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Microstructural and microhardness characteristics of gas tungsten arc synthesized Fe–Cr–C coating on AISI 4340

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Abstract

The effects of gas tungsten arc-processing (GTA) parameters on the microstructure and microhardness of Fe–Cr–C alloy coatings were investigated experimentally. Coatings were developed by GTA processing on an AISI 4340 steel substrate. Depending on the processing parameters, either hypoeutectic or hypereutectic microstructures were produced. The hypoeutectic microstructures consisted of primary dendrites of austenite (γ) phase and eutectic M_7C_3 carbides. The hypereutectic microstructures consisted of M_7C_3 primary carbides and eutectic. The formation of hypoeutectic or hypereutectic microstructures was influenced by the concentration of alloying elements (C, Cr). The hypereutectic microstructures showed higher hardness, which depend on the amount of powder delivered into the melt pool and extent of substrate melting. The lower hardness of hypoeutectic microstructure was related to the presence of austenite (γ) phase in the primary dendrites and relatively low concentrations of Cr and C.

Keywords: M_7C_3 carbides; Hardfacing; Retained austenite; Dendrite

1. Introduction

Recently surface modification of steel has attracted interest of many reseachers and new methods were attempted to improve its chemical and mechanical properties [1]. Surface treatment may improve the surface resistance to corrosion, impact breaks, or abrasive wear. The novel methods of materials processing have been achieved with high power lasers and gas tungsten arc synthesizing used in a number of ways to modify the properties of steel surfaces. In particular, laser-assisted surface modification of traditional materials has led to the development of coating with rapidly solidified fine microstructures consisting of crystalline and amorphous phases, but also the GTA processing can be used instead of laser treatment [2]. The improvement of steel properties by the GTA technique is achieved by introducing alloying materials into the gas tungsten arc-melted component surface, typically in the form of power [3]. The wear and corrosion resistance of such coatings are superior to those obtained with conventional surface treatment techniques [4]. The coating microstructure consists of primarily solidified chromium-carbides of the M_7C_3-type, which are embedded in an eutectic [5]. Earlier research on Fe–Cr–C alloys produced with conventional techniques has revealed the formation of microstructures comprising α-ferrite and complex carbides, such as M_3C, M_7C_3 and $M_{23}C_6$, depending on the alloy composition [6]. This type of microstructures showed good abrasive wear resistance [7]. However, in all of these investigations obtained microstructures with relatively larger primary carbides, in comparison with those obtained by rapid solidification methods. Nevertheless, the results of these studies have provided useful insight into the equilibrium phases and compositions of ternary Fe–Cr–C systems [8,9].

Conventional material-processing methods, such as casting and arc or induction welding, result in coarse microstructures, nonuniform distribution of primary car-

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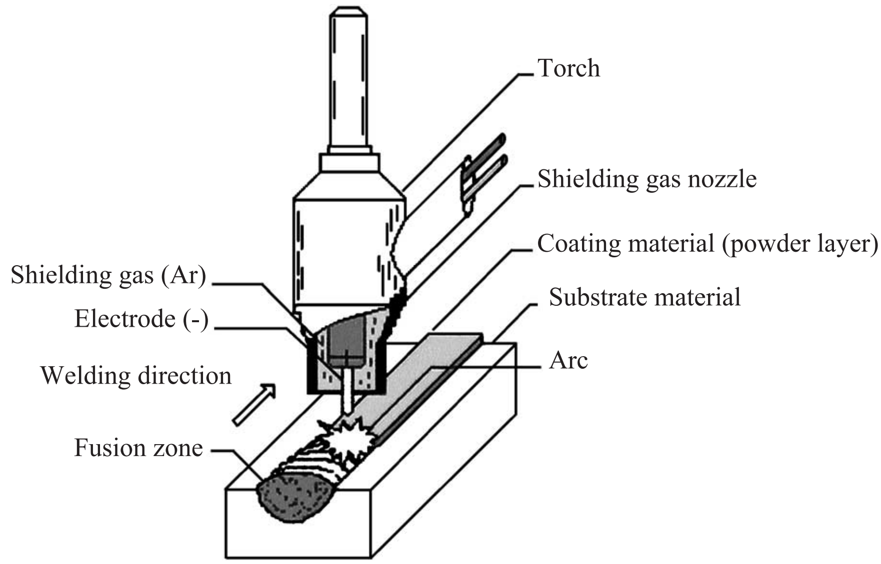

Fig. 1. Schematic representation of the coating.

bides, distinct segregation of alloying elements, thermal distortion of the workpiece, and presence of larger heat affected zones. However, rapid solidification techniques, such as splat quenching and GTA, overcome many of the previous undesirable characteristics. GTA surface modification by alloying is a process in which an alloy powder of a desirable composition and a thin surface layer of the substrate material are simultaneously melted and then rapidly solidified to form a dense coating metallurgically bonded to the base material. The surface layer obtained by this technique on various traditional substrate materials has fine microstructures with high hardness and wear resistance. The enhanced hardness of Fe–Cr–C alloy microstructures is associated with the formation of hard M_7C_3 (M=Fe, Cr) carbides and fine-grained nonequilibrium γ phase in the primary dendrites [10].

The objective of the present investigation was to systematically study the phase transformations, associated solidification mechanisms, and property changed of Fe–Cr–C alloy microstructures obtained by the GTA processing. Thus, the microstructure, chemical composition, and microhardness of the coatings obtained for a wide range of GTA processing parameters, such as the heat input processing speed and powder content were examined using various micro analytical techniques and indentation testing.

2. Experimental details

High-strength low-alloy steel samples (AISI 4340) with an area of 100–20 mm^2 and thickness of 10 mm were used as substrates in the GTA processing experiments. Its chemical composition in wt.% is 0.415% C, 0.267% Si, 0.656% Mn, 1.75% Ni, 0.237% Mo, 0.930% Cr and 95.54% Fe. However, the powders used in the experiments consist of 64% Cr, 1.80% Si, 6.84% C and 26.84% Fe. The alloying was carried out with the two-step method. Initially, the sample surface was polished with 400 grit SiC paper then the mixed powder layers of a thickness of about 1.0–3.0 mm were preplaced on the surface of the substrate with small amount of alcohol, and then the substrates with this coating were dried in

Table 1
Operation conditions and effect of processing parameters on the coating geometry and microhardness

Process parameters					Coating dimensions (μm)					
Sample number	Electrode diameter (mm)	Process speed (mm/s)	Powder content (g)	Heat input (kJ/cm)	d_c	h_c	t_c	w_c	Microhardness (HV)	
S_1	2.4	1.174	3.5	14.3	2160	1080	3240	8700	764	±48
S_2	2.4	1.292	5	14.1	1850	1330	3180	9670	861	±60
S_3	2.4	1.326	5	13.7	1350	1150	2500	8240	808	±21
S_4	2.4	1.438	3.5	12.1	750	970	1720	5700	712	±31

d_c=max depth below the original substrate surface; h_c=max hight above the original substrate surface; t_c=max total thickness (=d_c+h_c); w_c=max width; Heat input Q=η.U.I.60/(V.1000).