The Influence of Electrode Polarity and Welding Current on Mechanical Properties of Submerged Arc Weld (SAW) In C-Mn Steels

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An experimental study has been carried to study the effect of electrode polarity and welding current on mechanical properties of multipass SAW welds made by using C-Mn filler wire and basic flux. Weld deposits were characterised on the basis of tensile properties, hardness and charpy impact toughness. Hardness survey of the weld revealed that higher hardness occured in the coarse microstructural region than the reheat refined region. For a given polarity, there was an improvement in weld impact toughness as the current decreased from 700 A to 500 A. However the trend was reverse for tensile to be better for DCEP compared to DCEN.

INTRODUCTION

The mechanical properties of SAW joints are governed by proper selection of the welding parameters such as welding current, arc voltage and travel speed and polarity. A variation in these parameters changes the heat input and consequently affects deposition rate, bead geometry and penetration {1-3}.

SAW may be done either by a Direct current (DC) or Alternating current (AC) power source (1,2). It is normally carried out by direct current reverse polarity (Electrode positive, DCEP) because it gives more penetration in combination with good bead shape than that observed with direct current straight polarity (Electrode negative DCEN) However, a change in electrode polarity from DCEP to DCEN is found to increase the deposition rate (2 to 6). Hence from the economic point of view DCEN is appropriate for use in multipass SAW process. The acceptability of the polarity is dependent on its capability to produce a sufficient amount of "reheat refined zone" in weld deposit so that the required mechanical properties of the weld are achieved.

The current literature survey reveals no such systematic investigation on the effect of various welding parameters on the characteristics of weld beads deposited under different polarities in multipass SAW process. Keeping this in view, an effort has been made to study the effect of current on mechanical properties of multipass weld deposit under DCEP and DCEN.

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Experimentation

WELDING DETAILS

C-Mn steel plate of 40 mm thick was used in the present investigation. The weld preparation and test plate assembly is shown in Fig. 1. The plates were welded by multirun SAW process, using a 4 mm diameter copper coated mild steel electrode wire. A basic flux of type LW 710 having chemical composition as given in Table 1 was used. The welding was carried out at different welding currents with the arc voltage and speed kept constant, as may be seen from Table 2.

TABLE 1 : COMPOSITION OF WELDING FLUX LW 710, WT % AGGLOMERTED, FLURIDE BASIC FLUX, BASICITY INDEX : 3.1; MAXIMUM CURRENT : 400 A

SiO_2+ TiO_2	CaO + MnO	Al_2O_3 + MnO	CaF_2
15%	35%	20%	25%

TABLE 2 : WELDING PARAMETERS

Process	:	Submerged Arc Welding
Travel Speed	:	40 cm/min
Electrode Extension	:	30 mm
Flux	:	Agglomerted, Fluoride basic flux
Filler Wire Spec.	:	Class As 4, Grade A
Interpass Temperature	:	175 $\pm$ 20°C

Weldment No.	Welding Current Amp.	Arc Voltage V	Electrode Polarity
1.	500	28	DCEN
2.	500	28	DCEP
3.	700	28	DECN
4.	700	28	DCEP

HARDNESS MEASUREMENT

The Vicker's hardness HV5 of the weld deposit was measured on the etched transverse section of the weld. The hardness measurement was carried out along the centre line of the weld, starting from the top of reinforced bead region up to the bottom of the weld. During the hardness measurement, the Vicker;s hardness indentation has been made in such a way that the behaviour of different microstructural regions coming in the path of measurement can be revealed. After hardness measurement, the specimens are observed under an optical microscope to study the extent to which different microstructural regions are present across the measurement path.

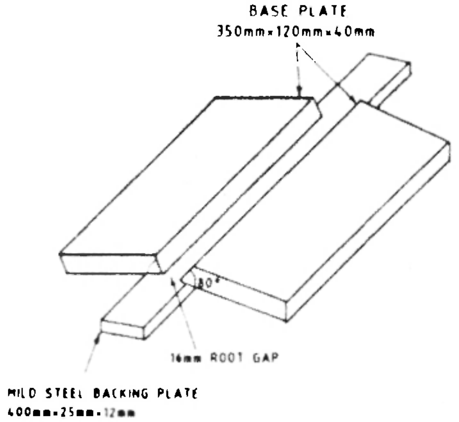

Fig. 1 : Weld preparation and test plate assembly

ALL-WELD METAL TENSILE TEST

The tensile test Specimens as shown in Fig. 2, confirming to DIN 50125 were machined from the weld metal along the longitudinal direction of the deposit. The tensile test was carried out on an universal testing machine. The load Vs elongation plots were obtained and the yield strength, ultimate tensile strength, percentage elongation and percentage reduction in area of the weld metal were estimated.

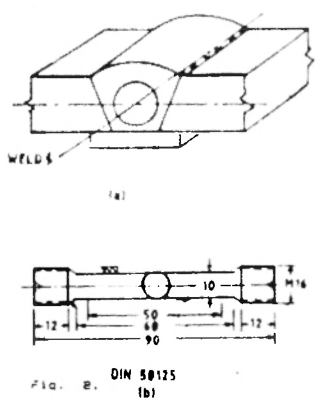

Fig. 2 : Location (1) and dimensions (b) of all weld metal tensile specimen

CHARPY V-NOTCH IMPACT TEST

For the Charpy impact test, samples of weld metal having an orientation to the welding direction were machined conforming to DIN 50115 as shown schematically in Fig. 3. The Charpy specimens were tested at -60°C, -40°C, -20°C, 0°C and room temperature. To obtain sub-zero temperature of the specimen, liquid nitrogen was used. Before breaking the specimen under impact loading, the temperature of the specimen was continuously measured with the help of a surface sensor attached to a digital thermometer and the test temperature and the test temperature was controlled an accurracy of ± 2°C.

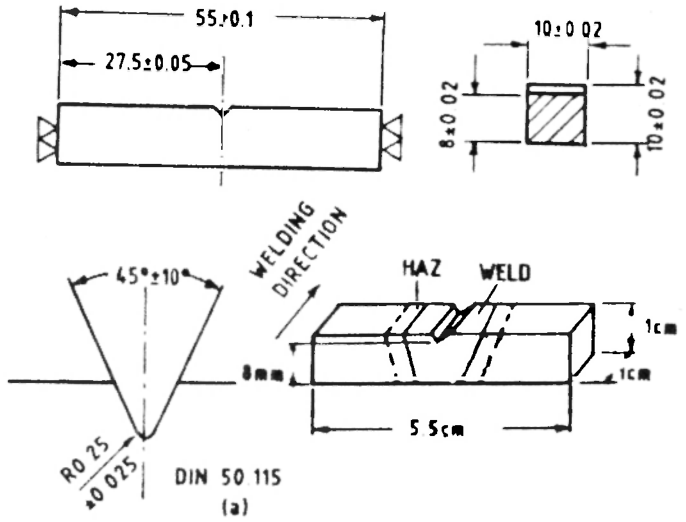

Fig. 3 : Dimensions (a) and Location (b) or Charpy V-Notch specimen.

Results And Discussions

The trend shows a higher hardness in the coarse microstructural region (castcolumnar) in comparison to that observed in the reheat refined region (Figs. 4, 5). This may be attributed to the heat treatment of a certain region of the earlier deposited weld bead by the subsequent run. During deposition of the later bead on the earlier one, a region of the earlier bead nearer to the later one is subjected to a heat treatment due to a rise in the temperature of this region above the recrystallization temperature. This causes the recrystallization and refinement of coarse columnar structure of the earlier bead which reduces its hardness from that of the columnar one [7,8].

At both 500 A and 700 A, a relatively higher average hardness of the weld metal is observed in case of DCEN than that observed incase of DCEP (Table 3).

This may be atributed to the higher deposition rate and also the lower amount of reheat refined, weld metal in case of DCEN as compared to that in DCEP

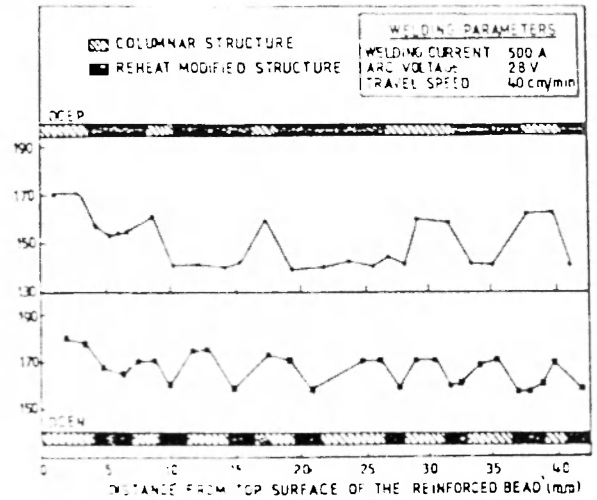

Fig. 4 Hardness distribution from top to bottom along the centre line of the weld measured in the transverse section of weldment

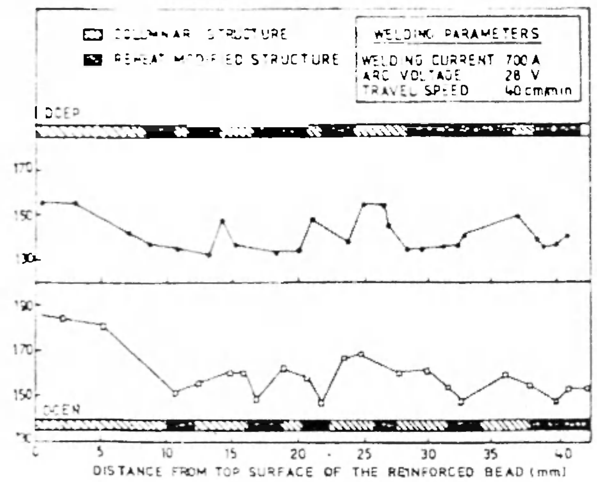

Fig. 5 : Hardness distribution from top to bottom along the centre line of the weld measured in the transverse section of weldment.

TABLE 3 : WELDING PARAMETERS, AVERAGE HARDNESS OF THE WELD METAL

Welding Current (Amps)	Arc Voltage (Volts)	Average hardness of WM, HV 5 DCEN	DCEP
500	28	166.90	148.16
700	28	156.00	140.22

It has been observed that the upper shelf energy of the weld metal is less with DCEN than that observed with DCEP (Figs. 6,7). This is because in case of DCEP, the extent of reheat refined metal is more than that in case of DCEN (Figs. 4,5).

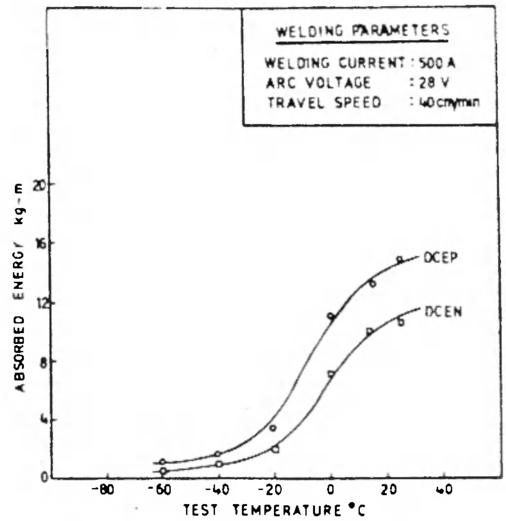

Fig. 6 : Charpy V-Notch impact test results

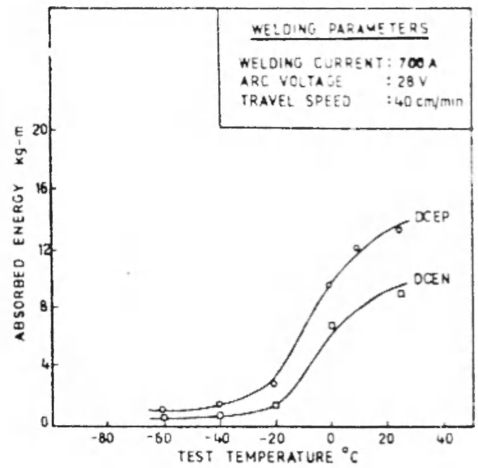

Fig. 7 : Charpy V-Notch impact test results

It was found that impact transition temperature (ITT) is more with DCEN compared to DCEP. This is because ITT decreases with increase in the amount of reheat refined zone in the weld metal, which increases with a decrease in deposition rate.

With a change in current from 500 A to 700 A, there is a decrease of 1.8 kg.m in the upper shelf energy with DCEP (Fig. 8). This is due to the reduction in the amount of reheat refined weld metal in the weld deposit. The same trend is also observed with DCEN.

Yield strength and ultimate tensile strength of the weldmetal are higher with DCEN than that with DCEP. But the percentage elongation and percentage reduction in cross sectional area are less with DCEN than that observed with DCEP (Table 4). This is because of the increase in deposit rate and bead hight reduction in penetration and bead width with DCEN compared to DCEP. The deposition rate and bead geometry directly reflect the amount of reheat refined weld metal.

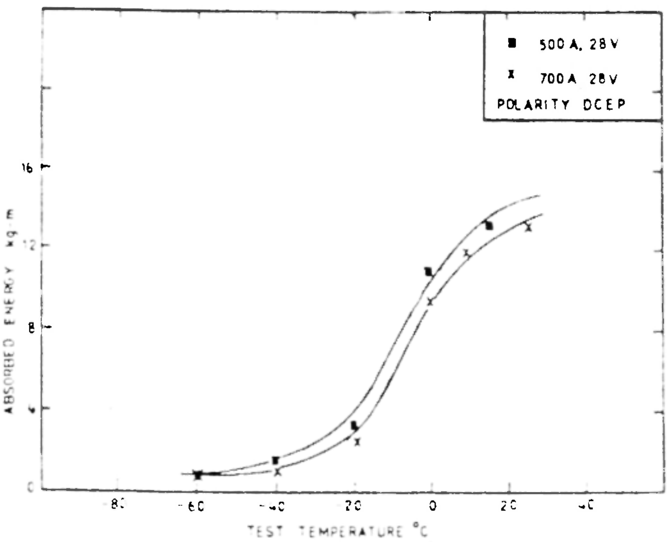

Fig. 8 : Charpy V-Notch impact test results.

Yield strength and ultimate tensile strength decreased and percentage elongation and percentage reduction in cross-sectional area increased with a decrease in welding current from 700 A to 500 A (Table 4). This is because the welds deposited at lower levels of current tend to heat treat (Due to deposition rate) more of the previously deposited structure in relation to the amount of columnar structure they create.

CONCLUSIONS

1. For a given polarity, higher amount of reheat refinement regions in the weld metal were obtained with a decrease in welding current.
2. For given welding parameters, higher hardness occured in the coarse microstructural region (cast-columnar) than that in the reheat refined region of the weld deposit.
3. ITT of the weld metal decreased with a change in electrode polarity from DCEN to DCEP
4. YS and UTS are higher with DCEN compared to DCEP. But vice-versa was observed with percentage elongation (%El) and percentage reduction in cross-sectional area (%RA).
5. YS and UTS decreased and % El. and % RA of the weld metal increased with a decrease in welding current.

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TABLE 4 : TENSILE PROPERTIES OF SUBMERGED ARC WELD DEPOSITS

I Amp	V Volt	Q KJ/mm	YS	N/MM2	UTS	N/MM^2	EL.,	(%)	RA.,	(%)
			DCEN	DCEP	DCEN	DCEP	DCEN	DCEP	DCEN	DCEP
500	28	2.1	240	330	441	413	27.0	31.4	41	43
700	28	2.9	366	357	453	421	23.2	26.9	40	42