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SOME EFFECTS OF PRESSURE ON CONSUMABLE ELECTRODE ARC MELTING

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SOME EFFECTS OF PRESSURE ON CONSUMABLE ELECTRODE ARC MELTING

by

J. W. Suiter*

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ABSTRACT

The effect of pressure, in a consumable electrode arc furnace, on the weight of metal melted per unit of energy dissipated was investigated while melting titanium electrodes of negative and positive polarity and steel electrodes of negative polarity. Provided that the arc length was sufficiently short, the weight of metal melted per unit of energy dissipated increased continuously as the pressure of argon was decreased from 650 mm Hg to 1 x 10^{-2} mm Hg.

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INTRODUCTION

Many workers (e.g. 1, 2) have reported the weight of metal melted per unit of energy dissipated in consumable electrode arc melting, but in most cases the experiments were done only at a few widely separated pressures. Beall et al[3] have reported the effects of varying the pressure in the range 10 to 760 mm Hg when melting titanium electrodes in an argon atmosphere. However, the present day emphasis on vacuum arc melting has made it desirable to extend their investigations to lower pressures.

This paper reports the effects of varying the argon pressure in the range of 1×10^{-2} to 650 mm Hg on the weight of metal melted per unit of energy dissipated when melting titanium and steel in a consumable electrode arc furnace.

MATERIALS AND EXPERIMENTAL PROCEDURE

The titanium electrodes were produced by welding, end to end, compacts of sponge titanium (20.4 x 5.1 x 5.1 cm) each weighing 1600 g. The mild steel (0.1% C) electrodes consisted of rolled bar 3.8 x 3.8 cm in cross section. These electrodes were attached to a water-cooled copper electrode stub which passed through a sliding seal in the top of the furnace. The electrodes were melted into a mould 34 cm long and 12 cm in diameter, producing ingots of 4 to 5 kg weight.

Power for melting was supplied by three motor-generator welding machines connected in parallel. The same generator settings were used in all experiments, and the arc current and voltage were allowed to vary with the pressure.

During melting the feed rate of the electrode was adjusted by the operator while observing the arc voltage pattern on a direct current oscilloscope and also the arc voltage and current as indicated by conventional meters. The desirable arc length was such that the pattern on the oscilloscope indicated the presence of occasional, momentary dead shorts. It was thought that these momentary dead shorts were due to droplets of molten metal shorting between the electrode and the molten pool. It was not possible to measure such an arc length but it appeared to be less than 1 cm. For some melts at pressures of 25 and 10 mm Hg, an arc length of approximately 8 cm was deliberately maintained; these were duplicates of melts made at the same pressures with a normal short arc length. The long arc length was used to determine what effect the presence of positionally unstable arcs would have on the weight of metal melted per unit of energy dissipated. It was possible to observe, through a sight glass, the presence or absence of positionally unstable arcs within the mould.

In the pressure range 10 to 650 mm Hg a static atmosphere of argon was used, but in the pressure range 10^{-1} to 10 mm Hg it was necessary to remove gas from the system while melting to maintain a constant pressure. No argon was used for pressures less than 10^{-1} mm Hg which were obtained by continuously evacuating the furnace so that the steady pressure during melting depended on the speed of the pumps being used and the amount of gas evolved from the electrode. The gas pressure was measured in the body of the furnace for it has been shown(4) that this pressure is very close to that in the melting region of this type of furnace if there are no volatile materials in the electrode. There were only very small quantities of volatile materials in the steel electrodes used in these experiments, but the titanium electrodes contained such volatiles as magnesium and magnesium chloride. Thus, the pressure measured in the body of the furnace did not accurately indicate the pressure in the melting region when melting titanium electrodes at very low pressures.

The energy dissipated during melting was calculated from the arc voltage, the arc current, and the time of the melting operation.

RESULTS

The effect of pressure on the weight of metal melted per unit of energy dissipated when melting titanium electrodes of negative polarity is shown in Figure 1. As the pressure was decreased from 650 mm Hg to approximately 10 mm Hg the weight of metal melted per unit of energy dissipated increased, but at lower pressures the increase was less marked. As the pressure was decreased the arc voltage decreased from 36 volts at 650 mm Hg pressure to 28 volts at pressures less than 5 mm Hg, and in the same pressure range the arc current increased from 1800 amp to 2200 amp.

In the pressure range 2×10^{-1} to 20 mm Hg, positionally unstable arcs were occasionally seen within the mould, but these were eliminated by decreasing the arc length. Two electrodes were melted at 25 and 10 mm Hg pressure while maintaining an arc length of approximately 8 cm. At a pressure of 25 mm Hg, melting with a long arc had little effect on the weight of metal melted per unit of energy dissipated. At 10 mm Hg pressure, the weight of metal melted per unit of energy dissipated was less when melting with a long arc, and there was also a large increase in the amount of positionally unstable arcs within the mould.

Figure 2 shows that the weight of metal melted per unit of energy dissipated increases with decreasing pressure when melting titanium electrodes of positive polarity, but the increase is less than when melting titanium electrodes of negative polarity (compare Figures 1 and 2). Thus, at low pressures the weight of metal melted per unit of energy dissipated was higher when melting electrodes of negative polarity, but near atmospheric pressure the position was reversed.

The effect of pressure on the weight of metal melted per unit of energy dissipated when melting steel electrodes of negative polarity is shown in Figure 3. The results are similar to those obtained when melting titanium electrodes of negative polarity. At all pressures the weight of steel melted per unit of energy dissipated was greater than that of titanium, but this result was not unexpected in view of the different heat contents of the two materials at temperatures just above their melting points. As in the case of titanium electrodes of negative polarity, a long arc at a pressure of 8 mm Hg favoured the occurrence of positionally unstable arcs, resulting in a decreased weight of steel melted per unit of energy dissipated.

DISCUSSION

When melting titanium electrodes of negative and positive polarity, and steel electrodes of negative polarity, in a consumable electrode arc furnace, the weight of metal melted per unit of energy dissipated increased continuously as the pressure was decreased. Beall et al[3] have reported the results of melting titanium electrodes in argon atmospheres in the pressure range of 10 to 760 mm Hg, and they found a sharp decrease in the weight of titanium melted per unit of energy dissipated as the pressure was reduced below 20 mm Hg (see Figures 1 and 2). Beall et al suggested that this decrease was due to the formation of positionally unstable arcs. The present work confirmed that the formation of positionally unstable arcs led to a decreased weight of metal melted per unit of energy dissipated but that by maintaining a sufficiently short arc length these positionally unstable arcs could be avoided. If positionally unstable arcs were avoided, then the weight of metal melted per unit of energy dissipated increased continuously as the pressure decreased. Beall et al used two horizontally opposed electrodes in a relatively large furnace in their experiments, and the different size and arrangement of electrodes used in the two sets of experiments may account for the different values of the weight of titanium melted per unit of energy dissipated that were obtained in the two sets of experiments near atmospheric pressure.

Although most of the melting experiments were done in an argon atmosphere, no argon was used for the melts when the furnace was evacuated continuously and the pressure during melting was less than 1×10^{-1} mm Hg. Since the results obtained under these conditions followed the same trend as those obtained when melting in an argon atmosphere, it appeared that at very low pressures the atmosphere in which melting occurred had little effect on the weight of metal melted per unit of energy dissipated. The steel electrodes contained very little volatile material, and the composition of the gas in the melting region when melting these electrodes under continuous evacuation differed greatly from the gas composition when melting titanium electrodes. These changes in the composition of the gas in the melting region appeared to affect neither the behaviour of the arc nor the weight of metal melted per unit of energy dissipated.

ACKNOWLEDGMENTS

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(Figures 1 to 3 follow,)
(on pages 8 and 9.)

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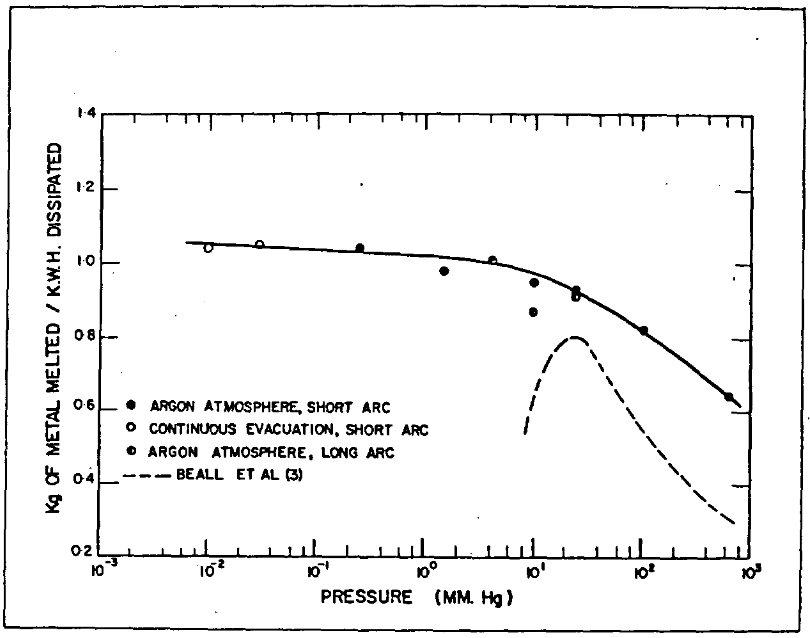

Fig. 1. - Effect of pressure on the weight of titanium melted per unit of energy dissipated when melting electrodes of negative polarity.

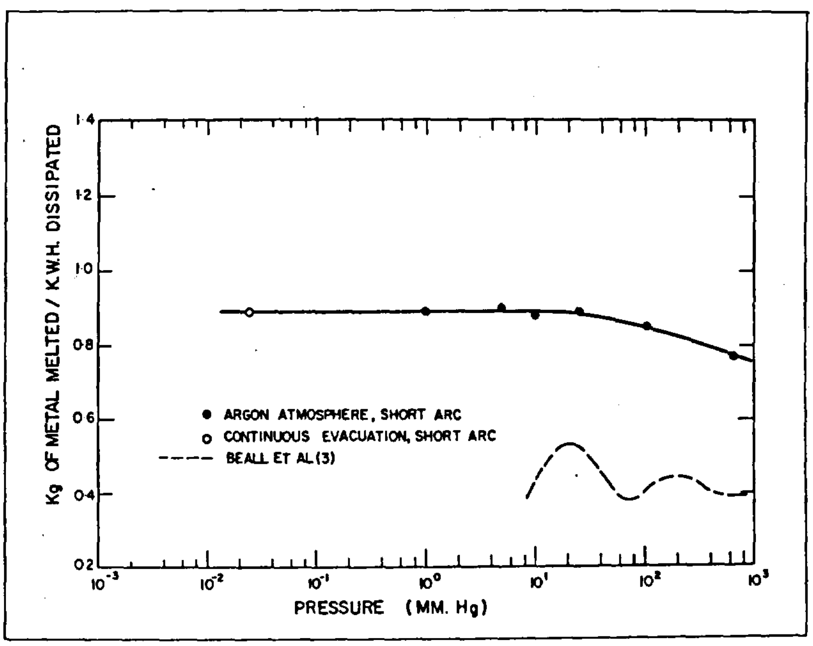

Fig. 2. - Effect of pressure on the weight of titanium melted per unit of energy dissipated when melting electrodes of positive polarity.

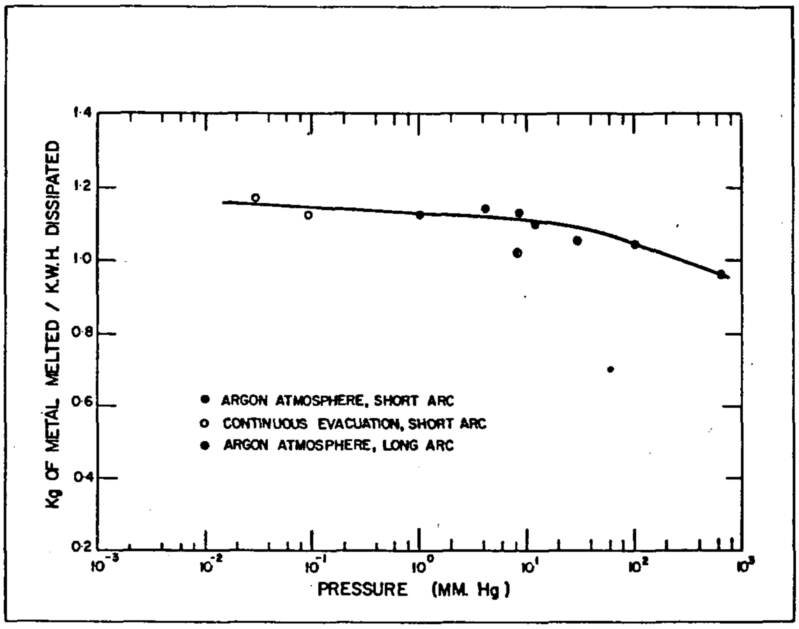

Fig. 3. - Effect of pressure on the weight of steel melted per unit of energy dissipated when melting electrodes of negative polarity.

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