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Studies on Electron Beam Surface Melting of AISI 316 Stainless Steel and AISI 347 Stainless Steel

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Abstract

In the present study, AISI 316 stainless steel and AISI 347 stainless steel are subjected to electron beam surface melting using an indigenously developed electron beam welding unit (80 kV & 12 kW). Electron beam processing was carried out at a gun voltage of 60 kV, current of 30 mA, scan speed of 1000 mm/min in a vacuum chamber with a vacuum level of 1.6 x 10-5 mb. Followed by surface melting, a detailed characterization of the surface was carried out and the effect of electron beam melting on the corrosion resistance property was evaluated. The effect of electron beam melting on the kinetics of aqueous corrosion has been determined in acidic 3.5 wt. % NaCl media.

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Keywords: Electron beam melting; AISI 316 stainless steel; AISI 347 stainless steel; Potentiodynamic polarization

1. Introduction

Identification and selection of suitable structural materials for successful generation of energy in nuclear-powered reactors is a major challenge [1]. Excellent combination of high corrosion resistance, and good mechanical properties make austenitic stainless steels a popular structural material in nuclear energy applications in general, and heat exchangers and steam generators in particular, wherein simultaneous presence of highly corrosive environments

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and temperature are the major key factors [2-3]. The major requirements for structural materials for nuclear application are good mechanical properties under all conditions of operation like low absorption of neutrons, stability under intense gamma and neutron irradiation, low rate of corrosion in the presence of fuel, moderator and coolant, ease of fabrication and acceptable cost [4]. However, choosing structural materials as per the desired properties is not good enough to extend the service life of the nuclear reactors [5]. Manufacturing of steam turbines for nuclear power plants have evolved and improved over time to limit/prevent some common causes of failures, which includes tube denting, resulting power generation in a safe and cost effective manner for as long as possible [6]. This problem can be overcome by improving the surface properties of the materials, which involves modification of surface properties of engineering components by surface alloying or by tailoring the surface microstructure through melting without altering the fundamental bulk properties of the substrate materials [5-6]. Modification of surface of commonly used structural materials by laser surface melting were attempted earlier and it was observed that it imparts improved hardness and corrosion resistance of the same structural materials in stimulated nuclear environments [7-10]. Nowadays, electron beam surface melting technique has found applications in nuclear, chemical and aerospace industries due to its several advantages as compared to the conventional broad heat source like oxy-acetylene torch and plasma torch [11]. However, no literary evidences are available detailing on the specific microstructural changes as a result of surface modification by electron beam melting of the austenitic stainless steels and its effect on corrosion resistance.

In the present study, two popular stainless steels like AISI 316 stainless steel and AISI 347 stainless steel have been subjected to electron beam surface melting and its effect on microstructure and corrosion resistance property have been studied in details.

2. Materials and experimental procedures

2.1. Test materials

Commercialized heat treated austenitic Type 316 and Type 347 stainless steel (SS) were chosen as the test materials. The chemical compositions of these materials are given in Table 1.

Table 1 - Chemical composition of materials (wt. %)

Mat.	Heat No.	C	Mn	P	S	Si	Ni	Cr	Mo	N	Cb	Fe
Type 316 SS	6523	0.04	1.75	0.004	0.003	0.47	10.52	16.37	2.20	0.05	-	Bal.
Type 347 SS	4423	0.05	1.80	0.004	0.003	0.50	9.79	17.33	-	-	0.56	Bal.

2.2. Experimental procedures

An electron beam machine with a maximum acceleration voltage of 80 kV and power of 12 kW was used for surface melting of two different austenitic stainless steels. Surface melting was carried out with fixed current of 30 mA, fixed voltage of 60 KV, and 1000 mm/min fixed scanning speed of the generated electron beam inside the melting chamber. Rectangular specimens with dimensions of 50 mm X 25 mm X 5 mm were machined from heat treated materials for each types of steels and were cleaned with ethanol and acetone before the melting. The motions of the samples were directly controlled by the Computer Aided Design (CAD) software.

Once melting was done, the melted area was characterized by light microscope, to know whether any melting defects were formed or not. Surface roughness evaluation of both pre and post electron beam melted (EBM) region was performed by using a scanning probe microscope (SPM). Cross sectional region of this melted specimens were again polished and etched for the observations on microstructural changes on both the pre and post EBM. Micro hardness of both of this regions were measured using a load of 0.49 N. Finally, the top surfaces of the melted