EXPERT TECHNOLOGY TOOLS

WTIA

Welding Technology Institute of Australia

TGN-R-01

Welding Austenitic Manganese Steel Rail

1. OBJECTIVE

This document provides information on the properties and welding of Austenitic Manganese Steel (AMS) components. It is intended for welding and engineering personnel involved in the fabrication or repair of AMS rail components.

2. ALLOY DESCRIPTION

AMS is widely known as Hadfield steel and is highly alloyed containing 11-14% manganese and approximately 1.2% carbon. The alloy was discovered and pioneered by one of the world's leading metallurgists, Robert A. Hadfield, in 1882. This was the first alloy steel that was extremely hardwearing and proved the perfect material for early railway track components. Currently it has applications in railway track particularly at crossings where resistance to high metal-to-metal wear and impact loading is required.

AMS is characterised by high strength, high ductility, and good wear resistance. As an austenitic steel it is non-magnetic, unless it has been work-hardened. On this latter point it should be pointed out that this steel has a large capacity to work harden and is widely used in equipment and parts that are subjected to heavy impact and compressive loads. In rail applications the loading tends to be high compressive loads. With AMS, these loads actually harden the new surface as the old is slowly worn away

3. RAIL APPLICATIONS

AMS is primarily used at switches and diamond crossings where high transverse axle loads produce high compressive loads and metal to metal wear.

Figure 1 Cast AMS monoblock vee crossing with factory welded rail ends

AMS finds applications at crossings because it has the following features and properties:

- resistant to severe impact and abrasion;
- work hardens rapidly under the influence of impact and abrasion and can reach surface hardness levels in the order of 500HV;
- retains good toughness;
- exhibits a low coefficient of friction in metal-to-metal applications;

AMS rail components are generally cast and maybe welded to standard rail for ease of installation, figure 1. Castings can contain defects such as shrinkage voids, porosity and inclusions that can result in failure during service and require weld repair.

4. TYPICAL PHYSICAL PROPERTIES & CHEMICAL COMPOSITION OF AMS

Yield Strength: 350Mpa Tensile Strength: 800-1000Mpa Elongation in 50mm: 35% to 50% Hardness: 180HV after quenching from 1000-1050^{o}C Work Hardenability: From 180HV up to 580 HV	Manganese: 12-14 % Silicon: 0.6%Max. Carbon: 1-1.25% Phosphorous: 0.05% Max. Sulphur: 0.04% Max. Iron: Balance

5. METALLURGY AND WELDABILITY OF AMS

The addition of 12 to 14% manganese to steel results in it assuming an austenitic microstructure as opposed to a ferritic-pearlitic microstructure common to carbon-manganese structural steels. One feature of an austenitic microstructure that is present in both austenitic stainless steels and AMS is that they are non-magnetic. This provides a simple sorting method to differentiate AMS crossings from ferritic steel ones. It should be noted however that AMS may exhibit a certain degree of magnetism which is indicative of the level of work hardening on the surface.

AMS are weldable but they are susceptible to carbide precipitation and embrittlement unless specific precautions are carried out.

AMS can dissolve more than 1% carbon within the austenitic microstructure at high temperatures. When the steel is cooled rapidly, the carbon is retained in solution. However, when the steel is cooled more slowly or when reheated to 260°C or higher, carbide precipitation occurs both within the grains and along grain boundaries resulting in embrittlement. The extent of embrittlement is related to the amount of carbide precipitation that in turn is dependent on the time and temperature – the higher the temperature the less time is needed to cause embrittlement.

When welding AMS, severe embrittlement can occur due to excessive carbide precipitation when cooling or reheating in the 450-900°C-temperature range. This embrittlement can occur in both the weld metal and heat affected zone.

Thus, from a welding perspective, it is necessary to avoid pre-heat, keep welding heat inputs low, keep interpass temperatures low and keep cooling rates rapid. Low interpass temperatures and rapid cooling rates are contrary to welding traditional structural steel!

If austenitic manganese steel is rapidly cooled the austenite work hardens rapidly under impact and the deformation of the surface layers due to the precipitation of a network of finely dispersed carbides. The carbide network is fine and well scattered so the tendency for embrittlement is only slight, but it results in a significant increase in hardness and wear resistance. It is for this reason that austenitic manganese steel is often supplied in the quenched condition.

6. WELDING AMS

6.1 General

There is a range of welding consumables that can be used to weld AMS but most welding supply companies supply specific welding consumables for AMS track components. <u>Welding consumables used for structural steel cannot be used to weld AMS since they will pick up carbon and manganese during welding which will result in weld metal cracking.</u>

Welding AMS with welding consumables of matching composition are also susceptible to carbide embrittlement and are generally unsuitable for multi-pass welding applications.
The FeMn welding consumables have been modified with additions of nickel (American designation = EFeMn-A) to produce welded deposits with superior toughness and superior tolerance to slower cooling rates even though quenching is still required to get the best toughness.

Additions of Molybdenum (EFeMn-B) produces welding consumables with superior toughness and yield strength and have applications in railway crossings.

In a recent study, the Lincoln Electric Co. supplied a 12-14 percent manganese electrode along with stainless steel electrode to seal cracks that were in the original castings. The stainless steel electrode was used only in the flange ways and deep in the bottom of the casting prior to the build-up with the manganese-based electrode. The study results of the stainless steel bead, used to seal a crack prior to build-up with the manganese electrode, show that the cracks in the base casting grew along the austenite boundary until they reached the stainless deposit. This deposit retarded the growth of the cracks and protected the weld deposit. Changing the technique to include a light layer of 308L or 312 stainless steel can improve the performance of such weld repairs according to Lincoln Electric. Study results indicate that a protective layer of stainless can protect the frog repairs and last three to four times longer than unprotected repairs.

6.2 Surfacing and rebuilding AMS

The AS 2576 12XX AMS consumables are also generally used for surfacing applications. Local loss of manganese can occur near the fusion zone when surfacing carbon steel with AMS resulting in martensite production and cracking. A stainless steel butter layer may be required in such circumstances. Welding supply companies supply specific welding consumables for rail applications.

In rebuilding AMS track components it is necessary to remove about 3 to 4mm of a work-hardened surface before hard-facing or building up a worn area. Failure to do so will result in weld bead spalling. Spalling is a time dependent process that first manifests itself as HAZ cracking followed by crack growth and eventual “shelling” (breaking out) of the repair weld. Grinding is a time consuming but vital part of the repair process.

6.3 Welding AMS to dissimilar metals

If arc welding a rail steel to AMS the rail steel must first be buttered with a welding consumable that is compatible with both AMS and the dissimilar metal. E308L or E312 austenitic stainless steel consumables can be used as a buttering layer on AMS <u>and</u> rail steel. For buttering AMS low heat input and no preheat is used. When buttering rail steel preheat (typically 350^{0}C) and slow cooling will be required. The E308L (and E312) designation is a generally available consumable that can be welded to both AMS and rail steel.

6.4 Welding Technique

Before rebuilding an AMS component check the worn part with a magnet. If the wearing part is strongly magnetic, grind or arc-air gouge to remove the magnetic material. This is important because work hardened manganese steel is more susceptible to embrittlement than it is in the soft condition. Note that arc-air gouging results in significant heat input so the maximum interpass temperature restrictions for welding need to be applied here. Any region that has been arc-air gouged needs to be dressed by grinding. Areas that cannot easily be indented with a centre punch should be ground out.

During welding, keep the heat input low by welding at high speed with a maximum inter-pass temperature of 260°C. When welding with MMAW, the weld beads should not be wider than 3 times the diameter of the core wire. The temperature of the zone 12mm away from the weld should not be allowed to exceed 260°C. Skip weld on the surface to disperse heat uniformly throughout the part is one way to keep temperatures to a minimum. However inter-pass temperatures are often kept down using water sprays or by keeping the component to be welded partially submerged in water during welding. Caution must be exercised when using water to keep interpass temperatures down; generation of steam can result in welding defects.

7. NDT

NDT must be carried out prior to weld repair to ensure complete removal of cracks. Spalling of repairs is often the result of incomplete or inadequate crack removal. Dye penetrant inspection is generally used to inspect for crack removal. Ultrasonic testing can be used on completed AMS welds but difficulties are encountered when inspecting dissimilar joints due to the acoustic velocity and attenuation variations existing between austenitic and ferritic steels. Similarly ultrasonic sizing of sub-surface defects prior to weld repairs is a difficult task. Ultrasonic inspection is limited to technicians with specific competence in rail inspection. Surface inspection for cracks or lack of fusion can be carried out with dye penetrant inspection.

8. WELDING PROCEDURES AND WELDER QUALIFICATION

Detailed welding procedures need to be developed prior to AMS welding. Close control of welding parameters is important and the methods used to control interpass temperature need to be well documented. For weld repairs, instructions on defect removal and preparation for welding are required. The methods by which complete removal of defects is assured is a vital part of developing repair procedures. Weld macros will be required for both welding procedure and welder qualification to demonstrate adequate fusion, absence of porosity and slag inclusions and a satisfactory HAZ microstructure.

9. OCCUPATIONAL HEALTH AND SAFETY

Fume and dust control precautions are required when welding and grinding AMS. Refer to the fume minimisation guidelines available free of charge from the WTIA website www.wtia.com.au for general information and WTIA Technical Guidance Note TGN-R-02 for specific guidance on fume control for AMS.

10. SERVICE PROBLEMS

Spalling as a result of rolling contact fatigue between the rail wheels and the track can occur when weld repairs are carried out with insufficient grinding beforehand. Horizontal cracks can develop below the surface. Continued service results in vertical fatigue cracks propagating from the ends of the horizontal crack, and eventual separation of a large piece of material (shelling), Figure 2. The sharp-edged cavity can cause damage to rail wheels passing over it which diminishes as further wheels blunts the edge of the defect.

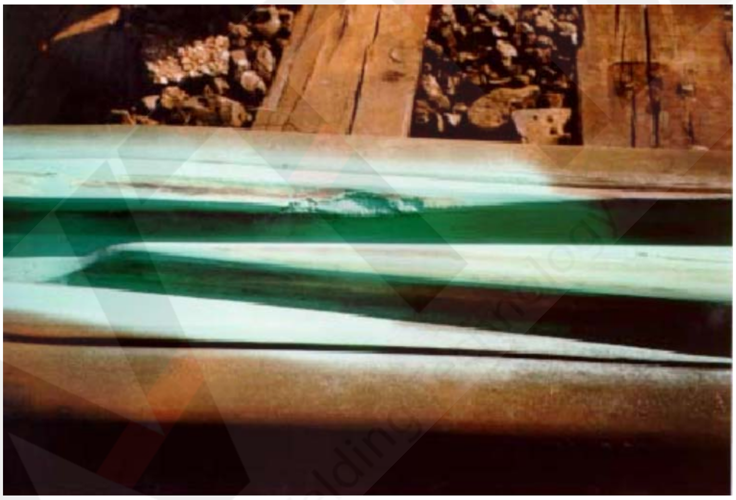

Figure 2 Spalling damage as a result of contact fatigue

REFERENCES

TWI - Tough repairs - technical advice casebook
www.stulzsicklessteel.com
WTIA Technical Note 4 “The Industry Guide to Hardfacing for the Control of Wear”
WTIA Technical Note 18 “Welding of Castings”
AWS 5.13 “Specification for solid surfacing welding rods and electrodes”
ASW Welding Handbook Volume 4 “Materials and Applications”
AS 2576-2002 “Welding Consumables for Build Up and Wear Resistance”
TSB Report Number R95T0259

WTIA Welding Technology Institute of Australia
ABN: 69 003 696 526
PO Box 6165, Silverwater NSW 1811
Unit 50, 8 The Avenue of the Americas, Newington NSW 2127
Ph: +61 (0) 2 8748 0100 Fx: +61 (0) 2 8748 0181 Email: info@wtia.com.au Webpage: www.wtia.com.au

As a valued technology expert in this area we would like you to be part of the Technology Expert Group to review this note. Please complete this questionnaire so that we can gauge the success of meeting this need.

Objective 1: Identify the need for good welding practice of AMS rail components.

AMS rail components are used at high wear locations such as diamond crossings. This guidance note is intended to provide the Rail Industry with advice on producing sound repair welds. How well does the document achieve these aims?

poor ☐ average ☐ good ☐ very good ☐

Comments:

____

Objective 2: Identify appropriate technology receptors

This document was written for Maintenance Engineers, Maintenance Contractors and Welding Coordinators in the Rail Industry. Are these people the appropriate individuals we should be targeting?

yes ☐ no ☐

What other types of companies and/or personnel do you suggest we target?

____

Objective 3: Identify current best practice for welding AMS

The document was written to reflect current best practice for the welding of AMS rail components. Do you envisage opportunities for the use of this practice in industry?

yes ☐ no ☐

If yes, what and where, if no why not?

____

Objective 4: Is the information provided clear, concise and accurate?

yes ☐ no ☐

If not, why?

____

Objective 5: Broad dissemination of technology to the Rail Industry

Please indicate how best to disseminate this Technical Guidance Note to the appropriate Industry Recipients

Free Website Download ☐ Poster☐ Pocket Guide ☐ Pamphlet ☐

If poster, what size? A1 ☐ A2☐ A3 ☐ Laminated ☐ What selling price? $

If a pocket guide, what selling price? $

Other format?

____

Objective 6: Continuous Improvement

Please Identify areas where the document can be improved or return the document with your recommended additions/amendments. Alternatively, please use the area below to provide any additional comments.

____

____

____

____

____

____

____

____

____

____

____

*Respondents Name:*________________*Company:* _________________*Phone:* ____________________

Fax: ___________________________*Email:* ___________________________*Date:* _______________

Please Fax (02 8748 0181) or E-mail (info@wtia.com.au) your feedback. Thank you.