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FCAW process to avoid the use of post weld heat treatment

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Abstract

Post weld heat treatment (PWHT) is the most common technique employed for relieving residual stresses after general repair welding. Besides, the primary purpose of reducing the effect of stresses induced by welding, PWHT is also intended to temper the metallurgical structure of the heat-affected zone (HAZ). Unfortunately, there are significant difficulties in carrying out post weld heat treatment such as; the complexity of weld geometry, the possibility of distortion in the case of any mechanical loads, difficulty in heating symmetrically, and also PWHT may cause degradation of the material properties (especially creep and tensile strength in the case of multi PWHT cycles). Most of the repairs in industry are performed with manual metal arc welding (MMAW), however, the benefits of the flux cored arc welding (FCAW) process have been appreciated by industry for many years.

Guidelines in the current welding standards in addressing the issue of temper bead welding (TBW) when fully automated flux cored arc welding is used are very limited. This paper reports research work carried out to investigate, whether a fully automated flux cored arc welding process with bead tempering can be used in repair welding instead of manual metal arc welding in order to eliminate the use of post weld heat treatment. The paper also examines different percentages of bead overlaps and studies their effects on the mechanical properties as well as the microstructures. The results show that desirable microstructures and hardness values can be obtained using flux cored arc welding when 70% bead overlap is used.

Keywords: Temper bead welding; Flux cored arc welding; Bead overlaps; Post weld heat treatment

1. Introduction

TBW has been accepted and employed as an alternative technique for PWHT [1–4]. TBW is affected enormously by welding parameters such as wire diameter, heat input and bead overlap [5,6]. Bead overlap is considered to be one of the most important factors that needs to be controlled in order to achieve a high percentage of refinement. Bead overlap in any repair welding and especially near the toe areas is very important in softening hard microstructure [7,8]. Repair welding in the industry is carried out by using 50% bead overlap due to its practicality, however, recent development in automated welding allows the use of different percentages of bead overlap precisely [9]. Unfortunately, there are limited number of detailed studies that focus on bead overlaps and their effects on microstructure and hardness. This paper studies different percentages of bead overlaps and examines their effects on the hardness as well as the microstructures of the HAZ.

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1.1. Post weld heat treatment (PWHT)

In repair welding, residual stresses may approach the yield point of the steel and undesirable microstructures may also be present due to fast cooling rates. Both situations are considered detrimental to the performance of the weld repair. PWHT is the common process for relieving residual stresses which are locked into a component after it had been repaired by welding. PWHT is also performed to temper hard and un-tempered microstructures such as martensite.

The Australian Standard AS4458-1997 for example, states that PWHT is intended to reduce residual stresses, improve resistance to brittle fracture and stress corrosion, and it is also intended to achieve or restore the material properties required for the design and service conditions. Another major role of PWHT is diffusing hydrogen trapped in the weldment as the weld metal cools and solidifies.

There are many reasons for omitting PWHT altogether in maintenance and repair activities because it is an expensive process, both in the requirements of the equipment and in the duration of the process which may go on for many hours.

1.2. Bead tempering for avoiding PWHT

Several techniques for bead tempering have been developed to modify the microstructure of both weld metal and HAZ in order to improve the as-welded fracture toughness. Among those are half bead and temper bead welding. In the half bead technique, the beads of the first layer are ground back before welding the next layer. In the TBW technique, however, the subsequent weld passes partially heat treat the earlier passes.

The TBW technique was originally developed to minimize the risk of stress relief cracking in the repair and reclamation of Cr–Mo–V steel casting and pipe work. This technique utilizes a controlled method of weld bead deposition to achieve microstructural refinement of the HAZ. The effectiveness of the approach is dependent on the welding parameters used for each layer of the weld [10].

The idea of bead tempering is that the heat of one pass of the weld pool will be used to temper the metallurgical structure of previous beads [9]. The second layer will then be used to control the eventual grain size in the HAZ of the first layer [10]. The final passes of the weld bead may be in an untempered state but these can be removed by grinding. The amount of damage and the depth of material required to be tempered are reduced by using small weld beads, hence small diameter consumables and lower amperages and heat inputs.

A key example of temper bead welding used in Australia is found in the Hazelwood Power Station. In the 1990s, some of Hazelwood station boiler drums (108 mm thick low alloy steel) were repaired (for the second time in some cases) using temper bead welding [1].

1.3. Flux cored arc welding (FCAW)

The Flux cored arc welding process used in the experimental stage is a fully automated process, in which the welding electrode is a tubular wire that is continuously fed to the weld area. The flux materials are in the core of the tube. The outer shell of the tube conducts the electricity that forms the arc and then becomes the filler metal as it is consumed.

Recent studies indicate [4–6,11] that FCAW has a number of advantages over the common welding techniques available that use solid wires such as manual metal arc welding (MMAW) and gas metal arc welding (GMAW). Using FCAW in any repair technique can provide better control over current and heat input that is necessary to carry out the temper bead repair, which is discussed in more detail in Section 2.

As a fully automatic process, FCAW should also have cost advantages over other commonly used processes. Flux cored arc welding is considered a high deposition rate welding process that adds the benefits of flux to the simplicity of MIG welding.

2. Experimental work

2.1. Consumables

The welds (beads on plate) were carried out on 200×100×12 mm steel plates (AS 3678-250). The welding of these steel plates (nominal chemical composition, as shown in Table 1) was performed by controlling the welding parameters as given in Table 2. The welds were carried out using a fully automated flux cored arc-welding machine with SUPER-COR5 welding electrode, conforming to AWS A5.20. The chemical analysis of the weld metal is given in Table 3. Argoshield 52 was used as an external supply of shielding gas (77% Ar and 23% CO_2).

2.2. Welding procedure

The first weld bead was deposited in the centre of the plate as shown in Fig. 1. The second weld bead was deposited to one side of the first bead after the latter had cooled to ambient temperature. The width of the weld beads varied from 12 mm at the start of welding to 14 mm at the end. The length of weld beads was approximately 165 mm. Fig. 1 shows the dimensions of the first bead. After depositing the first bead, the plate

Table 1
Nominal chemical composition of the parent material (AS 3678-250)

C	Si	Mn	P	S	Cr	Ni	Cu	Mo	Al	Ti	V
0.12	0.13	0.63	0.02	0.01	0.01	0.02	0.01	<0.01	0.03	<0.01	<0.01

Table 2
Fixed parameters used in the experimental work

Electrode diameter (mm)	Current range	Voltage range	Traverse speed (mm/min)	Wire feeding speed (mm/min)	Electrode stick-out distance (mm/min)	Gas flow rate (l/min)
1.6	260–280	28–30	360	3600	20	20

Table 3
Chemical analysis of weld metal using Argoshield 52

C	Mn	Si	S	P	Ni	Cr	Mo	V
0.10	1.73	0.68	0.017	0.019	0.05	0.03	0.04	0.04