Influence of Current Pulses During Submerged Arc Welding

Current pulses must be close to natural droplet frequency which depends on the arc characteristics of the flux

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Introduction

The use of current pulses to control the melting behavior of coated electrodes was first published by Erdmann-Jesnitzer and Weinschenk (Ref. 1). Anderson and Greene (Ref. 2), Needham (Refs. 3,4) and Jackson (Ref. 5) along with many other investigators in all parts of the world utilized current pulses during gas metal-arc welding which gave a new dimension to this process. Hildebrandt (Ref. 6) described the use of current pulses for submerged arc welding to provide the advantages of both direct current and alternating current submerged arc welding without the disadvantages of either. Hildebrandt did not attempt to study the metal transfer during pulsed current submerged arc welding. Bagryanskii (Ref. 7) found an improved alloying effect while using current pulses during submerged arc welding. Bagryanskii et al reported the use of high speed films to study metal transfer in an open arc. It is not clear, if droplet transfer was synchronous with the applied pulses of current under actual welding conditions. It is the aim of the present investigation to study the droplet transfer during pulsed current submerged arc welding to ascertain if droplet transfer is synchronized with the imposition of current pulses.

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Experimentation

A normal constant current power source was modified by changing the transductor connections as shown in the Figs. 1 and 2 to produce current pulses with a frequency of 50 and 100 Hz respectively. This power source was used for pulsed current submerged arc welding using 3 mm (0.118 in.) diam wire S2 and a manganese silicate flux LW 250 (11 by 496 according to DIN 8557). In view of the limitation on the available harmonic pulse frequency another power source normally used for GMA welding but capable of providing pulse frequencies of 25, 33 1/3, 50 and 100 Hz was used with a CO_2 wire of 1.6 mm (0.062 in.) diam and the same flux, to determine the effect of lower pulse frequency.

When welding with 3 mm (0.118 in.) diam wire, it was possible to get reasonably good high speed films of the metal transfer using the method described by Franz (Ref. 8). A schematic arrangement of photographing technique is given In the Fig. 3. When 1.6 mm (0.062 in.) diam wire was used it was not possible to obtain good films probably due to the small arc zone. The droplet transfer in this case was determined by depositing the bead on a water cooled copper plate moving at a high speed of about 200 mm/s (472 in./min).

Results

Pulsed Current SAW With 3 mm (0.118 in.) Wire

Pulse frequencies of 50 and 100 were used in this case. Due to tech-

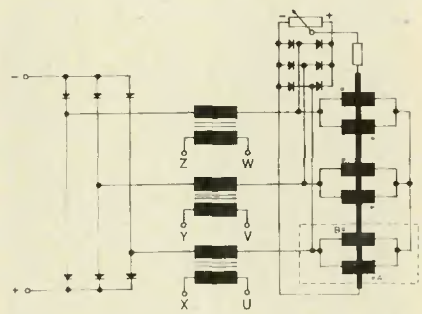

Fig. 1 — Simplified circuit diagram of welding power source

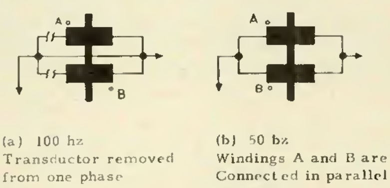

Fig. 2 — Change in transductor connections shown in dotted rectangle in Fig. 1 for producing current pulses

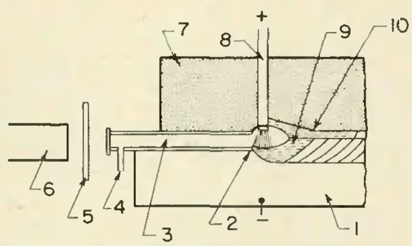

Fig. 3 — Schematic arrangement for photographing the events taking place in the arc zone. 1 base plate; 2 arc envelope; 3 ceramic tube; 4 gas; 5 filter; 6 camera objective; 7 flux; 8 electrode; 9 weld pool; and 10 slag

nical reasons it was not possible to vary the pulse duration or to increase the maximum amplitude beyond 800 A.

With a pulse frequency of 50 Hz the welding parameters were adjusted so as to give an average welding current of about 400 A at 28-30 V. The values were 600 A and 36 V respectively while welding with pulse frequency of 100 Hz. Fig. 4 shows the droplet transfer during pulse current submerged arc welding using current pulses of 50 Hz frequency; the corresponding oscillograms of arc current and voltage are given in Fig. 5. An examination of high speed film shows:

1. The droplet transfer is not at regular intervals and also is not synchronous with any distinct feature of the current pulse record; this would be the case if a controlled droplet transfer corresponding to every current pulse was achieved.

2. The droplet detachment appears to be mainly due to electromagnetic pinch force as indicated by the contraction of the electrode wire at the point where the drop hangs.

3. Occasionally an explosion of the drop was observed; this was similar to that which occurs from CO reaction in the case of arc welding with covered electrodes.

4. A droplet frequency of 35 drops per second was found under the selected welding condition which is far below the applied pulse frequency.

5. No plasma jet action was detected such as reported in the case of GMA welding.

Figs. 6 and 7 show the droplet transfer and oscillograms taken during pulse current submerged arc welding using a pulse frequency of 100 Hz. An evaluation of the films taken under these conditions showed the following:

1. The electrode end was tapered and drops smaller than the wire diameter were detached fairly regularly but not synchronous with any distinct feature of the current pulse curve even though the applied current pulse was as high as 800 A.

2. The droplet frequency was about 80 drops per second.

3. No explosion of the drop or presence of plasma jet action was detected. From this analysis, it is clear that controlled metal transfer using pulse current welding as in the case of GMA welding and as reported by Bagryanskii and Royanov (Ref. 7) is not shown in submerged arc welding for the flux-wire combinations in these tests.

The reason for this is obvious, most of the forces responsible for drop

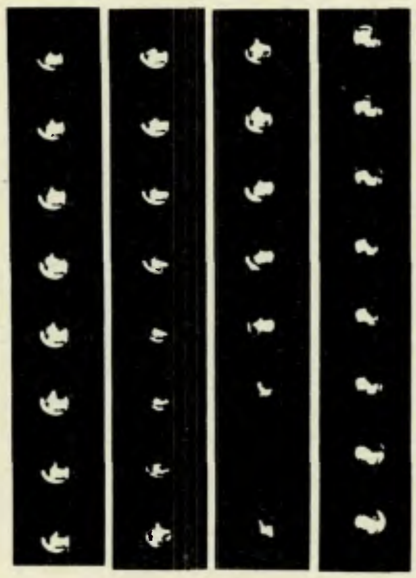

Fig. 4 — Drop detachment during pulsed current submerged arc welding of steel. Electrode diameter 3 mm (0.118 in.), pulse frequency 50 Hz, 1800 frames per second

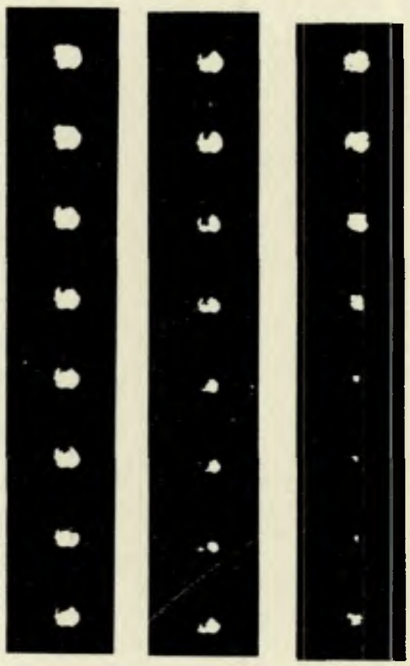

Fig. 6 — Drop detachment during pulsed current submerged arc welding. Electrode diameter 3 mm (0.118 in.), pulse frequency 100 Hz, 2200 frames per second

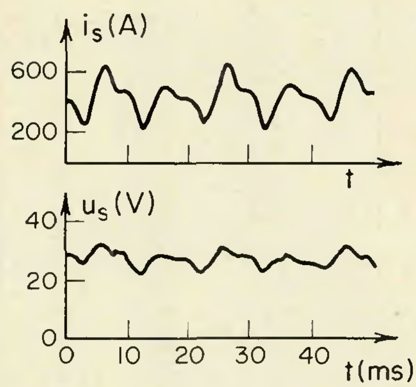

Fig. 5 — Oscillograms of arc current i_s and voltage u_s during pulsed current submerged arc welding with a pulse frequency of 50 Hz

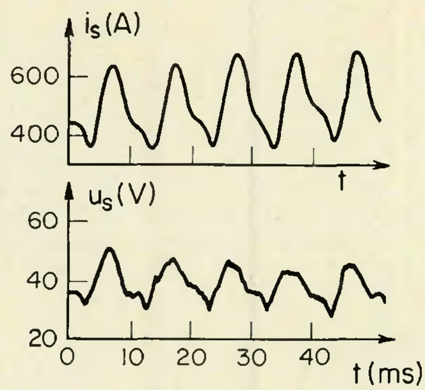

Fig. 7 — Oscillograms of arc current i_s and voltage u_s during pulsed current submerged arc welding. Pulse frequency 100 Hz

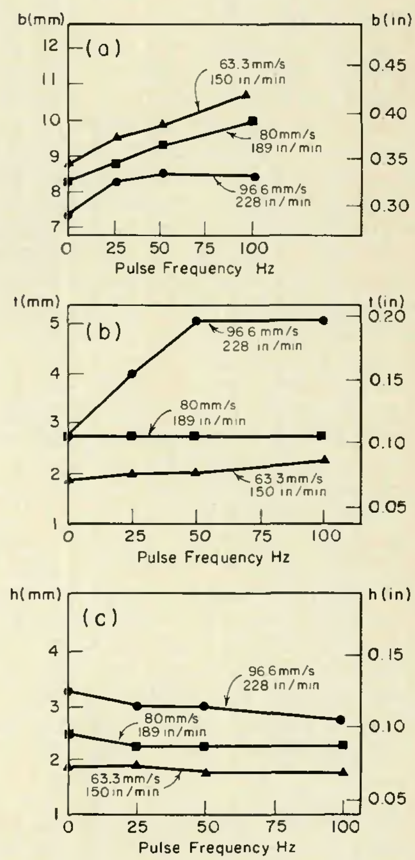

Fig. 8 — Influence of pulse frequency on weld width b; penetration t, and reinforcement h. Wire diameter 1.6 mm (0.062 in.)

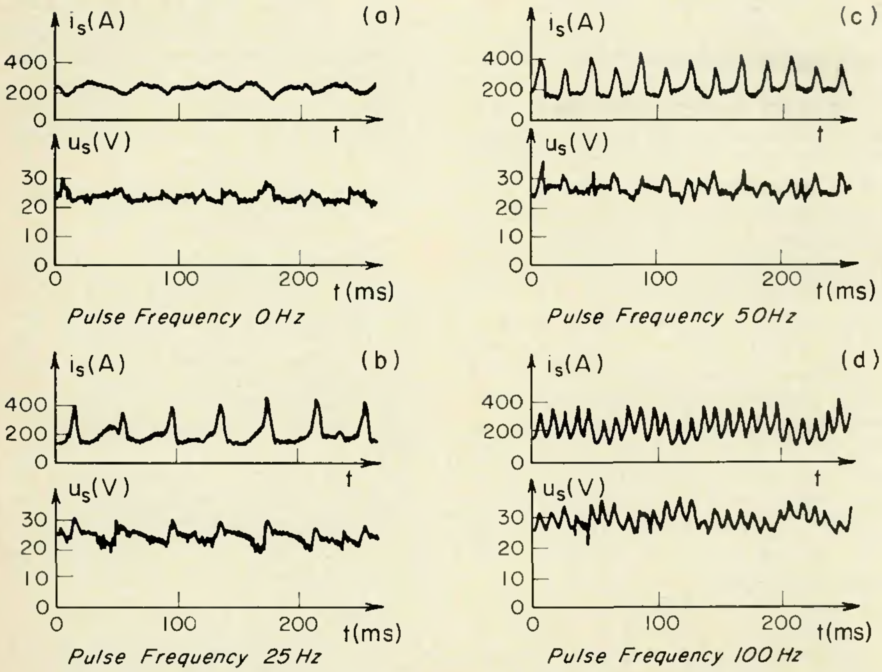

Fig. 9 — Oscillograms of arc current i_s and voltage u_s during pulsed current submerged arc welding. Wire diameter 1.6 mm (0.062 in.). Wire feed speed 3.8 m/min (150 in./min)

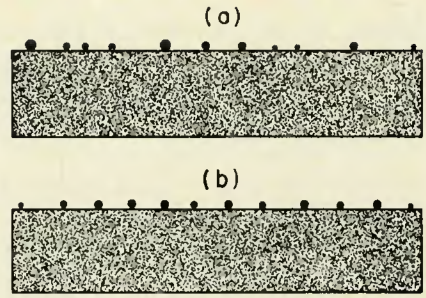

Fig. 10 — Metal drops deposited on water cooled copper plate. Pulse frequency: (a) 0, (b) 25 Hz. Wire diameter 1.6 mm (0.062 in.). Wire feed speed 3.8 m/min (150 in./min). Welding speed 12 m/min (472 in./min)

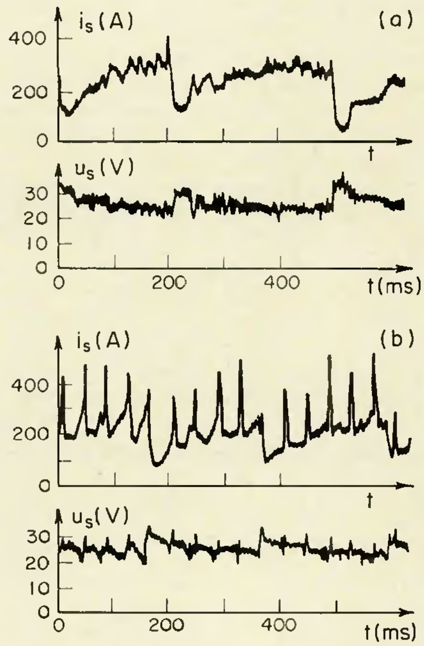

Fig. 11 — Oscillograms of arc current i_s and voltage u_s during submerged arc welding. Welding flux OP 40 TT. (a) pulse frequency 0 Hz; (b) pulse frequency 25 Hz

detachment depend largely upon the arc column configuration which is determined by the properties of the shielding atmospheres as well as the welding parameters. In submerged arc welding the properties of the shielding atmosphere depend upon the composition of the flux used. Different fluxes produce different shielding atmospheres, thereby affecting the shape of the arc plasma differently. It may be possible to achieve controlled metal transfer synchronous with the applied current pulses with other flux-wire combinations under certain welding parameters. However, it would be incorrect to state that a transition current exists which is dependent upon wire size, such as found in the case of GMA welding.

This view is further confirmed by the test welds made using lower frequency pulses and different fluxes as described in the next section.

Pulsed Current SAW with 1.6 mm (0.062 in.) Wire

Tests were performed to study the effect of employing current pulses on the weld shape in submerged arc welding. Cross sections of welds deposited on steel plates of St 37*, using 1.6 mm (0.062 in.) electrode and with pulse frequencies of 0, 25, 50, and 100 Hz at three wire feed speeds of 63.3, 80 and 96.6 mm/s (150, 190 and 228 in./min) were compared. Welding parameters of 210 A/25 V, 280 A/25 V, and 340 A/26 V at a welding speed of 8.3 mm/s (19.7 in./min) were employed.

Effect of Pulse Frequency on Weld Width b — Fig. 8 (a) shows the relationship between weld width b and pulse frequency for different wire feed speeds. The weld width increases with an increase in pulse frequency in all cases.

Effect of Pulse Frequency on Weld Penetration t — Fig. 8 (b) shows the influence of pulse frequency on weld penetration t for all three wire feed speeds. The weld penetration remains almost constant at wire feed speeds of 63.3 and 80 mm/s (150 and 190 in./min) respectively but increases up to the pulse frequency of 50 Hz in case of wire feed speed of 96.6 mm/s (228 in./min).

Effect of Pulse Frequency on Weld Reinforcement h — The relationship between weld reinforcement h and the pulse frequency is given in Fig. 8 (c) for different wire feed speeds. There is a slight reduction in weld reinforcement in all the cases as the pulse frequency increases.

Effect of Pulse Frequency on Fluctuation Pattern on Instantaneous Arc Voltage and Current — Oscillograms of arc voltge and current recorded during the above discussed test are given in Fig. 9 for wire feed speed of 63.3 mm/s (150 in./min). A very important feature was noted while comparing the oscillograms taken for welds deposited with pulse frequency of 0 and 25 Hz respectively at wire feed speed 63.3 mm/s (150 in./min). In case of welds deposited with 25 Hz pulses the arc current and voltage oscillograms appeared to have been arranged in saw tooth form by employment of current pulses indicating very strongly, a droplet transfer at the rate of 25 drops per second which was equal to the frequency of applied pulses. Attempts of making high speed films to observe the metal transfer were not successful, probably due to the very small arc zone.

**A mild steel containing typically 0.20% C, 0.30% Mn and 0.18% Si with a minimum tensile strength of 37 kp/mm² (52,500 psi)*

Welds were deposited on a water cooled copper plate at a very high welding speed of about 200 mm/s (472 in./min) in an indirect attempt to verify the above phenomenon.

Figure 10 (a and b) shows the weld bead deposited under the above welding conditions. In case of welds deposited using 0 Hz pulse frequency 22 drops were deposited in one second and the spacing of the drops was not uniform; these results indicated the detachment of the drops at irregular intervals. In case of welds made using the current pulses with a frequency of 25 Hz, 25 drops uniformly spaced on the plate were obtained during one second of welding. This suggests that it is possible with this welding condition to obtain the controlled droplet transfer in case of submerged arc welding when the applied pulse frequency is very close to the natural droplet frequency obtained without the use of current pulses.

Effect of Type of Flux on the Metal Transfer in SAW — A comparison of the oscillograms of arc current and voltage given in Fig. 9 (a) and 11 (a) recorded during submerged arc welding under simiilar conditions but using LW 250 and OP 40 TT fluxes respectively, indicate that the fluxes play an important part in determining the droplet frequency. The droplet frequency corresponding to oscillograms in Fig. 9 (a) was 22 per second (as measured by depositing a weld bead at very high speed on a water cooled copper plate) whereas the droplet frequency corresponding to oscillograms in Fig. 11 (a) may be only 4 per second, as observed from the oscillograms. When welds were deposited using a pulse frequency of 25 Hz with flux OP 40 TT no rearrangement of oscillograms took place, Fig. 11 (b), as in case of welds deposited using flux LW 250, Fig. 9 (b). Even the droplet frequency does not seem to be changed in case of flux OP 40 TT when pulse current was applied. This further confirms that current pulses can regulate the metal transfer in submerged arc welding only when the applied pulse frequency is quite close to the natural frequency. The natural frequency of droplet transfer, however, depends largely on the type of flux employed as well as other process parameters.

Conclusions

1. The natural droplet transfer frequency for a given material and welding conditions depends largely upon the arc characteristics of the flux employed.

2. Current pulses can regulate the metal transfer in case of submerged arc welding only when the frequency of applied pulses is quite close to the natural frequency of the droplet transfer obtained without the application of current pulses.

References

1. Erdmann-Jesnitzer, F. and Weinschenk, H. E., "Beitrag zur Verȁnderung des Abschmelzcharakters von ummantelten Elektroden durch den elektrischen Anschlusskreis," *Schweissen und Schneiden*, 11, V. 12, pp. 499-454 (1959).
2. Anderson, N. E. and Greene, W. J., U.S. Patent No. 3,071,680 dated June 17, 1960.
3. Needham, J. C. and Carter, W., "Material transfer characteristics with pulse current," IIW-Doc. XII-287-65.
4. Needham, J. C., "Pulse controlled consumable electrode welding arcs," IIW-Doc. XII-297-65.
5. Jackson, C. E., "Metal transfer in variable frequency gas shielded pulsed current arc welding," IIW-Doc. 212-163-69.
6. Hildebrandt, P. et al, W. German Patent No. 1910399, October, 1968.
7. Bagryanskii, K. V. and Royanov, V. A., "Alloying that occurs during pulsed arc deposition of metals," *Welding Production*, No. 10, pp. 44-48 (1968).
8. Franz, U., "Vorgȁnge in der Kaverne beim UP-Schweissen," *Schweisstechnik* 15, V. 4, pp. 145-150 (1965).