plasma melting process.
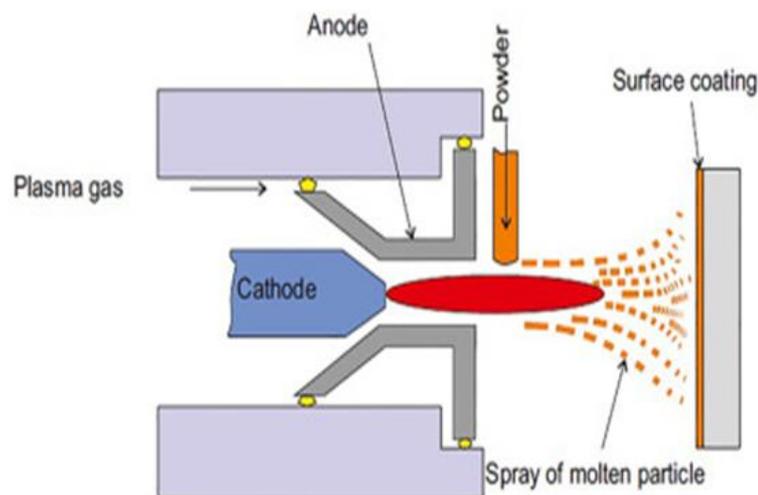

Figure1. Plasma Spraying Diagram

Source:Devasia et al., 2021

Tungsten Inert Gas (TIG) Welding

Tungsten inert gas (TIG) welding, commonly referred to as Gas Tungsten Arc Welding (GTAW), is an arc welding process that produces welds with a non-melting tungsten electrode. During the TIG welding process, an arc is formed between the non-melting tungsten electrode and the workpiece to be joined. The arc generated produces intense heat that melts the two metal parts and, through the use of filler metal, fuses them together to form a strong weld. The resulting weld has similar properties to the base metal. To protect the weld from atmospheric contamination, a shielding gas environment is used. Most commonly, TIG is used to weld thin sections of stainless steel, magnesium, aluminium, and copper alloys. The main equipment used in the TIG welding process is a welding torch, a non-melting tungsten electrode, a constant current welding power supply, and a gas source (helium or argon). In this project, the TIG welding process is used to develop a coating process because it is low-cost initial equipment.
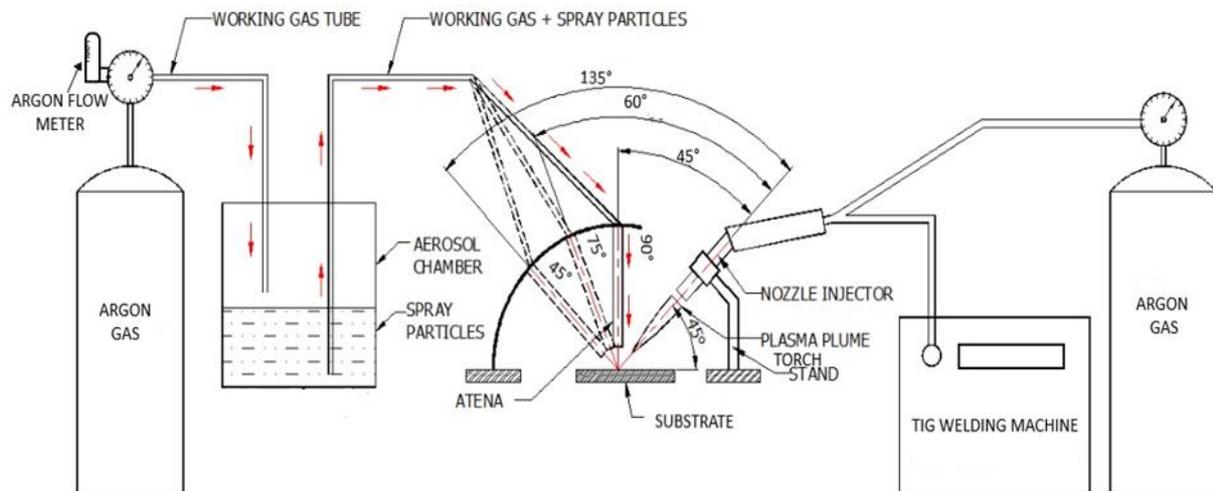
METHODOLOGY

Process Design

Figure 2: Schematic Representation of TIG Welding Machine with Plasma Arc Deposition

For the experiment set-up, the device used is the plasma arc deposition by TIG Welding instrument as shown in the Figure 2. This method makes use of a working gas, spray powder, nozzle, plasma plume, and TIG welding equipment. The system will be modified so that the angle of the nozzle from the TIG Plume and holder will 45°,60° and 135°. For the angle from the substrate is 45°, 75°, and 90°, and the gas working powder flow rate will be 10, 20, and 30(l/min). The distance between the nozzle and the substrate is 10mm, and the detailed parameters for the tests are shown in Table 1. Ar gas is utilised in studies because it is inexpensive to use as a working gas. It is heavier than air and has the following properties: thermal conductivity, heat transmission characteristics, relative air density, and ease of ionisation. As previously stated, aluminium powder will be used as the feedstock powder. The working gas, argon gas, travels via the tube to the aerosol chamber in this approach. The aerosolization process will next take place in the aerosol chamber. The working gas and spray particle will be transfer through the nozzle to be deposited onto a substrate. The TIG machine generate plasma and heat the particle until it melts.
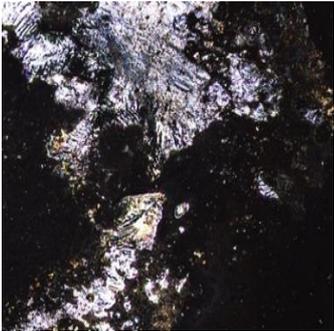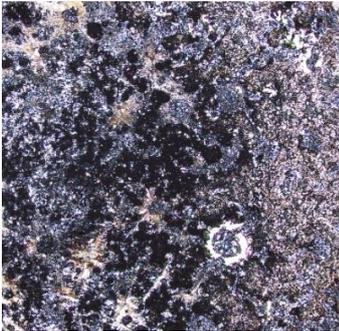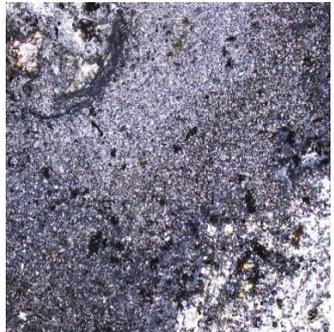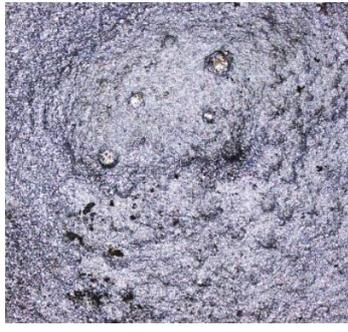
Table 1. Parameter of the Experiment

Parameter	Specification
Working Gas	Ar
Gas Flowrate (l/min)	10,20,30
Nozzle Angle (°)	45,75,90
Spray Distance (mm)	10
Nozzle Inner Diameter(mm)	3
Spray Powder	Al
TIG Welding Current (A)	120
Spray Time(s)	6

RESULT AND DISCUSSION

LEXT OLS5000 3D Measuring Laser Microscope that were used to analyse the coating on the surface substrate. There are two applications use to analyse the data of the sample coating which is data acquisition and analysis application .The three parameter measured were microstructure, diameter and surface roughness of coating by deposition method. From the data acquisition application there is three live image observation which is color image, laser confocal image and map image.

Table 2. Observation of the live Image Aluminium Coatings

Nozzle Spray Angle	Ar Gas Flow Rates		
	10 l/min	20 l/min	30 l/min
45°			
75°			
90°			
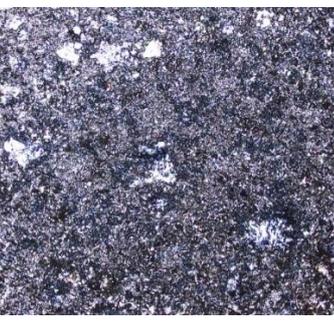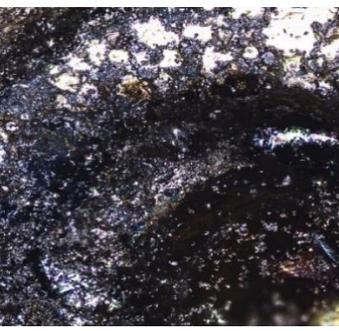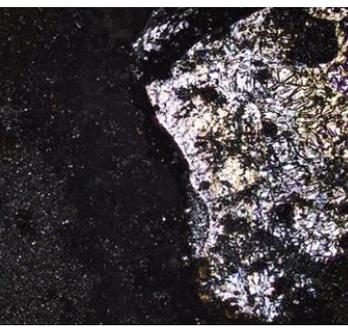
Measurement of Coating Diameter on Substrate

Table 3. Data taken for Coating Diameter on Substrate

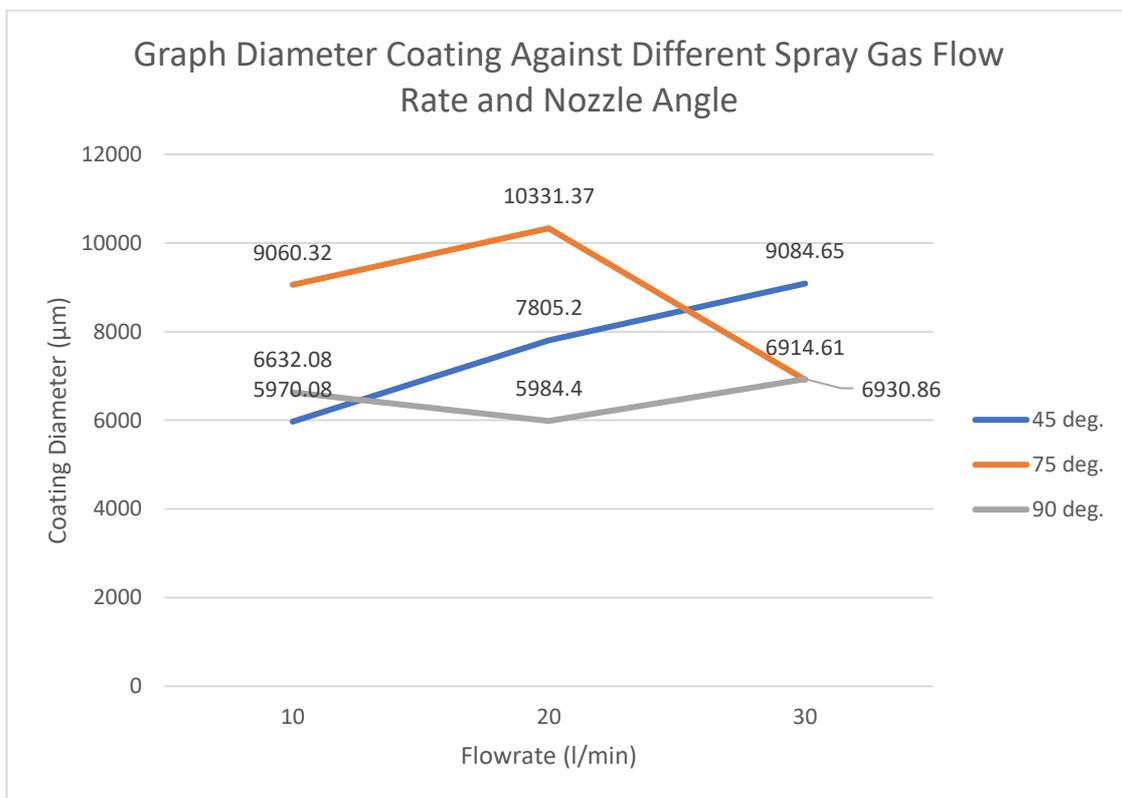| Angle of Injector Powder Nozzle	Flowrate Spray Powder(L/min)	Spraying Distance (mm)	Diameter of Coating (μm)
45°	10	10	5970.08
	20	10	7805.20
	30	10	9084.65
75°	10	10	9060.32
	20	10	10331.37
	30	10	6914.61
90°	10	10	6632.08
	20	10	5984.4
	30	10	6930.86

Figure 3. Coating Diameter Against Different Flow Rate Spray Gas and Nozzle Angle

Measurement of Coating Thickness on Substrate

Table 4. Data taken for Coating Thickness on Substrate

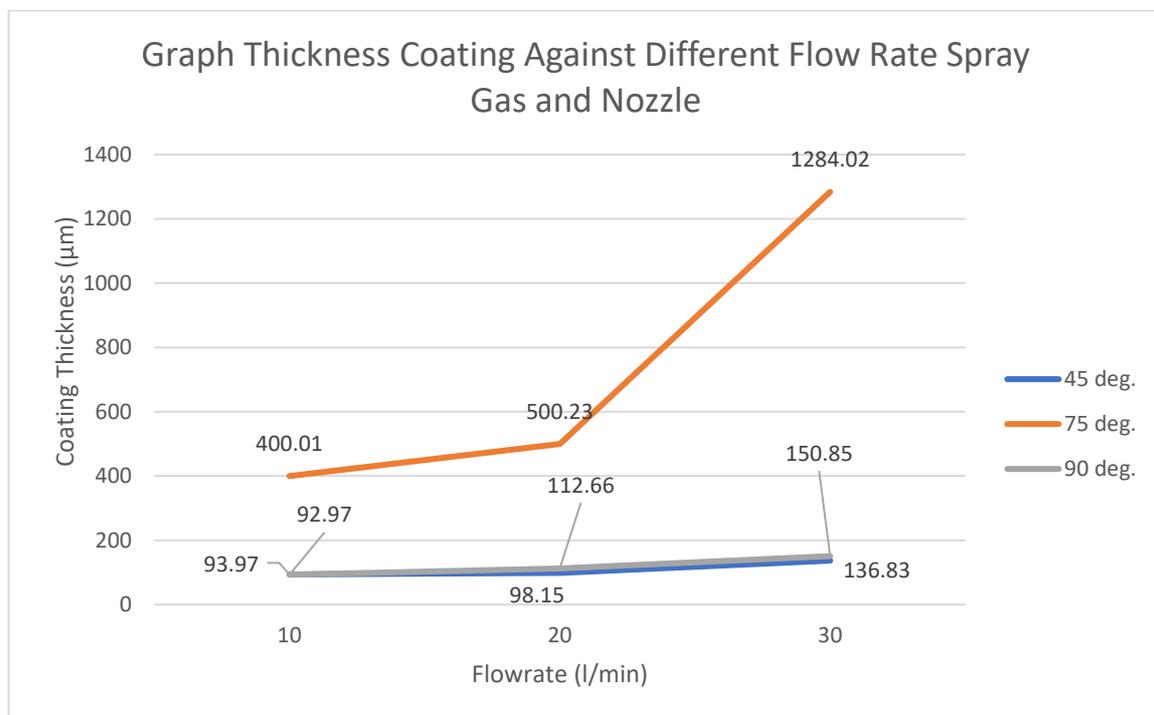| Angle of Injector Powder Nozzle	Flowrate Spray Powder (L/min)	Spraying Distance (mm)	Thickness of Coating (µm)
45°	10	10	93.97
	20	10	98.15
	30	10	136.83
75°	10	10	400.01
	20	10	500.23
	30	10	1284.02
90°	10	10	92.97
	20	10	112.66
	30	10	150.851

Figure 4. Coating Thickness Against Different Flow Rate Spray Gas and Nozzle

The graph in Figure 4 displays the thickness of the Al coating deposited on the stainless steel substrate for various working gas flow rates and powder nozzle angles. The flow rate regulates the output of Al powder. The graph illustrates that as the flow rate increases, the thickness of the coating deposited on the stainless steel substrate increases, indicating variations in coating thickness.

The thickness of the coating is also affected by changing the angles. The coating thickness reduces as the angle of the TIG nozzle increases. The graph above shows that the maximum thickness is 1284.02 µm at 75° with a flow rate of 30 l/min, with the smallest reading being 92.97 µm at 10 l/min and 90°. The larger flow rate and 75° nozzle angle from the substrate have a higher effect on the thickness of the aluminium coating, as shown in the result. The graph in figure 4-16 demonstrates the effect of varying working gas flow rates and nozzle angles on the thickness of the aluminium coating formed on the stainless-steel substrate. The flow rate regulates the output of aluminium powder. The graph illustrates that as the flow rate increases, the thickness of the coating deposited on the stainless-steel substrate increases, indicating variations in coating thickness.

Surface Roughness of Coating on Substrate

Table 5. Data Taken for Coating Surface Roughness on Substrate

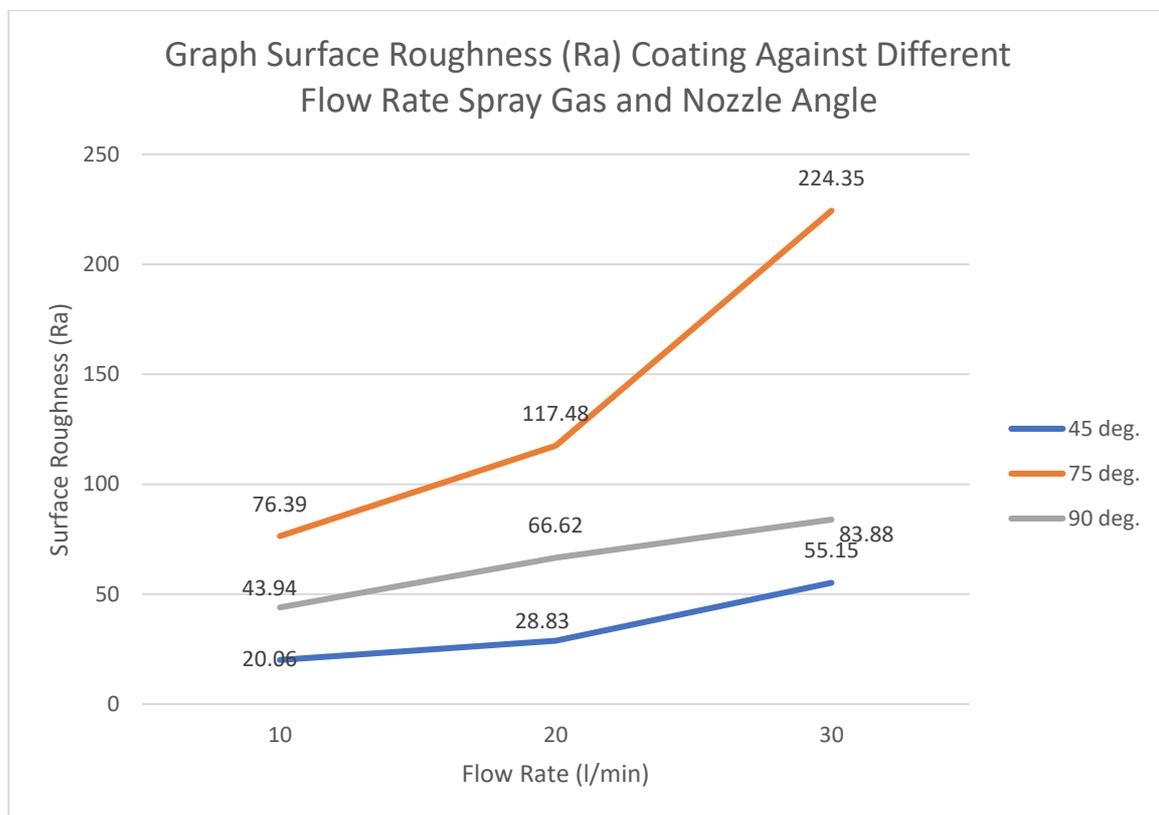| Angle of Injector Powder Nozzle	Flow Rate Spray Powder(L/min)	Spraying Distance (mm)	Thickness of Coating (μm)
45°	10	10	93.97
	20	10	98.15
	30	10	136.83
75°	10	10	400.01
	20	10	500.23
	30	10	1284.02
90°	10	10	92.97
	20	10	112.66
	30	10	150.851

Figure 5. Coating Surface Roughness (Ra) Against Different Flow Rate Spray Gas and Nozzle Angle

The graphin Figure 5 shows the surface roughness value of the aluminium coating deposited on the stainless-steel substrate for various working gas flow rates and powder nozzle angles. From the graph it can describe the increasing flow rate and change the nozzle angle degree will cause the higher aluminium coating surface roughness. From the graph shows that the highest surface roughness was 224.34 Ra obtained at angle of 75° with 30 l/min flowrate. The graph also shows that the lowest surface roughness was 20.06 Ra with 10 l/min gained at angle 45°. This explained that as the flowrate increase, the value of surface roughness of the coating deposited on the stainless steel as a substrate will increase and the angle of the nozzle spray powder also will affect the surface roughness value.

CONCLUSION

Throughout this study, it can concluded that this research result is for the analysis and observation of Al coating by TIG arc deposition method. The manipulated variable in this research is angle of injector powder and flowrate of gas spray powder and the constant variable is diameter or size of nozzle, spray time and TIG as a plasma spray angle which is 45 degrees. The use of 3D measuring microscope is vital process for the evaluation of the metal coating.

There are four types of the parameter result that wanted to analyse which is live image observation, diameter, thickness and surface roughness of the coating. For the live image observation show that the best rate of adhesion for coating is 75 degrees of angle with 10, 20 and 30 Litre Per Minute (LPM). Then, we can see from the data that the thickness is proportionally with the flow rate of the nozzle angle. So that, the best thickness to be chosen also 75 degrees with varying flowrate. Moreover, for the surface roughness we can see from the data that explained as the flowrate increase the value of surface roughness will be increase and the lowest value takes was 45 degrees spray powder angle with 10,20 and 30 LPM. Lastly for the surface roughness, the lowest value is the best value for producing an aluminium coating on the surface of the substrate. So, from the observation and analysis the lowest values taken for surface roughness is at 10,20, and 30 LPM with 45-degree angle. In conclusion, the best result for the aluminium coating based on combination of the parameter result is coating with 45-degree angle with 30 l/min flowrate of spray powder. It is because it has a good combination with a high thickness, low surface roughness value and good live image observation for the Aluminium coating on substrate.

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