Effect of argon flow rate on the weld bead characteristics of TIG coating

Surjit Angra, Lalit Thakur, Jasbir Singh*

Department of Mechanical Engineering, National Institute of Technology, Kurukshetra, Haryana, India

* jasbir.nitk@gmail.com

Abstract. The research work investigates the weld bead characteristics of WC-CoCr coating fabricated by using tungsten inert gas welding process. Owing to the heat generated during the TIG coating, the extent of the temperature rise is adequate to cause the significant changes in the melt dimensions of the coating. Toolmakers microscope has been used to capture the coating cross-section obtained at different values of argon flow rate. ImageJ software has been used to measure the porosity level in the coatings. The results show that higher flow rate of argon gas increases the porosity and weld contamination in the coating because the turbulence takes place at higher flow rate.

Keywords: Cermet, WC10Co4Cr, Argon flow rate, TIG welding

1. Introduction

Cermets are widely employed in numerous industrial equipments used in automotive, aviation, and cement industries that are subjected to severe erosion, corrosion, and wear. Cermet consists of hard phase reinforcement along with soft binder matrix. WC based cermet provides superior hardness and wear resistance. Therefore, WC-Co has been widely used as an alternative to hard chrome plating for wear resistance applications. The inclusion of chromium in the WC-Co powder further improves the toughness and wear resistance of the material [1, 2]. High hardness, toughness, and wear resistance makes the WC-CoCr as a perfect material for wear resistance coating.
A number of coating deposition method, such as PVD, CVD, HVOF[3], HVAF, PAW, SAW, TIG[4] and laser coating have been used widely for different materials. All these coating processes have their own advantages, limitations and applications. The coating produced by different deposition method gives different kind of microstructure, mechanical, and tribological properties. However, the coating fabricated by using TIG welding is a novel surface modification technique because of its flexibility, economy and high deposition rate [5]. It is a method of depositing a clad layer on the metallic substrate by the melting of preplaced powder, which is to be cladded on the substrate. Melting forms the metallurgical bond between the substrate and coating material, which improves the surface properties. Moreover, the properties of coating also depends upon the process parameters employed during the coating deposition. A number of researchers have studied the effect of processing parameters on the microstructure, mechanical, and tribological behaviour of TIG coating method.

TIG welding was used to fabricate the titanium aluminide coatings by preplacing the mixture of titanium powder and aluminum powder over the pure titanium sheet [6]. The process parameters, such as current, speed, and torch to workpiece distance were varied to examine the influence on microstructure, hardness, and wear. Coating layers without any pores and cracks was obtained at a current of 60 A and speed of 2-4 mm/s. Further, the developed coating showed the enhancement in wear resistance up to 3 times the pure titanium. A high carbon ferrochromium coating fabricated over the surface of SAE 4140 and SAE 1020 steel with the help of TIG welding method [7, 8]. The effects of preplaced powder thickness on the microstructure, hardness and wear properties of the steel were studied. SEM, EDS, and XRD techniques were employed for microstructural examination. Formation of martensitic structure and higher volume fraction of Cr7C3 carbides provides the sufficient abrasive wear resistance.

The influence of processing parameters, such as powder content, processing speed, and heat input on the microstructure and hardness of WC coating developed by using TIG welding was examined [9]. The result outcome showed that the formation of hypoeutectic or hypereutectic microstructures depends upon the processing parameters. The coatings at low heat input and high powder content attributed to the formation of hypereutectic
microstructures, which resulted in increased microhardness. The researchers studies the effect of shielding gases, such as hydrogen and argon-hydrogen mixture on the microstructure and tribological behaviour of FeCr, FeMo, and FeTi clad layer [10]. FeMo and FeTicoating deposited in the presence of argon-hydrogen gas mixture gives homogenous microstructures. Maximum hardness and wear resistance was observed in FeCrcoating followed by FeMo and FeTicoatings.

TIG welding was used to develop a SiC coating on the microalloy steel under the influence of different shielding gases, such as argon and a combination of argon and helium gas. The results revealed that the temperature during arc weld coating was increased by the use of argon helium mixture. Microstructural examination depicted the formation of large quasideendritic structure. Average hardness of the coating was reported to be 1000 HV with few pores and cracks. In another study, the influence of argon flow rate and standoff distance on the microstructure and wear properties of the WC-CoCr coating was investigated[11]. The results shows the improvement in hardness and wear resistance of the coating, which is developed at higher values of argon flow rate and standoff due to the lower dissolution of tungsten carbide phase in the binder matrix.

As per the available literature, a limited work has been done to study the influence of argon flow rate on WC-10Co-4Cr TIG coating. So, in current research work, WC10Co4Cr cermet powder was deposited over the AISI 304 stainless steel specimen using TIG welding process. Furthermore, the influence of argon gas flow rate on the weld bead geometry of coating was investigated.

2. Experimental Work

A WC-10Co-4Cr powder was selected as a coating material and AISI 304 stainless steel was taken as a substrate material. A steel plate having a size of 100 mm × 50 mm with plate thickness of 8 mm was polished with silicon carbide emery paper. Thereafter, substrate is rinsed with the acetone to remove surface contamination. A uniform paste is prepared by mixing the poly vinyl alcohol and coating material (WC-10Co-4Cr). This paste is dispersed over the steel specimen to form a preplaced layer of thickness 1 mm. Then, specimen is placed inside the furnace to remove the moisture and to allow the preplaced layer to stick to the steel specimen. Arc generated from TIG welding machine is scanned over the preplaced
layer by using CNC welding manipulator. Table 1 depicts the operating conditions of TIG deposition method. The directions of TIG welding machine scanning over the preplaced layer is shown in Fig. 1.

| Parameters         | Values        |
|--------------------|---------------|
| Tungsten electrode | 2.4 mm        |
| Current            | 110 A         |
| Voltage            | 16.2 V        |
| Scanning speed     | 150 mm/min    |
| Polarity           | DCSP          |
| Shielding gas      | Argon         |
| Argon flow rate    | 11, 13, 15 Litre/min |

Table 1: Operating conditions for TIG deposition method

Figure 1: Torch scanning direction over the preplaced layer.

Heat generated during the weld cladding process has been given by using equation (1)

\[
\eta = 0.48 \times \frac{\text{Voltage} \times \text{current}}{\text{speed}} \tag{1}
\]
On the completion of cladding process, samples for characterization and for the measurement of coating dimensions has been taken out by using WEDM machine. Then, double disc polishing machine is used to polish the specimens using different grades of emery paper. Specimens has been etched for microstructural examination with the help of 2% Nital solution. Toolmakers microscope has been utilized to capture the coating cross-section. ImageJ software is utilized to measure the porosity in the coating. Scanning electron microscope has been used to take the images of WC-CoCr powder. X-ray diffraction has been used to identify the phases present in the coating powder. EDS analysis has been performed to determine the elemental composition of specimen and coating powder.

3. Results and discussion
Figure 2: (a) FESEM micrograph (b) XRD analysis (c) EDS spectra of WC-10Co-4Cr powder (d) EDS of stainless steel specimen.

The Figure 2(a-c) depicts the FESEM, EDS, and XRD pattern of coating powder used for weld coating. The SEM images 2(a) shows the spherical morphology of WC-10Co-4Cr cladding material with grain size upto 3 μm. X-ray diffraction pattern reveals the existence of WC and Co phases in scan range of 20° to 90°. EDS spectra revealed the existence of powder composition of approx. 86 % (WC), 10 % (Co), and 4 % (Cr). Figure 2 (d) demonstrates the EDS spectrum of stainless steel specimen and confirms the elemental composition.
Figure 3: Toolmakers microscope image at argon flow rate of (a) 7 litre/min (b) 11 litre/min (c) 15 litre/min.

Figure 3(a-c) shows the toolmaker's microscope images of coating cross-section, which is produced at different flow rate of argon gas. A strong metallurgical bonding has been obtained for all process parameters. At low gas flow rate (7 Litre/min), atmospheric gases can easily enter into the shielding gas column and increases the weld contamination with reduced penetration. Figure 3(a) shows the presence of pores and porosity in the cladding. As the flow rate increases (11 Litre/min), shielding gas column becomes laminar in nature and prevents the inclusion of atmospheric gases into the weld pool (Figure 3b). This results in reduced contamination of cladding and tungsten electrode. At higher flow of shielding gas (15 litres/min), shielding gas column changes from laminar to turbulent in nature, which is highly undesirable. Due to this turbulence, atmospheric gases pulled into the argon gas shielding atmosphere. This results in increased contamination of weld pool and tungsten electrode. Moreover, the entrapped atmospheric gases can cause increase in the porosity of cladding at higher flow rate of argon gas, as shown in Figure 3(c).

4. Conclusion

TIG welding process has been used to develop the WC-10Co-4Cr coating on the steel specimens. The variation of argon flow rate on the characteristics of the coating has been analyzed. The results revealed that the higher flow rate of argon gas increases the porosity due to weld contamination caused by turbulent shielding gas column. At optimum flow rate of shielding gas, laminar type of protective atmosphere has been obtained, which prevent the entry of surrounding gases into the weld pool. Moreover, the coating developed at 11 litre/min of argon flow rate gives minimum porosity in the coating.

References

1. Berger, L.M., Mantyla, P., Kunert, W., Lengauer, W., Ettmayer, P.: Microstructure and Properties of WC-Co-Cr Coatings. In: Thermal spray: practical solutions for engineering problems. pp. 97–106 (1996)

2. Karimi, A., Verdon, C., Barbezar, G.: Microstructure and hydroabrasive wear behaviour of high velocity oxy-fuel thermally sprayed WC-Co (Cr) coatings. Surface & Coatings Technology. 57, 81–89 (1993)
3. Thakur, L., Arora, N.: Sliding and Abrasive Wear Behavior of WC-CoCr Coatings with Different Carbide Sizes. Journal of Materials Engineering and Performance. 22, 574–583 (2013). https://doi.org/10.1007/s11665-012-0265-5

4. Singh, J., Thakur, L., Angra, S.: Abrasive wear behavior of WC-10Co-4Cr cladding deposited by TIG welding process. International Journal of Refractory Metals & Hard Materials. 88, 105198 (2020). https://doi.org/10.1016/j.ijrmhm.2020.105198

5. Peng, D.: The effects of welding parameters on wear performance of clad layer with TiC ceramic. Industrial Lubrication and Tribology. 64, 303–311 (2012). https://doi.org/10.1108/00368791211249692

6. Mridha, S., Ong, H.S., Poh, L.S., Cheang, P.: Intermetallic coatings produced by TIG surface melting. Journal of Materials Processing Technology. 113, 516–520 (2001)

7. Eroglu, M., Önalp, S.: Tungsten inert gas surface modification of SAE 4140 steel. Materials Science and Technology. 18, 1544–1550 (2002). https://doi.org/10.1179/026708302225007826

8. Eroglu, M., Zdemir, N.O.: Tungsten-inert gas surface alloying of a low carbon steel. Surface and Coatings Technology. 154, 209–217 (2002)

9. Buytoz, S., Ulutan, M., Yıldırım, M.M.: Dry sliding wear behavior of TIG welding clad WC composite coatings. Applied Surface Science. 252, 1313–1323 (2005). https://doi.org/10.1016/j.apsusc.2005.02.088

10. Cay, V. V., Ozan, S., Gök, M.S.: The effect of hydrogen shielding gas on microstructure and abrasive wear behavior in the surface modification process using the tungsten inert gas method. Journal of Coatings Technology and Research. 8, 97–105 (2011). https://doi.org/10.1007/s11998-010-9263-4

11. Singh, J., Thakur, L., Angra, S.: Effect of argon flow rate and standoff distance on the microstructure and wear behaviour of WC-CoCr TIG cladding. In: Journal of Physics: Conference Series. pp. 1–8 (2019)