

Microstructure and erosive wear behavior of weld deposits of high manganese electrode[☆]

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Abstract

Low carbon steel plates were surfaced with single, double and triple pass bead on-plate welds using the shielded metal arc welding technique with a high manganese electrode. After deposition, the microstructure, hardness and erosive wear behavior of the deposit layers were investigated. Erosion tests were conducted at impact angles of 30, 60 and 90° using angular erodent with particle velocity of 30 m/s. From the results of microstructural investigation and hardness measurement, when each layer was superficially processed by the same electrode, it was seen that the microstructure changed from martensite with retained austenite to austenite. Hardness values decreased as the number of layer was increased. This was related to the higher contents of Mn and C as a result of increased layer number. The erosion test results showed that the erosion rate varied as a function of the impact angle as well as the number of the layers. The highest erosive wear occurred at 90° for all layers. Taking into consideration the erosion wear resistance, it was consequently found that the deposition with single pass gave good results for a low speed erosion test.

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1. Introduction

Welding processes are used to apply hardfacing materials ranging from the traditional (e.g., oxyacetylene torch) to new and sophisticated (plasma transferred arc and laser) methods.

The processes can be grouped as torch process, arc welding process, and high energy beam techniques [1,2]. The torch process, oxyacetylene welding, is the oldest and the simplest hardfacing process which involves simply heating the substrate with the flame and then melting the filler rod to get the hardfacing to melt. High-energy-beam techniques use laser beam welding or electron beam welding to alloy the surface by adding alloy powders to the weld pool. In arc welding, the heat is generated by an arc between an electrode and the workpiece.

To accommodate different overlay processes, the hardfacing materials are available in a variety of forms. They can be deposited, as a thick alloy coating ranging from 750 µm to a few

millimeters [3]. The deposits may have one or two layers so that the effect of dilution is significant [4]. Hardfacing materials fall into six categories: built-up alloys, metal-to-metal wear alloys, metal-to-earth abrasion alloys, tungsten carbides (for extreme earth sliding and cutting wear), nonferrous alloys, stainless steels [5]. The built-up alloys are used as wear resistant materials under mild and severe wear conditions [6], and to return worn parts back to, or near, its original dimensions and to provide adequate support for subsequent layers of true hardfacing materials. These types of alloys fall into two categories: alloy steels and austenitic manganese steels. Alloy steel built-up materials are used with carbon steel, alloy steel [7] and cast irons [8–11] substrate; austenitic manganese steels are used for the purpose of joining, repair and/or protection of manganese steel components. Typical examples of applications where built-up are used include tractor rails, railroad rail ends, steel mill table rolls, and large slow-speed gear teeth [5].

Austenitic manganese steel containing about 1.2 wt.% C and 12 wt.% Mn is known for a high resistance to impact wear caused by a rapid cold work-hardening [12]. But, there is little work reported on the mechanism leading to this behavior. In general, it is known for the formation of numerous strain-

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Table 1
Chemical composition of substrate, wt.%

C	Si	Mn	P	S	Fe
0.185	0.25	0.605	0.019	0.021	Bal.

induced martensite transformation and twins [13,14]. Due to its low yield strength, it may be deformed markedly before its work-hardening become effective [15]. The deformation can result in a strain-induced martensite that can have either bcc or hcp crystal structure, known as α' and ϵ martensite, respectively [16]. Metastable austenitic manganese steels, in comparison with Hadfield steel, appear to have a higher work-hardening capacity and a better wear resistance under low stress abrasive wear conditions. Creation of metastable austenite structure reinforced with martensite exerts positive effect on cavitation resistance in the hydraulic turbines [17].

Recently, a stainless type of Hadfield steel has also been developed [18] to resist corrosion in pit mining, where a slightly acidic environment is encountered. However, solid particle erosion of high manganese hardfacing layers has not been studied in detail so far.

The purpose of the present study is to investigate the microstructure, hardness and erosive wear behavior of weld deposits made with high manganese electrode on the surface of low carbon steel.

2. Experimental procedures

2.1. Material and surface processing

Low carbon steel (AISI 1020) substrates measuring $150 \times 30 \times 10$ mm were prepared for hardfacing purposes. The composition of the substrate is given in Table 1. The specimens were surfaced with single, double and triple pass bead on-plate welds, respectively, using the shield metal arc welding (SMAW) technique with high manganese electrode (DIN 8555: E 7 UM-200K) having 4 mm diameter. The hardfaced specimens were cooled with water to prevent the possible formation of manganese-carbide precipitation. The welding parameters are given in Table 2.

2.2. Metallography and hardness measurement

The specimens were prepared using standard metallographic techniques, involving grinding with successive silicon carbide papers with 1200-grit finish. The polishing was carried out with diamond paste to obtain a surface finish of $1 \mu\text{m}$. The polished specimens were subsequently etched with 2% Nital. Scanning electron microscopy (SEM), optical microscopy and micro

Table 2
Welding parameters

Current (A)	Voltage (V)	Travel speed (mm s^{-1})
160	24	1.1

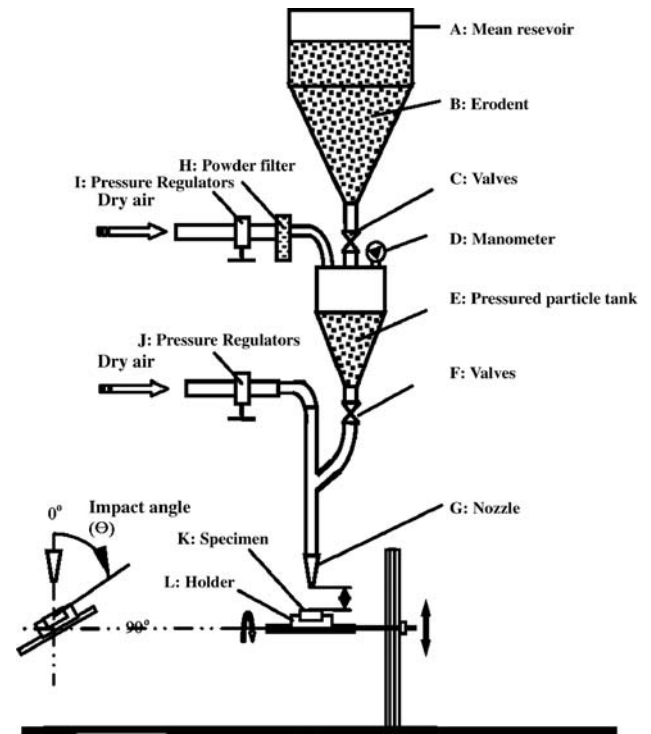


Fig. 1. Schematic illustration of the erosion test rig.

vickers hardness scanning were used to differentiate between the various phases in the microstructures of the weld overlays.

Hardness measurements on the weld overlays were performed at least five times, before, after and during erosion tests in Brinell hardness scale for all the layers. Average hardness values were compared.

2.3. Erosion test procedure

Samples with the sizes of $20 \times 20 \times 10$ mm used for erosion tests were cut from the welded specimens. The surfaces of the layers were ground and polished prior to the tests. The erosion tests were conducted at impact angles by changing the orientation of the sample with respect to the stream of the impinging particles, using erodent particles of nominal diameter of $420 \mu\text{m}$. The impact angles were set at three different values of 30° , 60° and 90° , respectively. The particles were angular steel grits (SAE No: G40), with hardness of 55 HRC and uniform martensitic microstructure, at a density of 7.2 g cm^{-3} . The steel grits were blasted onto the surfaces through a blast rig shown in Fig. 1. The impact angle was defined as “ θ ” in the

Table 3
Chemical compositions of weld deposit layers, wt.%

Layer	C	Si	Mn	Ni	Fe
First	0.35	0.12	4.95	1.20	Bal.
Second	0.49	0.11	8.10	2.10	Bal.
Third	0.67	0.10	12.4	2.75	Bal.
Layer ^a	0.70	0.10	13.0	2.80	Bal.

^a Given by producer for triple pass weld overlay.

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