# Effect of polarity on melting rate in submerged ARC welding

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***ABSTRACT***

*The influence of polarity at various levels of welding currents varying from 300 Amp to 700 Amp between the arc voltage of 28 volt and 32 volt on the melting rate, and the bead geometry has been investigated. It has been observed that at a given value of welding current and voltage the melting rate is larger at DCEN as compared to that at DCEP. At a given arc voltage the difference in melting rate increases with the increase in current. However, at a given welding current the variation in crc voltage shows an insignificant effect on melting rate under straight polarity (DCEN). The DCEN produces an irregular bead shape due to piling up of metal deposition and gives lower penetration along with lower bead width and higher bead height than those observed at DCEP.*

## 1. INTRODUCTION

A large number of variations in the technique of Submerged Arc Welding (SAW) have been practiced to increase deposition rate. These include use of multiarc multiple power sources in various combinations with reference to (i) type (AC/DC) and number of power sources used, (ii) arrangement of arc (series/parallel). Lately references have been made about the use of straight polarity for increasing melting rate, however, no practical data are available indicating the extent of increase in melting rate using straight polarity. Also there is no evidence available suggesting the use of straight polarity by manufacturers in actual fabrication. This may be due to lack of data regarding the suitability of weld bead geometry as well as the microstructure of the multilayer welds obtained by using straight polarity Submerged Arc Welding process.

The present work is the first step of a large programme to establish the influence of polarity on (i) melting rate (ii) weld bead geometry and (iii) microstructure of weld metal and its influence on mechanical properties in a multilayer weld.

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## 2. MELTING RATE

Melting of filler wire as well as parent metals is obtained by the heat generated in the arc. Heat in the arc is generated by electrical reactions at the anode and cathode regions and also within the plasma. The energy corresponding to reactions in plasma column does not directly contribute to melting of cathode and anode materials. It, however, influences the cathodic and anodic heating.

In addition to the energy supplied by the welding arc, the electrical resistance heating of the electrode by welding current also affects the electrodes melting rate. This effect is particularly significant in welding processes which use small diameter electrodes.

Considering the above factors the melting rate (MR) can be expressed as :

$$MR = aI + bLI^2$$

where, a = the constant of proportionality for anode or cathode heating its magnitude is dependent upon composition and polarity in case of direct current arcs.

b = the constant of proportionality for electrical resistance heating and includes the electrodes resistivity.

L = electrode extension

I = welding current.

The value of 'a' have been found greatly differing for Direct Current Straight Polarity (DCEN) and Direct Current Reverse Polarity in case of MIG welding. It is higher in case of Direct Current Straight Polarity as compared to Direct Current Reverse Polarity resulting in a higher melting rate with Direct current straight polarity. No difference in value of 'b' is reported when working with DCEN and DCEP.

Unfortunately no data are available regarding the value of 'a' in case of Submerged Arc Welding, although it has been indicated by several authors (1,2,3,) that the deposition rate is higher in case of DCEN. But there is great variation in the extent of increase in melting rate. It varies from 10 - 15% as suggested by (1) to 30 - 40% as given by (2-3). Furthermore, inspite of higher melting rate, the use of DCEN has not been adopted by the manufacturer even in multilayer welding, specially for filler runs. This situation calls for an investigation into the influence of polarity on melting rate as well as bead characteristics and microstructure of the different layers in case of multilayer submerged arc welding using DCEN. The present investigation is a first step in this reference.

## 3. EXPERIMENTAL DETAILS

Bead on plates were deposited on 15 mm thick mild steel plates by using 3.15 mm diameter LS2NiMO filler wire and OP41TT flux under different welding current and polarity at the arc voltage of 28 Volt and 32 Volt, for studying the influence of change in polarity on melting rates of the filler wire.

Each specimen was weighed before and after welding. The difference between the two weights divided by bead length and multiplied by travel speed provided the deposition rate in gms/min which was later on converted to kilogram/hour. The bead width and bead height were measured with the help of a vernier calliper at several points along the length of the bead and the average has been reported. The penetration was measured with the help of optical microscope.

## 4. RESULTS AND DISCUSSIONS

### Effect of Polarity on Deposition Rate

The variation in deposition rate with the change in current under different polarity have been

**Note** : Straight polarity means Electrode negative (EN) and reverse polarity means Electrode positive (EP).

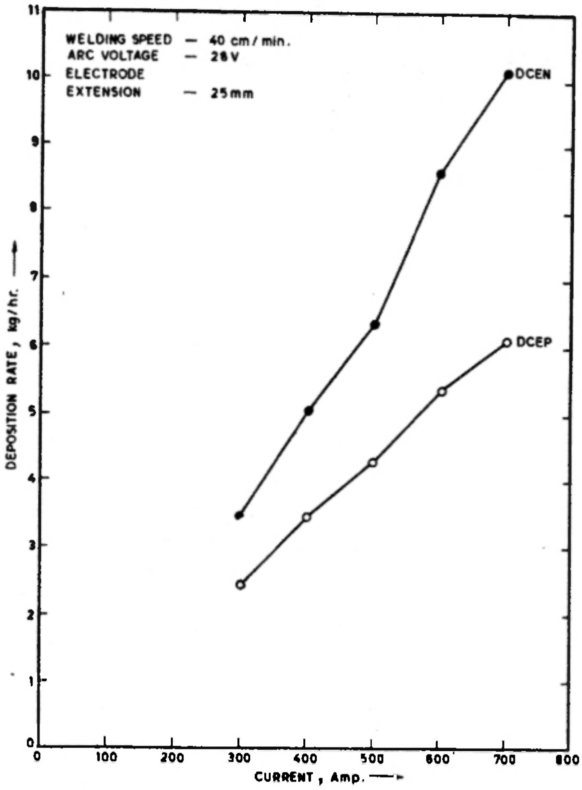



Fig. 1 Effect of welding current on the deposition rate under different polarity at an arc voltage of 28 Volt.

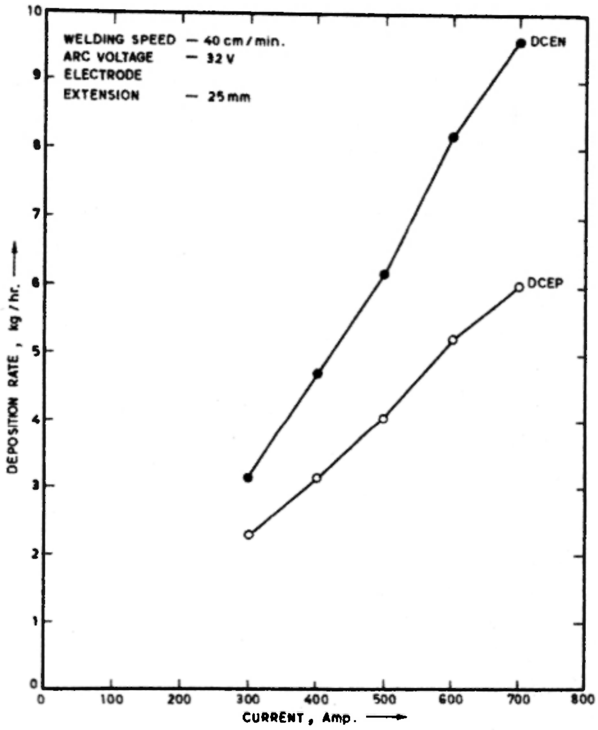



Fig. 2 Effect of welding current on the deposition rate under different polarity at an arc voltage of 32 Volts.

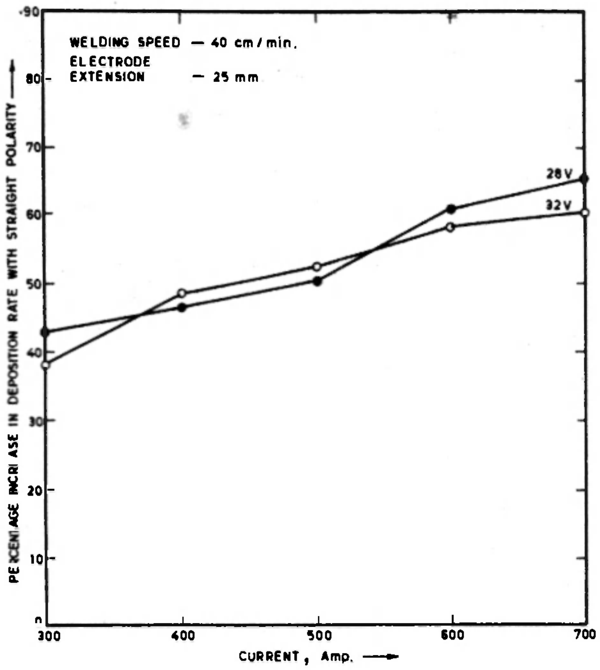



**Fig. 3** Under straight polarity percentage increase in deposition rate with the increase of welding current.

shown in Figs. 1 & 2 for different arc voltages of 28 Volts and 32 Volts respectively. The variation of percentage increase in deposition rate between the different polarities, with the change in current has been shown in Fig. 3 at the arc voltages of 28 Volt and 32 Volts. The deposition rate increases steadily with the increase in current following a linear mode. This may be attributed to the increase in heat input with increase in current. It is evident from Figs. 1 & 2 that with electrode negative deposition rate is higher as compared to electrode positive. The greater amount of deposition rate in case of direct current electrode negative (DCEN) can be attributed to higher cathodic heating.

Cathodic heating qc is given by the following relation,

$$qc = [Vc - (\theta + 3KT/2e)]I$$

where,

Vc = cathodic drop in volts

$\theta$ = the work function (volts) of the material

3KT/2e = the thermal energy of electrons.

whereas anodic qa is given by

$$qa = [Va + (\theta + 3KT/2e)]I$$

where,

Va = anode drop in volts

In case of most of structural steels the values of Vc, $\theta$ and 3KT/2e have been reported as follows (4)

Vc = 15 volt

$\theta$ = 4.5 volt but reduces to 3 - 3.5 volt due to surface contamination.

3KT/2e = 0.5

for an arc temperature of 6,000 K in case of most ferrous metals.

Therefore,

$$qc = [15 - (3 + 0.5)]I = 11.5I$$

with electrode positive, Va = 3V and therefore,

$$qa = (3 + 3.5)I = 6.5I$$

The difference in the value of qc and qa is responsible for the difference in melting rate at different polarities.

Unlike Tungsten Inert Gas Welding (DCEN), in Submerged Arc Welding of steel the emission of electron is by the mechanism of Field Emission whereby a few cathode spots are formed at the electrode end. These cathode spot keep on moving from one point to another point and in this process, climb the surface of electrode. This causes besides higher cathode drop, larger surface being heated resulting in larger amount of melting although the temperature of the molten drop is less as compared to the temperature of the drop in case of DCEP or also when using activated cathode. Larger cathode drop with DCEN (as compared to cathode drop in DCEP) is partially due to this climbing of cathode spot. This is evident from the fact that in case of activated cathode the cathode drop is less with consequent reduction in cathode heating resulting in smaller amount of deposition rate.

### Effect of Polarity on Penetration

The penetration increases with the current for both the polarity as shown in Fig. 4. It may be attributed to increase in heat input which causes the higher amount of melt. It is also seen from Fig. 4 that the rate of increase in penetration is much higher at values of current above 500 Amp. This is due to significant increase in arc plasma pressure above 500 Amp. The increased arc pressure displaces the molten metal from the weld pool and thus increases the penetration. It is clear from the Fig. 4 that the penetration with the DCEP is larger as compared to DCEN. This may also be due to the higher cathodic heating, the workpiece being cathode in this case.

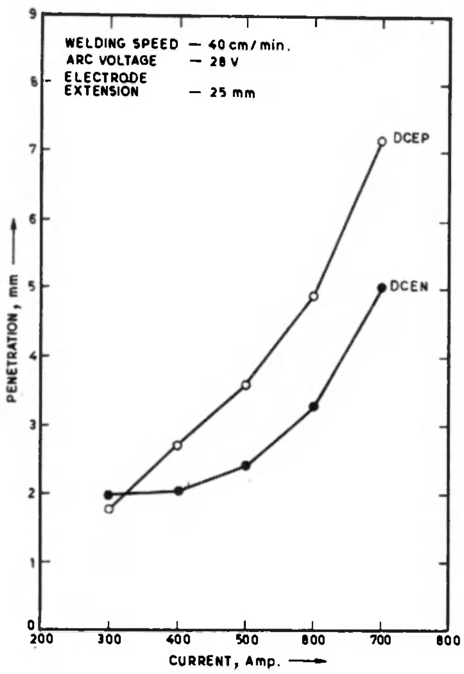



**Fig. 4** Variation of penetration with the change in welding current under different polarity.

The Fig. 5 (a to c) show the penetration and bead shape at different current values i.e. 300, 500 and 700 Amp. respectively. The effect is already being discussed.

### Effect of Polarity on Bead Width

The effect of current on bead width is illustrated in Fig. 6. This shows that the bead width increases with increasing current in both the cases, DCEP and DCEN, but percentage increment in bead width with increase in current reduces as current increases. It is likely that beyond a certain value of current (beyond the scope of this work), bead width may decrease with further increase in current. This is due to the fact that with increasing current the increse in penetration rises significantly with a consequent reduction in the rate of increase in weld width.

Further, at all current levels, the bead width is greater for DCEP owing to higher cathoding heating.

### Effect of Polarity on Bead Height

Fig. 7 presents the relationship between bead height and current. The bead height increases with current in both DCEP and DCEN.

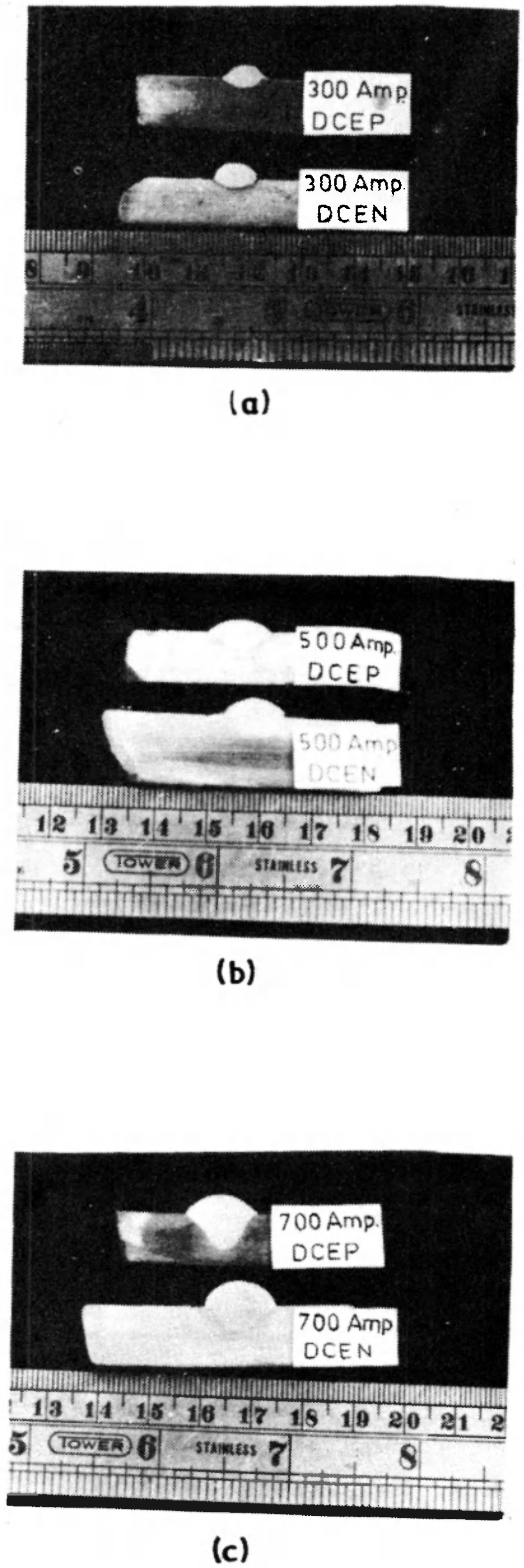



**Fig. 5** Effect of current and polarity on penetration and bead shape.

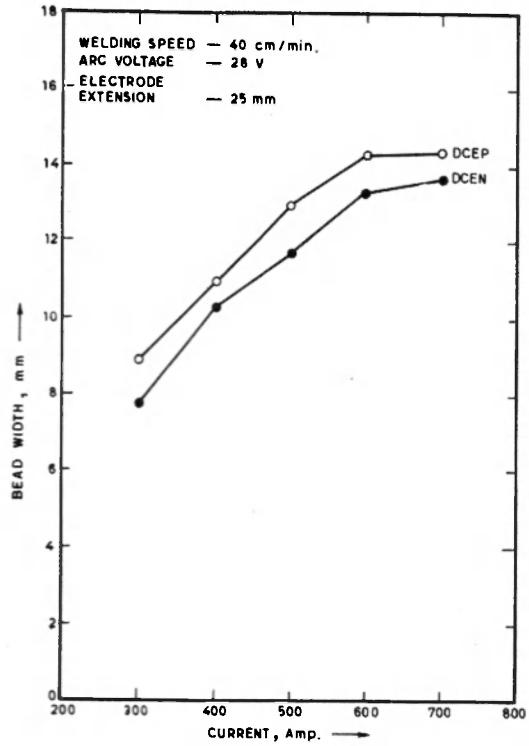



**Fig. 6** Variation of bead width with the change in welding current under different polarity.

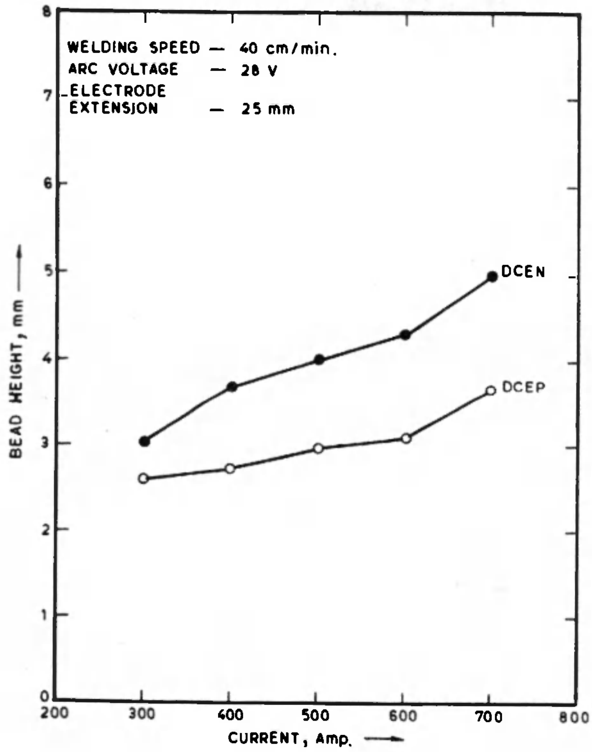
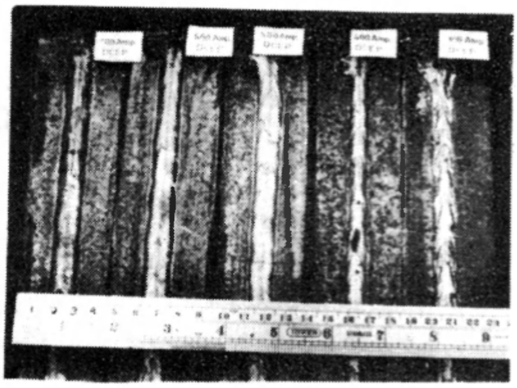



**Fig. 7** Variation of bead height with the change in welding current under different polarity.

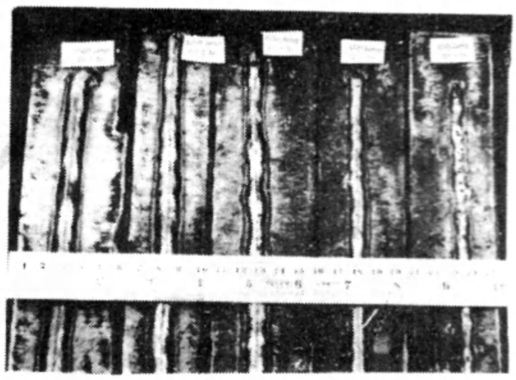
The increase in bead height can be attributed to the fact that with increase in current the deposition rate increases but the increase in weld width is relatively less, accordingly, bead height increases. The increase in bead height with increase in current is relatively larger in case of DCEN. This is due to the fact that the increase in deposition rate with increase in current is also greater in case of DCEN as shown in Fig. 7 whereas the increase in weld width is of the same magnitude as in case of DCEP.

**Influence of Polarity on Appearance**

The Fig 8 (a & b) show the influence of polarity on the bead appearance at various values of current. The Figs. 8 (a & b) clearly show that the bead appearance is smooth when welding with DCEP in all cases, whereas bead appears to be irregular when welding with DCEN. The beads are comparatively more straight in DCEP. The irregularity in shape of bead can be attributed to larger shapeless (irregular shape) droplets which may be attributed to low temperature



(a)



(b)

**Fig. 8** Effect of polarity on bead appearance with varying current.

of molten droplets in DCEN. The lower temperature results from climbing of cathode spot and consequent heating of larger volume electrode end. Lower temperature causes increase in surface tension allowing drops to grow to larger size before being detached. This results in piling of cold metal giving rise to irregular bead.

## 5. CONCLUSIONS

1. The deposition rate in submerged arc welding is higher with electrode negative (DCEN) than electrode positive (DCEP) and difference is larger at higher currents.

2. The penetration is lower in case of DCEN.

3. The bead shape is quite irregular in welding with electrode negative (DCEN), showing piling of cold metal.

4. The DCEN gives higher deposition rate with lower penetration and can therefore be employed in multipass submerged arc welding provided the mechanical properties are adequate.

This calls for further investigations of the weld metal mechanical properties in case of multilayer submerged arc welding welds DCEN.

There is a possibility that irregular piling up of metal may be improved by oscillating the wire in case of multilayer welding. The effect of pendulum motion of electrode over bead shape in DCEN may therefore be also investigated in case of multilayer submerged arc welding welds with DCEN.

## 6. REFERENCES

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