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Fabrication of Fe/TiC Surface Composite on Carbon Steel Using SMAW Process

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1- Introduction

One of the most effective ways to improve the mechanical properties of the industrial parts is composite making. TiC ceramic particles have high hardness and thermal stability and can used to reinforce Fe-based composites. Conventional coating methods such as chemical vapor deposition (CVD) and physical vapor deposition (PVD) are not suitable for applications that need a thick layer of coating. In addition these processes are complex, expensive and not practical for large industrial components. Recently, new attempts have been made by arc welding process to achieve surface composite because this process are inexpensive and easy to apply. In the present study, an attempt has been made to prepare TiC reinforced composite coating by direct reaction of the mixture of graphite and ferrotitanium powders on an AISI 1045 steel substrate during SMAW process, rather than the TiC particles being directly added into weld pool.

2- Experimental

In this study AISI 1045 carbon steel with dimensions of 100mm × 50mm ×8mm was used as substrate material. AISI 1005 steel tubes filled with the reactant materials (ferrotitanium and graphite) was used to holding the powders and prevent them from oxidation during welding process. The main chemical composition of Fe-based alloy, steel tube and ferrotitanium listed in Table 1. A powder mixture of ferrotitanium and graphite (99.9% purity) with 3 different chemical composition was used as listed in Table 2. In order to obtain homogeneous mixture and increase the possibility of reaction, the combined powders milled for 3h using high-energy planetary mill operated at 600 rpm.

Table 1 Chemical composition of AISI 1045, AISI 1005 steel and FeTi (wt. %)

Element	C	Si	Mn	P	S	Ti	Fe
AISI 1045	0.445	0.216	0.528	0.011	0.013	-	Bal.
AISI 1005	0.050	0.044	0.212	0.014	0.016	-	Bal.
FeTi	≤0.1	-	-	≤0.02	≤0.002	70	Bal.

Table 2 Chemical composition of powders

Sample	Atomic ratio C:Ti	FeTi (wt%)	C (wt%)
1	45:55	87	13
2	50:50	85	15
2	55:45	82	18

Finally, the AISI 1005 steel tubes filled with the milled powders and placed on the substrate material. The amount of powder filled in the tubes was measured about 0.5 grams per cm. Cladding was conducted using the SMAW process, which is presented in Fig. 1. An AWS A5.1: E7018 electrode with thickness of 3.5mm was used. The welding parameters were as follows: welding current 120 A, electrode traveling speed 0.1mm/s and DCEP polarity. Samples were cut using electrical discharge machining (EDM). Optical and scanning electron microscopes were used for microstructural analysis and X-ray diffraction for phase analysis. The Vickers hardness of the cladding was measured to determine the effect of primary powder chemical composition.

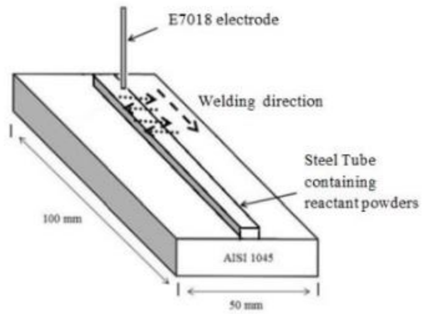

Fig. 1 Schematic representation of welding cladding

3- Results and Discussion

Thermodynamic analysis and prediction

Fig. 2 shows the change in the Gibbs free energy for possible reactions as function of temperature. It can be seen that Gibbs free energy formation of TiC is always negative and lower than Fe_3C, FeTi and Fe_2Ti. It can be seen that TiC has stronger carbide formation tendency compared with Fe. So, TiC formation is possible in Fe-Ti-C system. It should be noted that Ti has a strong tendency to form oxide. The primary powders should be kept away from oxygen during the process. Therefore, steel tubes were used in this work.

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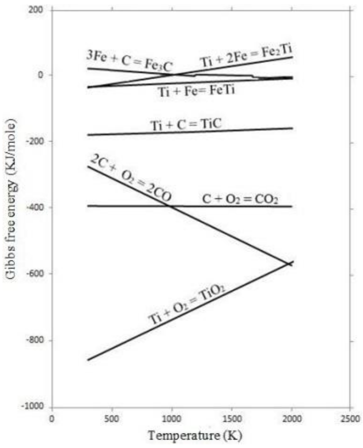

Fig. 2 Gibbs free energy of formation of possible reaction

Microstructure and hardness of coating

Fig. 3 shows the SEM micrograph of TiC particles in samples. It can be seen TiC particles are mainly cubic. Comparing (Fig. 3a, 3b and 3c) indicates that with increasing carbon to titanium ratio in primary powder, size and volume ratio of TiC in coating were increased. Maximum size and volume ratio of TiC particles was observed in sample 3 with carbon to ferrotitanium ratio 18 to 82 respectively.

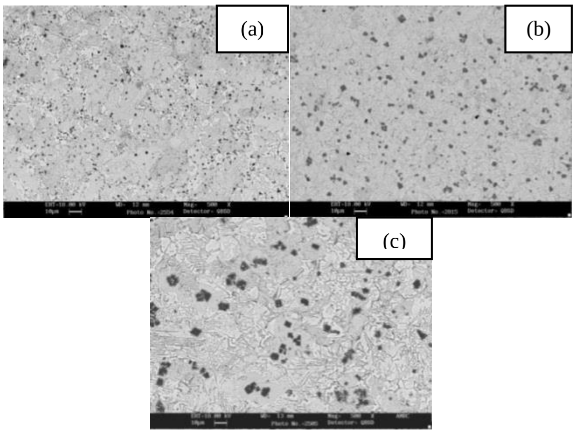

Fig. 3 SEM micrographs of coating with different chemical composition of reactant powders (a) sample 1(C13 FeTi87) (b) sample 2 (C15 FeTi85) (c) sample 3 (C18 FeTi82)

Fig. 4 shows the X-ray diffraction pattern of composite coating, presence of TiC can be clearly seen, indicating formation of TiC particles in composite coating. In addition α-Fe and Fe_3C peaks were also present.

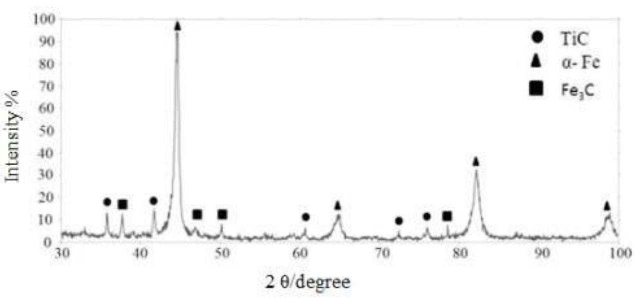

Fig. 4 XRD spectrum of composite coating

Micro hardness of samples was measured across the transverse section from top of coating to substrate (along A-B line in Fig.5 (a)). Fig. 5(b) shows that hardness of the coating gradually decrease from top to bottom of the coating. It can be attributed to decrease of TiC from top to bottom of coating. The main reason is that the density of TiC is much lower than molten steel and TiC particles tent to segregate to the upper regions in coating. The density of TiC and molten steel are reported 4.90-4.93 g/cm^3 and 7.1 g/cm^3, respectively.

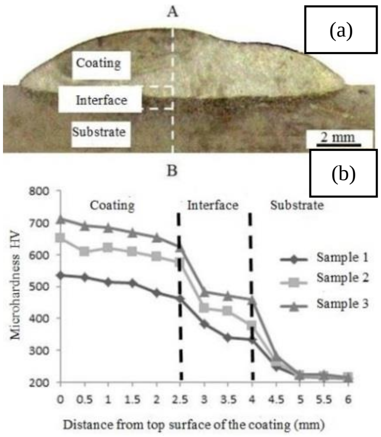

Fig. 5 (a) Macrograph of coating (b) micro hardness of the coating along A-B line

4- Conclusions

SMAW process has produced Fe-based composite reinforced by TiC particles, which formed from reaction of graphite and ferrotitanium. Results showed that maximum size and volume ratio of TiC reinforced particles was achieved in sample with graphite to ferrotitanium ratio of 18 to 82 and the maximum hardness of the coating (712 HV) was obtained by mentioned chemical composition.