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Weldability of class 2 armor steel using gas tungsten arc welding

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ABSTRACT

Purpose: In this study, microstructural and mechanical evaluations of class 2 armor steel after single-pass and pre-heated/single-pass welding were investigated to reveal the effect of pre-heating on heat affected zone (HAZ) in thin armor steel parts.

Design/methodology/approach: In this research, class 2 armor steel parts were welded using single-pass and pre-heated/single-pass conditions to examine optimal welding parameters in relatively thin parts. Welded specimens were investigated using optical microscopy and Vickers hardness tests. Optical micrography was used to characterise transition sites of base metal, HAZ and weld zone. Hardness test was conducted to characterise homogeneity of welding in terms of mechanical properties.

Findings: The results have shown that pre-heat/single-pass welding of armor steel could provide homogeneous hardness distribution along welding region. Similar microstructures and mechanical properties were found in base metal and HAZ.

Practical implications: Armor steel was succesfully welded using GTAW without any defects either in weld seam or HAZ.

Originality/value: Weldability of class 2 armor steel using gas tungsten acr welding was investigated.

Keywords: Gas tungsten arc welding; Welding parameters optimization; Armor steel; Microstructure; Hardness test

MATERIALS MANUFACTURING AND PROCESSING

1. Introduction

The earliest monolithic armours were derived from the 0.25 weight per cent carbon nickel-chromium steels that were used in the face-hardened naval armours used in armoured battleships. These were used at varying hardnesses up to 650 HB, but normally at lower hardnesses. Process details were included in the description of the steels, such as the comment that finish rolling of the steel had to be carried out at 850°C. In a 1941 review of alloys for armour it was emphasised that steels had to be carefully processed, for example by using electric arc manufacture, in order to prevent cracking and spalling at armour hardnesses. These were around 300-330 HB for thick armour, although thin armours could be produced up to 390 HB for machinable armour and 440-475 HB for hard armours. Carbon contents varied, with a tendency to reduced carbon values in the more modern steels in order to aid welding, the maximum reported being 0.53 weight per cent for a German chromiummolybdenum steel heat treated to a hardness of 350 HB. These armours were produced to military specifications and their supply was restricted to approved customers [3].

Armoured vehicles have large number of joinings due to their complex structure. Welding is one of the most widely used joining process in combat and logistics vehicles [3, 4].

Choosing correct combination of welding parameters and filler is crucial in field performance of armoured vehicles. Class 1 armour steels are designed to resist to penetration of a projectile while Class 2 armour steels are designed to resist to explosions [6].

The multiple interactions of diverse types, e.g. physical, chemical and mechanical, established during arc welding are nowadays far from being understood yet. However, significant progress has been accomplished on the most important interactions controlling the processing–structure–properties relationship for some classical welding processes of rather simple ferrous alloys, particularly, low-alloy structural steels. Armour steels are mostly used in armoured combat and logistics vehicles. Despite of recent researches focus on the use of different steel types and composite materials, armour steels have a great importance in mass production [5].

Steel armours are advantageous due to their high strength potential and weldability when compared to aluminium alloys. Although, coarse and inhomogeneous carbide distribution results in lower impact toughness, thus, pre-heating and multi-pass welding could be used to prevent it [2, 9].

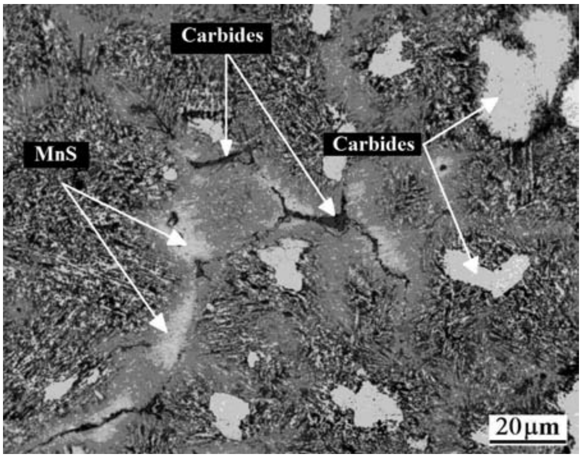

Fig. 1. Microstructure of as-cast specimen [1]

2. Materials and method

In this research, Class 2 armour steel parts were welded using single-pass and pre-heated/single-pass conditions to examine optimal welding parameters in relatively thin parts. Armour steel parts were produced in high frequency induction furnace and cast into resin-bonded sand mould. Specimens were then machined into 5x10x100 mm dimensions, cut into two pieces (5x10x50 mm) and gas tungsten arc welded (GTAW) using a low-alloyed high-strength steel filler rod (AWS A5.5:E 8018-B2). Filler material was chosen depending on previous works [1].

Chemical compositions of typical and cast armour steels were given in Table 1.

Test parts were welded using 70 A current and 10 l/min argon flow. (A) parts were single pass welded. (B) parts were pre-heated to 100°C and then single pass welded. Welded specimens were investigated using optical microscopy and Vickers hardness tests. Optical micrography was used to characterise transition sites of base metal, HAZ and weld zone. Hardness test was conducted to characterise homogeneity of welding in terms of mechanical properties.

3. Experimental results and discussion

Segregation is generally inevitable in castings which results in degradation of mechanical properties. Armour steels without annealing have significantly MnS segregated sites. In present study, no heat treatment was conducted in weld region to examine the characteristics of HAZ. Microstructure of as-cast test parts was given in Fig. 1.

Previous studies have shown that approximately 2% $M_{23}C_6$ and 0.5% MC carbide formation. Microstructures of HAZ of parts single-pass welded (A) and pre-heated/single-pass (B) were given in Fig. 2a and Fig. 2b. Fine grained microstructure was resulted due to rapid cooling. However higher hardness alone is not a significant property in steels used in armoury equipments since it does not have direct influence in fracture strain [7, 8].

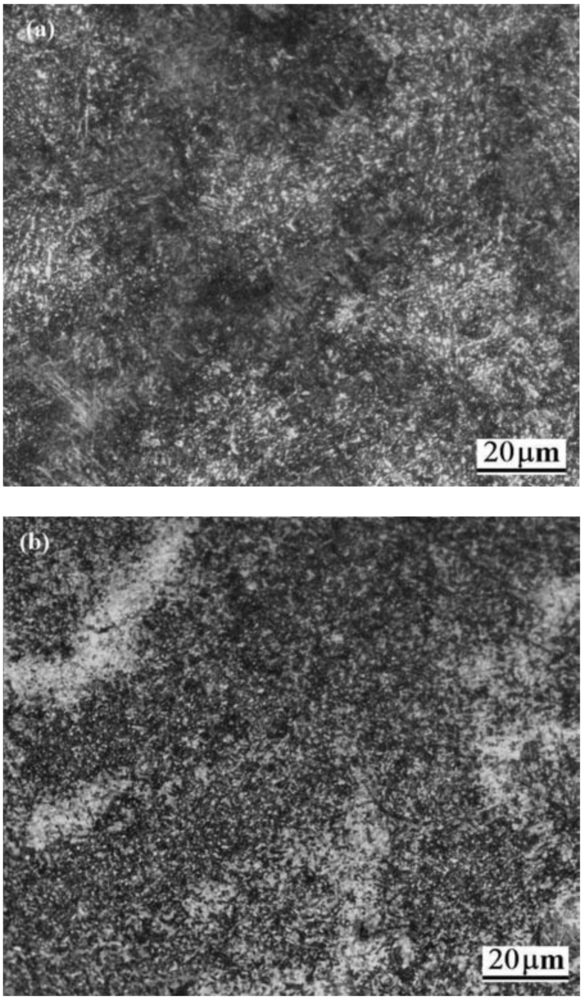

Fig. 2. Microstructures of HAZ of parts single pass welded (a) and pre-heated/single-pass welded (b)

Table 1.
Class 2 armour steel compositions according to MIL MIL-A-11356F and used in experiments

Element	C	Mn	Si	P	S	Cr	Ni	Mo	V
% (wt) Standard	0.30	0.50	0.50	0.05	0.05	0.70	0.70	0.20	0.10
% (wt) Experimental	0.28	0.45	0.50	0.006	0.02	0.67	0.74	0.22	0.08

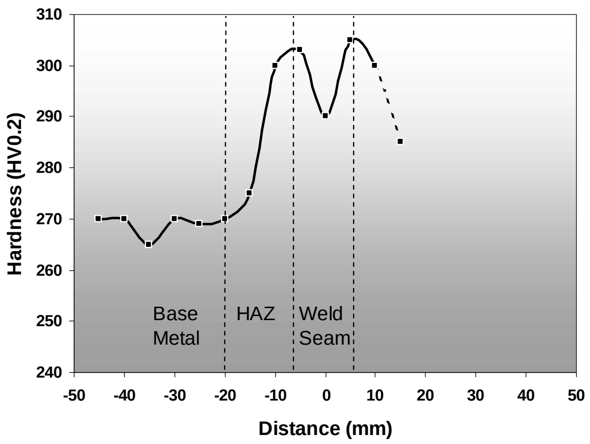

Fig. 3. Hardness distribution in pre-heated/single-pass specimen

HAZ regions have shown different microstructural characteristics due to different cooling rates. HAZ in single-pass welded specimens was achieved as partially martensitic. However HAZ in pre-heated specimens has shown a structure similar to tempered martensite. The hardness of base metal was measured as 270 HV which is typical for as-cast Class 2 armour steel. Hardness in HAZ of single-pass welded specimens was measured as 460 $HV_{0.2}$ and hardness in HAZ of pre-heated specimens was measured as 300 $HV_{0.2}$. Hardness distribution in pre-heated/single-pass specimen was given in Fig. 3.

4. Conclusions

In this research, Class 2 armour steel has been gas tungsten arc welded using AWS A5.5:E 8018-B2 (DIN 8575:E CrMo1 B26) filler electrode. Results have been concluded below:

- Armour steel was successfully welded using GTAW without any defects either in weld seam or HAZ.
- 5 mm thick armour steel can be welded with pre-heated/single-pass conditions successfully.
- Hardness of HAZ (in all specimens) was observed higher than both weld seam and base metal owing to carbide precipitation and martensite formation in all welding conditions. Pre-heated specimens have shown lower hardness because of lower cooling rates.
- Consistency of mechanical properties in HAZ was higher in pre-heated/single-pass welding.
- Pre-heated/single-pass welding was found necessary and sufficient in GTAW of armour steel below 10 mm in thickness. Multi-pass welding was not found necessary depending on the previous studies.

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