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Surface Alloying of CP-Ti Using preplaced Fe-C-Si powder by Tungsten Inert Gas Torch Technique

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Abstract

Surface alloyingcan play an important role for the protection of metallic components against wear and fric-tion.In this study, the surface alloying of CP-Ti material was performed using pre-placed powder mixture of carbon,silic on and iron under TIG arc techniques at an energy of 945 J/mm. The melt geometry, topogr-aphy, microstructure and hardness were investigated on the surface modified Cp-Ti alloy. The results indicated that the TIG torch prod uced at the energy input of 945 J/mm gave melt pool is in hemispherical shape.Pores were seen to be concentrated at the bottom of the melt pool where low melting energies are promin-ent entrapped escaped gases upon fast melt solidification. The melt pool microstructures glazed contained variation of dendritic and armed type of TiC to be precipitated in the presence of longer solidification time. TiC precipitation were higher in population and bigger i n sizein the middle of the melt pool compared to the track edges. Surface modified Cp-Ti alloy exhibited hardness values ranging from 600 Hv to 780 Hv which was 3 to 3.5 times higher than base metal hardness. The higher har dness observed at particular areas are attributed to high population and big sizes of dendritic microstrucutres of TiC.

Keywords: *Surface alloying, TiC, TIG, dendrites, microhardness*

1. Introduction

Due to the high specific strength-to-weight ratio, excellent corrosion and high temperature resistance, titanium alloys are widely employed as a suitable material for aeronautical, chemical, petrochemical and marine applications. However, owing to their low wear resistance and hardness values, their potential application is restricted.One of the ways to overcome this problem is to modify the surface on the substrate material by melting process via high energy input. Since then, research works showed improvement in surface hardness under this processing technique [1,2] thus allowing the modified material to be a suitable candidate for aggressive wear application. Subsequent rapid solidification of the melted layer might lead to the formation of structures which are not achieved under equilibrium condition [3]. Azmi and Shamanian [4] studied the effect of silicon on the microstructures and properties of Fe-Cr-C and reported that effect of silicon exhibited increase in microhardness and better wear resistance. Mridha [5] found that the hard titanium nitride layer that is processed in the pure nitrogen environment under TIG arc gave maximum hardness of about 2000 Hv.HajbagheriAdibet. al. [6] studied the wear resistance of CP-Ti by surface alloying with silicon under TIG torch melting technique and they found that the created layer achieved hardness values of approximately 4 to 5 times higher than the substrate material. Several research works found in literatures focusing on melting different alloying powders by using state of art processing techniques such as laser and plasma welding which are generally known to give higher in production price [7, 8]. Yet, no study has been carried out to melt the mixture of Fe-Si-C ternary material system by using the conventional and cheaper TIG method for surface modification. As such, the objective of this work is to investigate the quality of the melt pool layer using Fe-Si-C powders on CP-Ti substrate melted at the energy input of 945 J/mm. Melt pool geometry, topography, microstructure and microhardnessresults are presented in this paper. The success of this work will provide new opportunities for coating manufacturers to use this cheaper TIG technique rather than using laser or plasma beam processes and ternary powder mixtures with cost effective manner

Experimental

In this work, commercial purity titanium (CP-Ti) substrate with the dimension of 100 mm x 40 mm x 10 mm was thoroughly cleaned using acetone to remove contaminants such as dirt and grease on the surface. Weighed iron powder was added with carbon and silicon powder at given weight ratio as shown in Table 1. The mixed powders were blended using ball milling process for 1 hour with ball-to-powder weight ratio of 10:1. The blended powder weighed at 1 mg/mm^2 was mixed with Polyvinyl acetate solution before it was evenly spreaded across the titanium substrate surface. The amount of binder was restricted within limit in order to prevent excessive pores formation to be embedded in the re-solidified melt tracks [9]. The powder coated samples were heated in the oven at 80 ^oC for 1 hour to remove excessive moisture and for ensuring the layers are well adhered on the substrate surface. Single tracks were produced at energy input of 945 J/mm using TIG 165 welding machine with 2.4 mm in diameter of tungsten thoriated electrode. The arc energy input was calculated using a simple mathematical expression which can be found elsewhere. Fig.1 shows the schematic diagram of the surface melting process under the TIG torch. Pure argon gas with the flowing rate of 20 lit/min was purged into the melt pool to protect the tracks against excessive oxidation. The sectioned track layers were grounded on emery papers to the grit size of 2000 followed by polishing process that uses alumina paste with the size of 1 micron in diameter on the polishing pad cloth. The Kroll's reagent at the mixture 50 % HF, 30 % H_20_2 and 20 % distilled water by volume was used to etch the surface of the sectioned layers. The sample microstructures and topographies were observed by scanning electron microscope and Nikon measuring microscope respectively while experimental analysis was carried out using energy dispersive x-ray. The Vickers microhardness test across the melt depth was conducted using Wilson Wolpert testing machine at the load of 500 gf with 10 seconds delay.

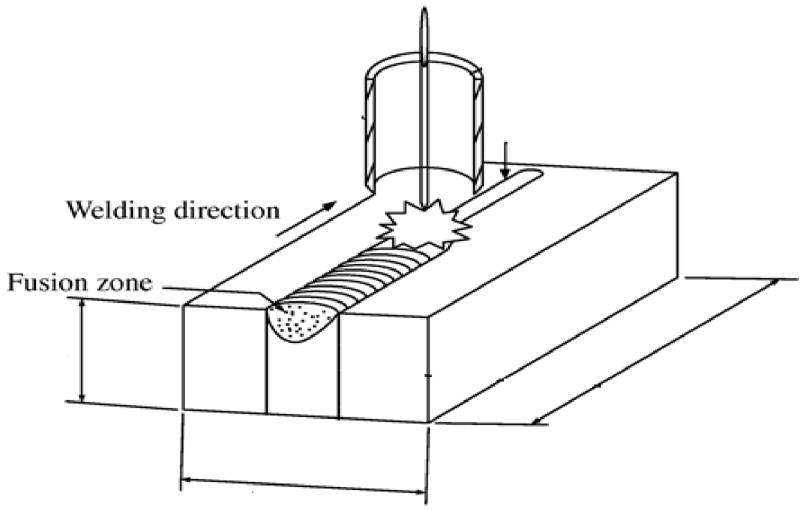


Fig.1 Schematic representation of TIG torch glazing features

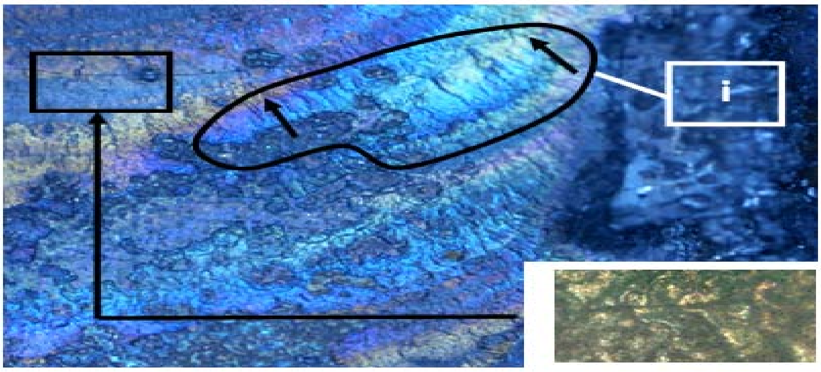
Table. 1. Processing conditions and alloy powder ratio

Processing conditions			**Powder ratio**
Energy (J/mm)	Depth(mm)	Width(mm)	Fe:C:Si ≡ 94 : 4 : 2
945	1.03	6.16	

3. Results and Discussion

3.1 Surface topography

The surface topography of modified Cp-Ti alloy with ternary alloy of Fe-C-Si using TIG torchtechnique at an energy input of 945 J/mm depicted in Fig 2.Rippling marks on the glazed sample was found to form in two different directions which are along and perpendicular to the electrode traversing direction. The radial rippling formations along the electrode traverse direction showed that solidification of molten melt pool was taken place near the base metalhowever, it solidified finally near the arc source. This low heat input energy produces a small radial mark along the electrode traversing direction on the noticeable re-solidified melt waves of the rippling marks that are perpendicularly to the direction of electrode movement (Fig. 2). The thick melt solution that formed slightly above melting temperature fused at this energy input created the surging fluid greater in penetration resistance and upon little solidification time, this high viscosity melt wave freezes as perpendicular rippling marks on the substrate surface. Previous works have showed that greater in ripples marks were formed by greater convection force that stirs the melt liquid in the presence of longer solidification time and fast solidification using low heat input caused rough and undulated surface which are the sign of incomplete melting at the beneath of surface layer [10, 11].



Note:Perpendicular rippling marks indicated by (i)

Fig.2.Topography of the processed tracks showing perpendicular rippling marks and the radial marks along electrode traversing direction by black arrows.Cracks are indicated at the insets.

3.2 Melt Microstructure

The micrographs of the resolidified melt layer fused showed hemispherical melt pool shape layer embedded on the surface of the substrates (Fig. 3) The Gaussian energy distribution which is known to provide greater heat intensity in the middle of the melt and gradually decreases to both edges are responsible to give such hemispherical in shape behaviour upon solidification. This phenomenon was also explained by other researchers using lasers and TIG melting process for composite coating where the hemispherical melt pool shapes are formed by the Gaussian energy distribution [1, 10, 12]. Continuous fusion line observed between the coating layer and the substrate in Fig. 2proved that good metallurgical bonding was incurred in this region from extensive mixing of dissolved reinforcing material with an amount of diluted substrate. Pores were seen to be entrapped at thelow energy area which are the edges due to fast solidification (Fig. 3). In the pre-placing technique, pores are reported due to escaped gases from the burnt binder which does not efficiently released to the environment upon solidification [2, 17].However, the microstructure showed little dilution of the base metal with smaller amount of dissolved reinforced powders especially carbon which permitted to the precipitation of the new dendritic armed TiC phase in the presence of longer solidification time (Fig. 4). It is worth noting that the diffusion of carbon in titanium in presence of higher carbon content (4 wt%) via diffusion hardening process assists the formation of dendritic TiC as shown in Fig. 4. Fig. 5 shows the EDX elemental analysis on the SEM micrograph and it is clear from the results that modified metal faceconsists of both Ti and C. The high affinity of carbon for titanium than other elements is significant to develop such populated TiC phase. In the previous work, the re-precipitated TiC consist of iron, titanium and carbon using pre-placed TiC particulates melted on the low alloy steel substrate by high TIG energy input [1]. At this low energy input of 945 J/mm, the melt fluid is thick and as such, the solidification time for the melt to freeze isvery short and this retarded the possibility for greatamount and sizes of TiC to be precipitated. In the previous work, the low energy at the edges fused by TIG arc showed poor dissolution efficiency thus giving high un-melted and partially melted particulates to be agglomerated with minimal re-precipitation of TiC microstructures [1] and this was also observed in other research works [14].

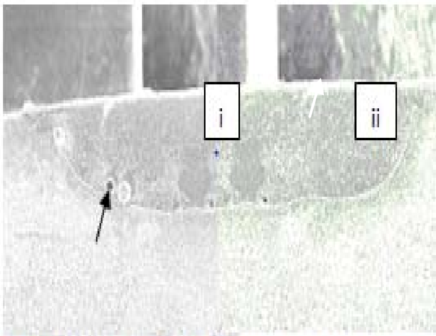


Fig. 3. Micrograph of Fe-C-Si coated surface with the arrow showing porosities

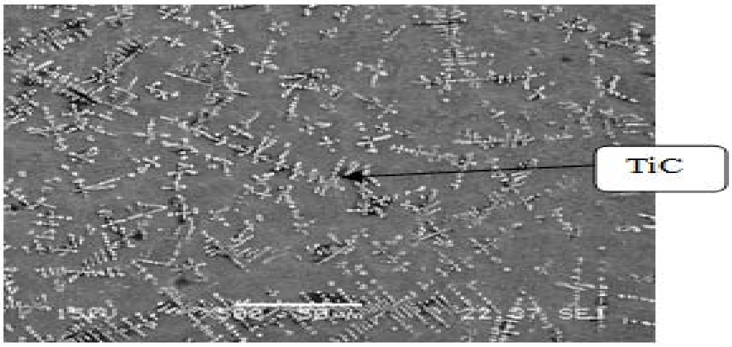


Fig. 4. SEM micrograph of modified surface showing dendritic TiC observed in Fig. 3 (i)

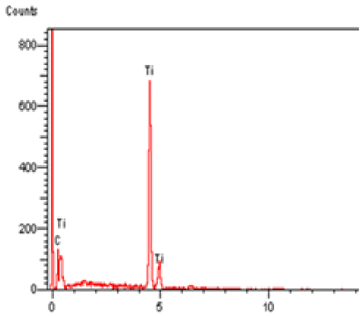


Fig. 5. Elemental analysis in the dendrite (Fig 4) showing Ti and C.

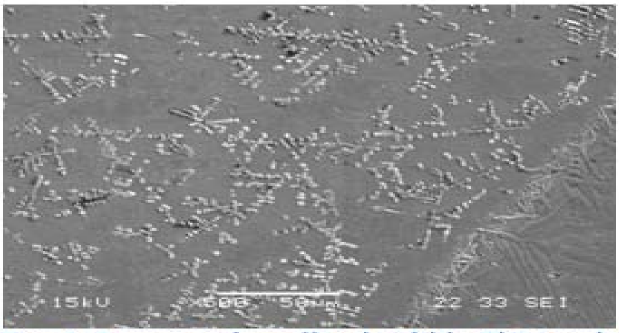


Fig. 6. Lesser and smaller dendritic TiC precipitation observed in Fig.3 (ii).

3.3 Microhardness Profile

Themicrohardness profile of the ternary alloy prep-placed powder modified Cp-Ti alloy processed under the energy input of 945 J/mm is presented in Fig. 7. The microhardness recorded for modified surface were found ranging from 600 to around 780 Hvwhile the Cp-Ti substrate microhardness value was 200 Hv.In this work, the main contribution to the increase of microhardness value areprecipitation of the new dendritic armed TiC microstructure that were mainly populated near the arc source. The enrichment of TiC dendrite attained maximum hardness of approximately 780 Hv and this value decreases to the lowest of about 600 Hv at the depth of 200 micron. The variation of hardness is attributed by the gradient distribution of variety TiC types and population across the depth of the track layer [2, 14]. Emamian et al. [15]reported that fluctuation in hardness result normally occurs due to the difference in hardness value of matrix and reinforcement particles. Greater in basemetal dilution by melting using high energy input may reduce the microhardness value in the re-solidified melt layer. However, allowing the new hard phase of TiC to be precipitated at the expense of longer solidification time via high this energy input may overwhelm the poor hardness properties in the re-solidified melt layer.

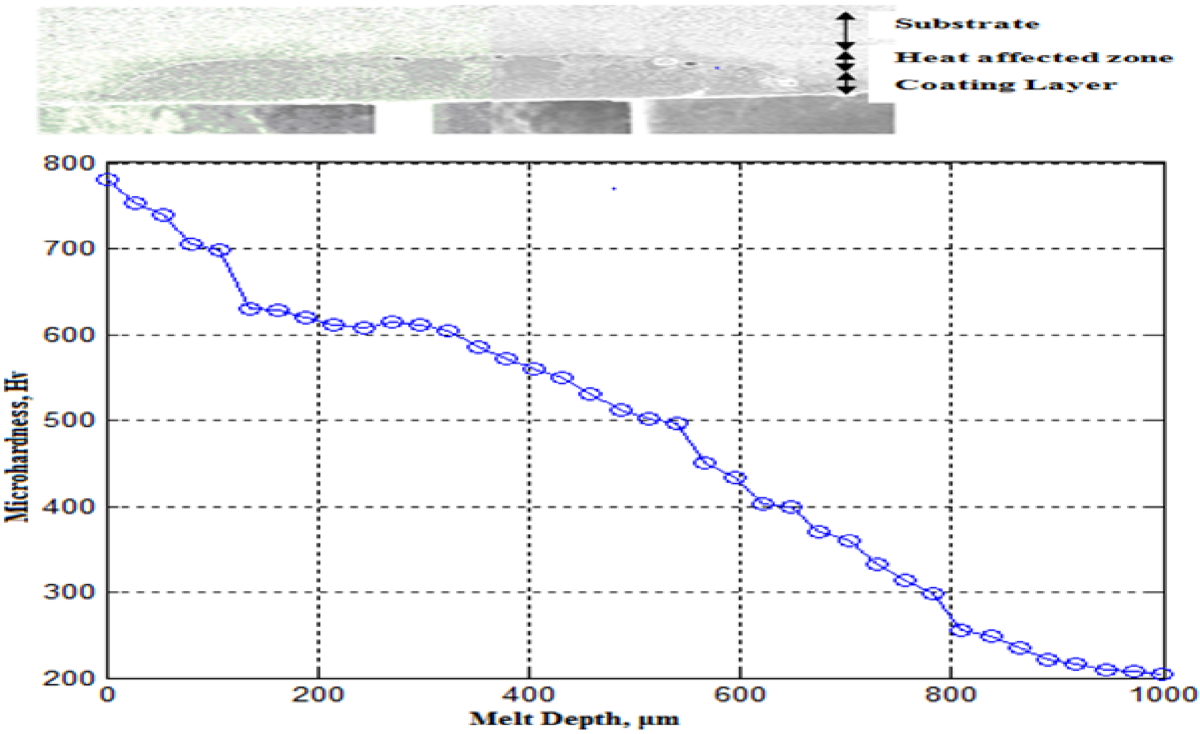


Fig.7. Microhardness profile of the processed track layer at energy input 945 J/mm

4. Conclusions

The surface of CP-Titanium has been successfully modified with Fe-Si-C ternary powders that is preplaced on the substrate via TIG torch technique. The melt pool obtained was hemispherical in shape and populated with precipitationof the new dendritic armed TiC microstructure that was almost homogeneously distributed within the melt pool. Pores were prominent to be embedded at the edges due to fast melt solidification from the viscous liquid during melting process. The maximum hardness in the surface modified area is about 3 to 4times higher than the base metal hardness. The increase of microhardness value within the ternary alloy on the substrate suggest that this processed material is suitable to be used in the aggressive wear environment where low material removal rate is likely to take place on the surface.

5. Acknowledgements

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6. References

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