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ScienceDirect

Procedia Engineering 184 (2017) 737 – 742

Procedia Engineering

www.elsevier.com/locate/procedia

Advances in Material & Processing Technologies Conference

Surface Modification of Duplex Stainless Steel with SiC Preplacement Using TIG Torch Cladding

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Abstract

Surface modification of duplex stainless steel is important to make this material suitable for tribological and high temperature applications. The surface modification using fine SiC (20 µm) powder preplacement by TIG torch technique has been performed on the surface of duplex stainless steel. The TIG torch was employed with varying operating welding variables such as welding current of 80 A, 90 A and 100 A and energy input of 648, 768 and 1440 J/mm. The composite surface layer was characterized using Vickers micro-hardness tester and scanning electron microscopy (SEM). Based on the experimental results, it was found that re-solidified composite layer produced maximum hardness of 833.6 $Hv_{0.5kgf}$ from substrate hardness of 250 $Hv_{0.5kgf}$ for TIG processed of 768 J/mm energy input. The microstructure revealed the formation of dendrite phase due to complete melting of SiC in the modified layer. The formation of dendrite contributes to the increase of hardness of this material.

Peer review under responsibility of the organizing committee of the Advances in Materials & Processing Technologies Conference

Keywords: Duplex stainless steel; powder preplacement; dendrite; hardness; silicon carbide; tungsten inert gas.

1. Introduction

Duplex stainless steel (DSS) with the grade of ASTM A240 equivalent to UNS S32205 also known as Duplex 2205 consists of both ferrite and austenite. DSS are nowadays extremely dynamic with high potential success in many new applications such as rail car manufacturing, automotive and chemical industries.

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1877-7058
Peer review under responsibility of the organizing committee of the Advances in Materials & Processing Technologies Conference
doi:10.1016/j.proeng.2017.04.151

These materials offer unique combination of high mechanical properties and corrosion resistance [1]. Although DSS is widely used in various industries, this material has faced wear and hardness problem in many applications [2]. Due to this, in the past few years, a number of researchers have attempted to improve this limitation by various types of surface modification or surface coating. A wide variety of methods are available to produce a hard coating layer including PVD, CVD, laser surface cladding and thermal spraying. However, all these techniques have a limited application because of the expensive establishment and precision control of the system. Therefore, an alternative approach was developed using conventional TIG torch for surface modification [3]. This technique was employed to improve the performance of engineering surface properties of several engineering metallic materials. This modification can be done by changing the surface microstructure without affecting the bulk properties of the material.

Several research works have focused on melting using different alloying powders and substrate materials via TIG torch [4-6] and laser cladding [7, 8]. Laser surface alloying of Al with Fe was studied and reported elsewhere [8]. It was found that the hardness of laser alloyed layer increases until 1000 Hv with increasing of Fe content. The wear resistance of the alloyed layer improved along with the increases of the hardness due to the formation of the fine Fe rich intermetallic compounds. Maleque et al., [9] explored the TiC-CNT hybrid composite coating on low alloy steel using TIG torch technique. Based on the result, the particle preplacement using TiC-CNT and TIG torch melting technique is a successful technique to develop a composite layer with depth of 1 mm and high hardness of about 900 Hv (4 times higher than substrate material) when glazed at a relatively higher current.

Due to high hardness, melting point and good chemical stability, SiC dispersed composite layer can improve the surface properties in terms of hardness and wear behavior [7, 10, 11]. Buytoz [10] analyzed the microstructural properties of SiC particulates hardfacing on carbon steel with varying SiC between 30-45 µm. From the study, it can be observed that the microstructure of coating surface consists of primary dendrites and eutectic mixture of carbides and austenite. The microhardness of the surface layer was significantly improved to as high as 1135 Hv as compared to 220 Hv of the substrate material. Surface melting by incorporation of ceramic particles can produce composite layer dispersed with ceramic particles which enhance the surface hardness [12]. In this process, the alloy powder in a form of hard ceramic particles with desirable composition is homogeneously deposited onto the surface of the substrate material.

The heat sources such as laser, electron beams or TIG torch were used to melt the alloy powder and substrate material [9]. A coated surface obtained by TIG torch has the potential to produce a dense coating with good metallurgical bonding to the base material. Dyuti et al. [13] have found that the composite layer can be produced on carbon steel by melting via preplacement of Ti and Al powder mixtures in nitrogen environment under a TIG torch with energy inputs between 540-675 J mm^{-1} energy inputs. The clad layer that formed with dendrite microstructure consists of Ti-Al nitrides which distributed homogeneously throughout the melt pool. They also claimed that the hardness of the composite layer depends on dendrite population and maximum hardness was achieved ~900 Hv.

Most of the findings have showed that surface modification via melting are proven methods to improve surface coating of many substrate materials in terms of surface hardness, tribological and corrosion resistance. No information is available in the literature on the incorporation of SiC particulates composite coating on DSS by TIG torch melting technique in the earlier works. This paper presents the influence of processing conditions to develop hard re-solidified composite layer with SiC on DSS through TIG torch melting technique in terms of surface topography, microstructure and hardness properties.

2. Experimental methods

The material used in this study was duplex stainless steel with grade of ASTM A240. The specimen preparation was conducted by cutting the plate to the size of 100mm x 50mm x 10mm. Prior to surface coating, the surface of the substrate was ground with emery paper and degreased in acetone. A powder of SiC with a particle size of 20 µm was used as a coating material for surface modification. The SiC powder mixture weighed of 0.5 mg/mm^2 was mixed with two drops of polyvinyl acetate (PVA) binder and agitated to form a paste with the aid of distilled water and one drop of alcohol. The addition of binder is to keep the powder on the surface under the flow of the shielding gas. Then the paste was pre-placed on the substrate surface and dried in oven at 80 ºC for 1 hour to remove moisture.