TIG Torch Melting as Surface Engineering Technology

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Introduction

In various engineering applications, the surface properties of engineering components are enhanced using surface modification technology. As a consequence, the interest in surface engineering has risen greatly throughout the past decades. Surface engineering involves the development of a new or modified exterior phase on the substrate material (Chattopadhyay, 2014; Hardell and Prakash, 2010). Through surface engineering, the thin near-surface layer of substrate material is modified while maintaining their core structure and properties (Bello *et al.*, 2016; Dong, 2010; Mridha and Dyuti, 2011).

The surface melting technique also known as cladding which has been widely used as surface engineering technology. The surface melting technology involves of high energy source that is applied to melt the surface of the substrate fed with reinforcing particles (Sathiya *et al.*, 2009). Upon solidification, the reinforcement is strongly bonded with the substrate material. Powder blown, wire feed and pre-place powder are the three methods to feed the reinforcement onto the substrate material prior or during the surface melting technology (Folkes, 1994).

Various surface engineering technologies were introduced by previous researchers through several famous approaches such as tungsten inert gas welding (TIG) (An *et al.*, 2017; Bello *et al.*, 2016; Kumar *et al.*, 2017; Maleque *et al.*, 2017; Sahoo and Masanta, 2017a,b; Saroj *et al.*, 2017a,b) laser cladding (Qunshuang *et al.*, 2017; Yang *et al.*, 2016; Zhou *et al.*, 2016), electron beam welding (EBW) (Lienert *et al.*, 1993; Peng *et al.*, 2011) and thermal spraying (Aussavy *et al.*, 2014; Shibe and Chawla, 2014). Tungsten inert gas welding (TIG) melting technology or also commonly known as gas tungsten arc welding (GTAW) has started to be used during the Second World War. TIG torch technology was designed by Russel Meredith and developed by Linde Company. After several years of development, it was finally modified in 1941 and patent issued in 1942. The heat in TIG melting technology is initiated from an electric arc between the tungsten electrode and substrate material. The melting of substrate surface is protected from contamination using common protective gases such as helium, argon or the mixture of them. The following solidification of the substrate material fed with reinforcement particle produced new intermetallic compound with altered wear and hardness behavior (Maleque *et al.*, 2018; Musa *et al.*, 2018; Mridha *et al.*, 2012a,b).

Another surface melting technology known as electron beam welding (EBW) was developed in 1950s. The kinetic energy of accelerated electrons is used as the heat source for surface melting process in this technique. The generation of high velocity electrons is performed by heating the negative-charged cathode filament up to its thermionie emission temperature. The electron beam with diameter between 0.3 and 0.8 mm hit the base material with velocity up to 70% of the speed of light. Around 95% of the electron's kinetic energy is generated into heat. The power density is up to 10^{10} Wm^{-2}. The superior power density makes EBW capable of deep melting of the substrate surface. This could be an good to fused two metals together, however, surface melting technique does not need such high heat source since the purpose is to modify only the thin near surface layer of the substrate (Sun and Karppi, 1996).

Laser cladding is a recent surface engineering technology where another substance is combined onto the substrate surface for surface modification. Laser cladding is considered as one of the surface melting technology. The fusion of reinforcement particles onto the substrate surface is done using laser as heat source. The method was developed in 1970s and usually used as utility to repair and enhance the surface of engineering parts (Gedda, 2004). The modified layers produce by this method is said to have strong metallic bond, low dilution and less distortion between the reinforcement and the substrate (Huang *et al.*, 2010; Zanzarin *et al.*, 2015). Fernández *et al.* (2014) recommended to control the surface coating thickness by varying the process parameters of laser cladding.

Thermal spraying is a surface engineering technology developed in 1910s to 1920s where the reinforcement materials is melted, sprayed and latched onto the substrate surface. From the same category, a common surface engineering technology known as plasma spraying is developed in 1970s where a high temperature (can exceed 15000K) plasma jet is used to spray refractory materials for examples, oxides and high melting point metals such as molybdenum (Seiji *et al.*, 2008). The deposited reinforcement particles solidify and form laminar structure of the new modified layer (Aussavy *et al.*, 2014; Begg *et al.*, 2016; Seiji *et al.*, 2008; Shibe and Chawla, 2014). The method highly depends on the cleanliness and roughness of the substrate surface. Therefore, surface preparation prior to the surface melting process is very crucial. Furthermore, the grit blasting is usually used on the substrate surface to allow adhesive bonding with the reinforcement. However, grit blasting require more labor and the surface finish for the method is said to be non-consistent (Begg *et al.*, 2016).

Among the surface engineering technology discussed previously, TIG torch surface melting technology is believed as crucial key in the development of the surface modification technology due to its simplicity, flexibility and cheap establishment. The method was used in the world war era by the military on stainless steel, aluminium and magnesium for aircraft components. TIG torch melting now is used in numerous applications in aerospace, automotive, nuclear reactors, ship, civil parts etc. TIG torch technique