STUDIES ON THE WEAR AND CHANGE IN MICROSTRUCTURE OF WELD-JOINT OF A STRUCTURAL STEEL

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ABSTRACT

The wear characteristics of a multi-pass weld-joint, of a low carbon- manganese structural steel has been studied together with the characteristics of its varying microstructure and hardness at different locations. Attempts have been made to correlate the wear characteristics with the varying microstructure and the varying hardness values in the weld-joint. It is observed that the wear characteristics, e.g. wear rate and coefficient of wear resistance are considerably dependent only on the microstructure. The various sub zone microstructures observed in the weld metal and HAZ on a SA weld are spherodized, partially transformed; grain refined and grain coarsened area exhibiting predominantly Widmanstatten ferrite with pearlite, with the others sub zones of HAZ reveal polygonal ferrite and pearlite. Depending on the number, size and distribution of inclusions, the weld microstructure varies because of the prevalence of varying cooling rates in weld metal, a wide range of microstructures such as periodic pearlite, grain boundary ferrite with pearlite and side place with cementite along the side plate boundaries. This study has been performed to investigation on the wear of a weld joint of a structural steel and variations in the microstructure at various regions of heat affected zone base metal and a weld metal.

Key words: Weld, HAZ, Wear, Weld microstructure, HAZ microstructure, Hardness

INTRODUCTION

A weld-joint, comprising of weld metal, heat-affected zone (HAZ) and the parent metal ('metal' indicates here any structural material like steel), exhibits a variety of microstructures at different locations. Each region of the weld-joint possessing different microstructures usually has different mechanical properties such as strength, ductility, hardness and fracture toughness, and also possesses varying amounts of associated residual stresses. Wear behaviour of a material is known to be dependent on its microstructure and/or hardness. However, systematic investigation on the influence of varied microstructure of a weld-joint on its dry sliding wear behaviour is lacking. The present investigation focuses on this aspect and examines the wear behaviour of the weld-joint of a structural steel using a pin-on-disc wear machine. The studies on wear characteristics are supplemented with examinations of the microstructures and hardness values at different locations of the selected steel. An attempt has been subsequently made to correlate wear characteristics of the different locations of the weld-joint with the corresponding microstructures and hardness values.

LITERATURE REVIEW

Automated submerged arc welding is a versatile process, as it gives best quality, saves time, reduces cost, resurfaces wear surfaces on steel castings, improves repair procedure, process control, increases efficiency and productivity[1]. Kolhe K.P. and Datta C.K. studied the effect of welding variables to control the dimensions and properties of weld bead surface to see the impact of wear on the welded metal surface[2]. Dennis et al reported the application of narrow groove submerged arc welding to remove a radical crack in the kiln tyre. As the crack grows from the inside diameter surface, the fatigue crack developed large gouge on the inside surface known to form by complex wear mechanism, and the groove was filled using a constant layer thickness approach where seven to eight beads were typically required per layer, and two 152.4 mm-thick mock-ups with weld groove extension[2]. Richard Lafave and Richard Wiegand reported the application of SAW for economical repair of turbo machinery shaft; the repair process has considered three important attributes,

1) The ability to produce ultrasonically clean weld deposit.
2) High deposition rate requires deposition of hundreds kilograms of weld metal for the typical repair.
3) It eases mechanization and operation.

The analytic approach requires unit-operating conditions be understood so that operating stresses, typical component characteristics and failure mechanism can be determined using tools such as finite element modeling[3]. Mallya U.D and Srinivas H.S. revised the literature to show heat input was the sole variable on the variation of bead characteristics. They correlated welding variables with bead characteristics. On increasing current, bead width, height and penetration increased, while increasing voltage, bead width increases but bead height and penetration increased between 24V to 26V and decreased between 26V to 30V and remained constant after 30V. With travel speed bead width and penetration increased; while height decreased[4]. However, in present investigation it is observed that on increasing travel speed, bead width, height and penetration decrease. Kotecki D J and others studied the effects of bead to bead stepover, wire size, wire feed, speed, voltage, flux chromium contents and polarity on dilution and ferrite in single wire submerged arc cladding of ER309L on mild steel plate. It was reported that, dilution found, to be promoted by reduced step-over[5-7]. Kotecki D. J. has clearly demonstrated that the usual choice of type 309L filler metal for joining mild steel to 304 (or other austenitic stainless steels) is not without considerable risk in SAW[8]. Kim J.H and others, conducted experiments on the influence of process parameters, on oxygen transfer in submerged arc, shielded metal arc and gas tungsten arc welding which showed both electrochemical and thermo-chemical reactions are active in direct current arc welding and electrochemical reactions are significant in certain ranges of welding parameters. Welding current and weld travel speed are both important factors in the control of electrochemical oxygen transfer[9] Eroglu M. and Aksoy M. studied effects of nickel content along with varying heat input on the microstructure and mechanical properties of HAZ of low carbon steel. Low heat input gives the highest hardness value in grain coarsened heat affected zone (GCHAZ) [10]. Gunaraj V. and Murugan N. suggested the process variables in SAW, to control HAZ dimensions by developing mathematical models for predicting and controlling the dimensions of different regions of HAZ of a weldment, and investigated the effects of heat input, welding speed, arc voltage, nozzle to plate distance, wire feed rate on heat affected zone to show the few results as, 1) Heat input has a considerable positive effect on almost all HAZ dimension 2) Wire feed rate had positive effect but welding speed had a negative effect on all HAZ dimensions[11]. The metallurgical feature that directly affected by heat input rate is the grain size in the heat-affected zone and in weld metal. Grains in the solidifying weld metal grow coherently with grains in the solid metal at the fusion boundary. Therefore; the longer the time spent above the grain coarsening temperature of the alloy in question, coarser the structure in the heat affected zone and in the weld metal[13-14]. The present paper shows the results of an investigation concerning the effects of welding variables on bead characteristics; mechanical properties penetration, HAZ hardness of the weld made by SAW and the metallurgical changes in the weld metal and HAZ on mild steel.

EXPERIMENTAL PROCEDURE

Material and weld-joint

A shipbuilding steel with a nominal composition of C= 0.15%, Si= 0.3%, Mn= 1.3%, P= 0.017% S= 0.008% was used in this investigation. This steel is commonly referred to as B-quality steel and was available in the form of 14 mm thick plates. The weld-joints used in this investigation were prepared by multi pass metal active gas (MAG) welding process. Three weld-joints were fabricated from sample blanks of approximate 150x400 mm size, under identical conditions. The major process parameters of welding are summarised in Table 1.

Macro- and Microstructures

A polished macrostructure of the fabricated weld-joint is shown in Fig 1. Specimen blanks for microstructure, hardness and wear studies were cut from the weld-plate as schematically illustrated in Fig 2. The length, width and thickness of the plate are referred in the figure as L, T and S respectively. The microstructural studies were carried out on sample surfaces having T-S planes and L-S planes. The microstructures were prepared following the standard metallographic practice, followed by etching in 2 % Nital.

Hardness Measurement

The micro hardness measurements were carried out on T-S plane using a digital microhardness tester

Table 1- Major process parameters considered for fabrication of the weld-joints.

Process parameters	Details
Electrode	1.2mm diameter wire electrode, AWS Code: A 5.18-ER 70 S-6
Shielding gas	A mixture of Argon and CO_2 gas in the ratio of 80:20 were used at a flow rate of 18 litres / minute
Welding current	180 Amps (without auto-arc strike current controller)
Welding voltage	Open circuit voltage=30 V, Closed circuit voltage=22.5 V
Weld-joint details	Single V grove with an included angle of 60° and root gap of 6 to 8 mm
Welding position	LG (down hand), with reverse polarity
Number of weld passes	Multi pass welding with four runs, and the root run was welded with a ceramic backing strip of M/s Gulco's product IC 42 D.
Welding speed	120 mm / min for the root run and 150 mm / min for the remaining three runs

(LECO DM 400). These tests were carried out at a load of either 100 or 300-gmf. For an indentation time of 10 s using a Vickers pyramid indenter.

Wear studies

Wear experiments were carried out on a pin-on-disc machine (model: Ducom TR 20). Some of the pertinent details of this machine are summarized in Table 2. Wear data is monitored as specimen height loss and tangential frictional force with respect to time, by electronic sensors and transferred to a computer for recording.

Fig-1 Macro view of the weld-joint.

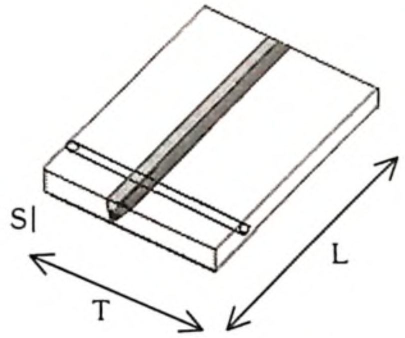

Fig-2 Schematic diagram of weld plate.

The specimen pin for the wear experiment was machined from the weld plates as shown in Fig 2. The L-S plane of the weld-joint was subjected to wear, so that it shows different microstructures along its depth. The pin diameter was 6 mm and the length was approximately 30 mm. The test parameters were selected as follows: 3, 5, 6, 9, 10, 12, 15, 18 kgf, for normal load and 1 m/s for sliding speed. All tests were carried out at room temperature with out lubrication. The worn out surface of the specimen and the wear debris were subsequently studied using a scanning electron microscope (SEM), model JEOL 5800.

Table 2: Details of the pin-on-disc wear machine.

Machine particulars	Details
Disc material and hardness	EN 31, Rc 58 - 62
Disc size	160 mm diameter and 8 mm thick
Track diameter	10 to 140 mm
Range of sliding speed	0.26 to 10 m/s
Maximum wear measurements	2 mm
Maximum normal load	20 Kgf

RESULTS AND DISCUSSIONS

A typical microstructure of the parent metal (on T-S plane) is shown in Fig 3. This exhibits banded ferrite and pearlite microstructure. The microstructures along the weld-joint (on the T-S plane) were examined at different locations. As one examines different microstructures along the weld profile from the base metal to the weld, one encounters varied microstructures sequentially, as depicted in Fig 4 (a) to Fig 4 (d). Figure 4 (a) to (d) shows intercritical HAZ-(ICHAZ), fine grain HAZ (FGHAZ), coarse grain HAZ (CGHAZ) and the weld zone, respectively. ❑