Metal Transfer Characteristics in Self-shielded Flux Cored Arc Welding for Mild Steel and 50 kgf/mm² Class Tensile Steel (Report II)†

– Effects of Some Key Elements in Flux on Metal Transfer and Feasibility of Welding –

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Abstract

Effects of some key elements in flux on metal transfer and feasibility of welding in self-shielded flux cored arc welding for mild steel and 50 kgf/mm² high tensile steel are studied by using a high speed cine photographic technique.

Three types of wire of CaF_2-$CaCO_3$ flux, including Al, Mg and Al-Mg as killing agents, and other three wires including Ba, Na and $CaCO_3$ as additional minor elements in the CaF_2 flux using Al-Mg as killing agents, respectively, were examined with electrode positive polarity.

With respect to the effect of killing agents, Al made the droplet size large compared with that by Mg. The spattering of droplet was conspicuously violent in the case of Mg killing agent.

Addition of Ba resulted in the increase of droplet size and therefore the transfer of droplet was not regular. But it lowered the voltage limit of stabbing-in of electrode. On the other hand, addition of Na made the detaching of droplet rather smooth and regular by comparatively small size of droplet and increase in transfer frequency, and cosequently it made the allowance on optimum condition of welding wide.

KEY WORDS: (Self-shielded Arc Welding) (Flux Cored Wire) (Metal Transfer) (Self-shielded Flux Cored Wire) (Arc Welding)

1. Introduction

In a previous paper[1)], the metal transfer phenomena and the feasibility of welding were investigated with a wire of basic type flux including Aluminum-Magnesium as killing agents. The factors included in the feasibility of welding are the bead appearance characteristics, the covering of slag formed on the top of weld bead and its removing after welding, spattering during welding and occurrence of porosities.

The composition of flux in the core influences remarkably the arc behavior, metal transfer phenomena and consequently the feasibility of welding. In particular some minor elements like alkali metal and alkaline-earth metal have decisive effect on the arc behavior. The basic purpose of the work described here is to study the effect of some key elements in flux on the metal transfer characteristics and the feasibility of welding. As the killing agents, Aluminum, Magnesium and Aluminum-Magnesium are examined. The effects of Barium, Sodium and $CaCO_3$ in the fluxes are also examined with Al-Mg killing agent wire.

2. Experimental Procedures

In order to examine the effects of killing agents on metal transfer phenomena, three types of wire, B, C and D were made. These wires have Al, Mg and Al-Mg as killing agents respectively in the CaF_2-$CaCO_3$ type fluxes.

Other three types of wire E, F and G, including Ba, Na and $CaCO_3$ in the CaF_2 type fluxes individually, were also made. The main compositions and diameters of these wires listed in Table 1. Wire A, metioned in the previous paper, is also listed in the same table.

All wires B, C, D, E, F, G and A have single folded type cross sections as shown in Fig. 1.

Welding procedures in this experiment are also the same as those in the previous paper.

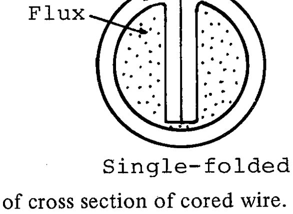

Fig. 1 Shape of cross section of cored wire.

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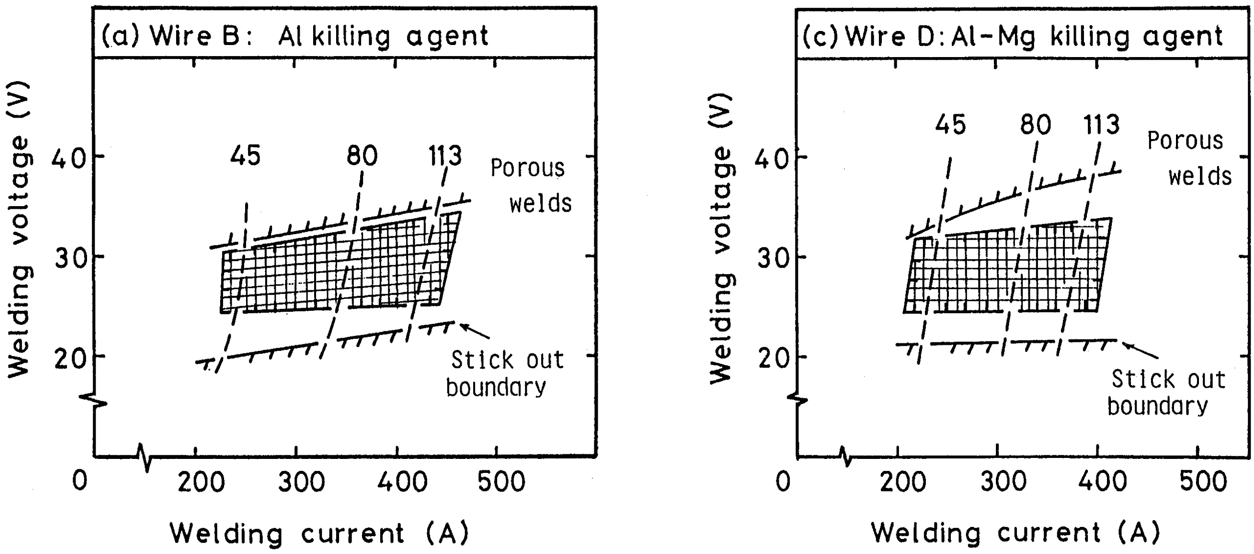
Table 1 Chemical composition of flux

Wire	Diameter (mm)	Flux ratio (%)	Composition of core material (%)								
			CaF_2	Mn	Al	Mg	Al-Mg	Ba	Na	$CaCO_3$	Others
B	2.4	25	37.5	4	20	–	–	–	–	5	33.5
C	2.4	25	37.5	4	–	20	–	–	–	5	33.5
D	2.4	25	37.5	4	–	–	20	–	–	5	33.5
E	2.0	20	45.0	5	–	–	25	6	–	–	19.0
F	2.0	20	45.0	5	–	–	25	–	2	–	23.0
G	2.0	20	45.0	5	–	–	25	–	–	6	19.0
A	2.0	20	45.0	5	–	–	25	–	–	–	25.0



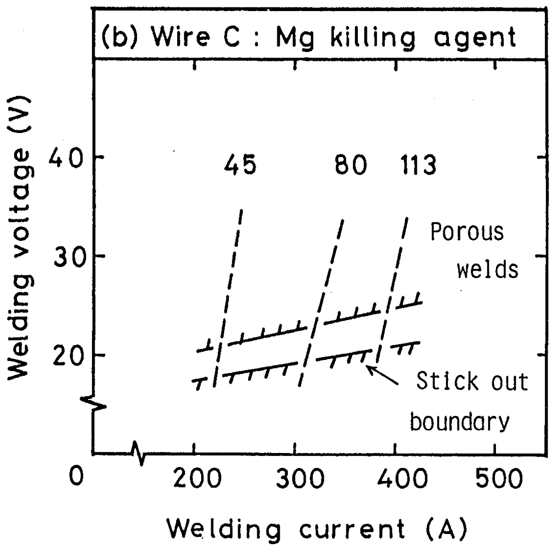


Fig. 2 Current and voltage characteristics and the area for proper welding conditions for wires B, C and D, which are shown by meshed zone.

3. Experimental Results and Discussions

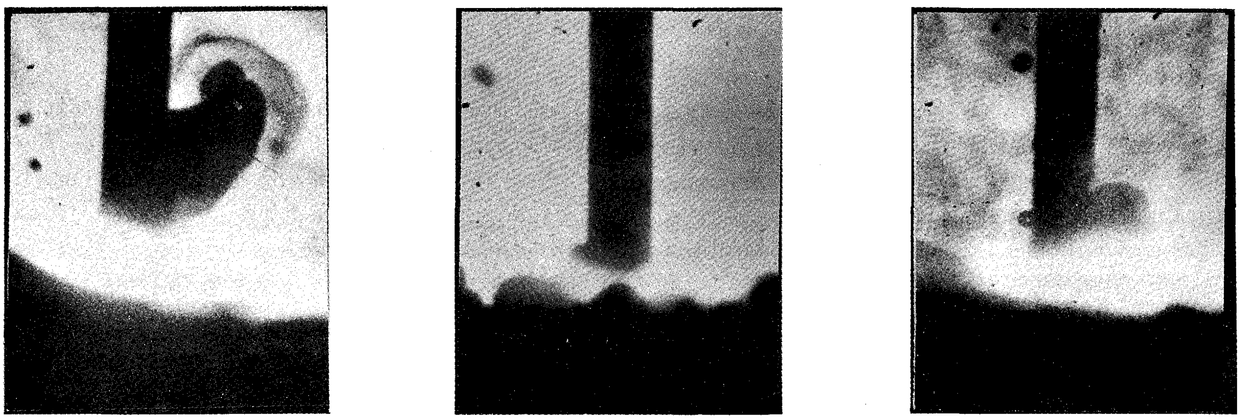
3.1 Effects of killing agents Al, Mg and Al-Mg on metal transfer phenomena

Figure 2 shows the operating conditions of welding current and out-put voltages in various feeding rates of the wires B, C and D. In the figure, there are three condition areas resulted in porous weld metal, in occurrence of wire buckling (stick-out boundary) and in good welds which is shown by enclosed meshed zone. The condition area of proper welding was decided from the view point of feasibility of welding discussed in the previous paper. The factors of feasibility of welding were consist of the bead appearance characteristics, the completeness of covering of slag formed on top of weld bead, the easiness of removing of slag after welding, the amount of spattering and the occurrence of porosities.

The proper welding condition area became wide by applying Al as killing agent and its effect is more remarkable by the increase in the content of Al. In the case of

Al-Mg killing agents, also, its effect on the extension of area of proper welding condition was similar to that of Al killing agent wire B. When these two wires have the same level of aluminum content, the Al-Mg killing agent wire C has the wider area of proper welding condition.

In **Fig. 3**, it is shown the typical pictures of arc and droplet taken by high speed cine-camera. In the case of wire B, the molten part existing in the wire end grows



(a) Wire B : Al killing agent
(b) Wire C : Mg killing agent
(c) Wire D : Al-Mg killing agent

Fig. 3 Typical photographs of metal transfer with wires B, C and D.

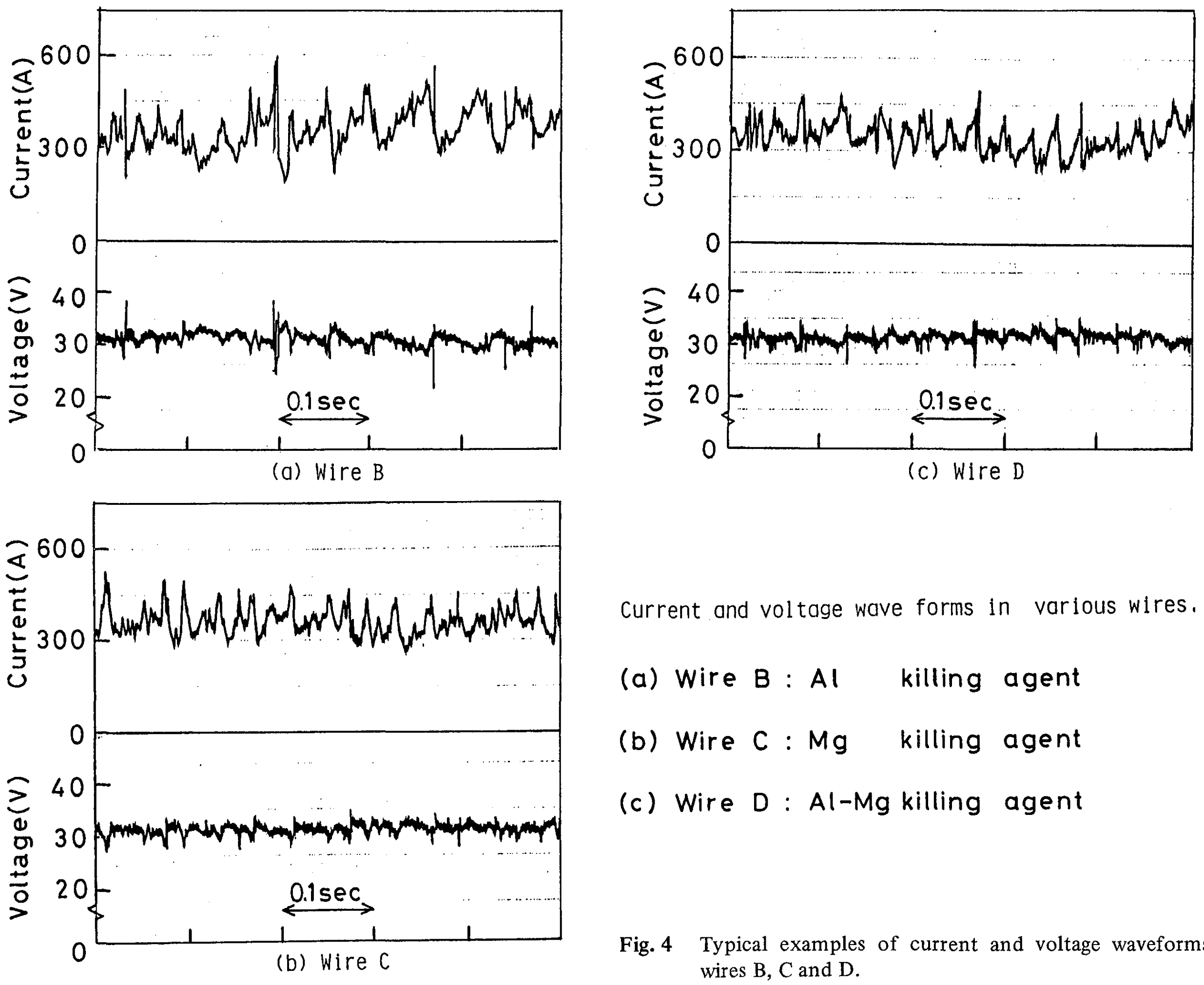


Fig. 4 Typical examples of current and voltage waveforms for wires B, C and D.

large and therefore the detaching is not so frequent. On the other hand, in the case of wire C, the droplet, which means the lump of the molten part formed at the end of wire here, is comparatively small and the detaching is more frequent, but the spattering caused by explosion of droplet occurs repeatedly. The wire D gives the intermittent behavior between those of wire B and C.

Figure 4 shows the examples of current and voltage waveforms of these three types of wire. When the droplet is relatively small and its detaching is more frequent, the currnet waveform is comparatively regular as shown in **Fig. 4(b)**. Contrarily the wire B has some irregular waveforms, that is attributable to the excess grow up of the droplet at the end of wire.

Above results manifest the addition of Mg suitably to Al is effective to obtain the wide area of proper welding condition and the stable and regular transfer of molten droplets.

3.2 Effects of some minor element, Ba, Na and $CaCO_3$ on metal transfer phenomena

Small amounts of Barium, Sodium and $CaCO_3$ were individually added in the flux of wire A and they are called wire E, F and G, respectively. The metal transfer phenomena for three wires were examined in the same procedure used in the previous paper. Metal transfer phenomena were classified into three modes, say, (Ia) Bridging transfer mode, (Ib) Bridging transfer without arc interruption mode, and (II) Free flight transfer mode, and they were related to the welding parameters, current, voltage and feeding rate of wire.

Figure 5 shows the change in the area of various transfer mode and of proper welding conditions among the three wires. Under the condition of the region (III) in the figure, the welding is impossible due to stabbing-in of the wire (below the stick-out boundary voltage). The area of proper welding condition is shown by enclosed zone with

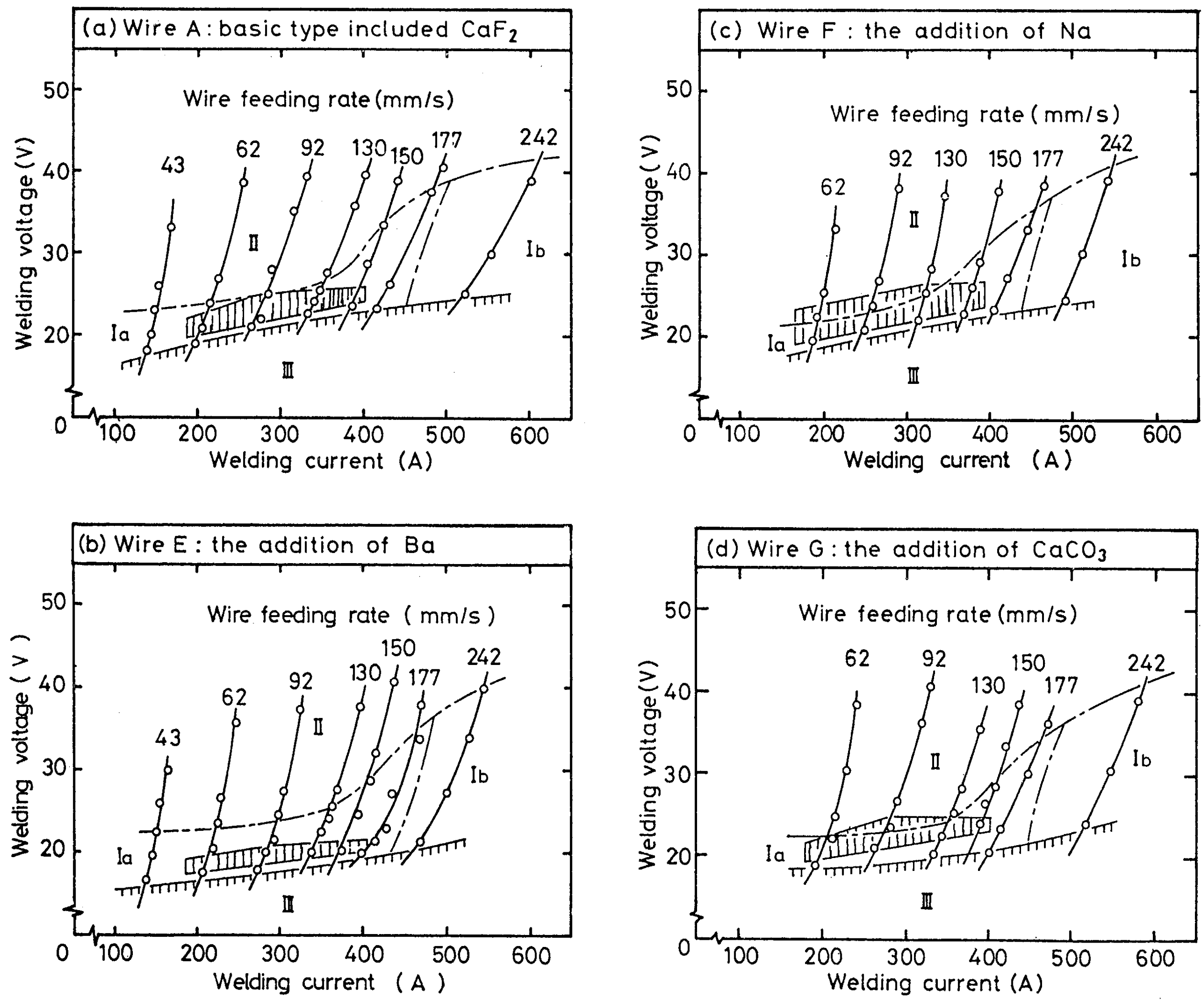
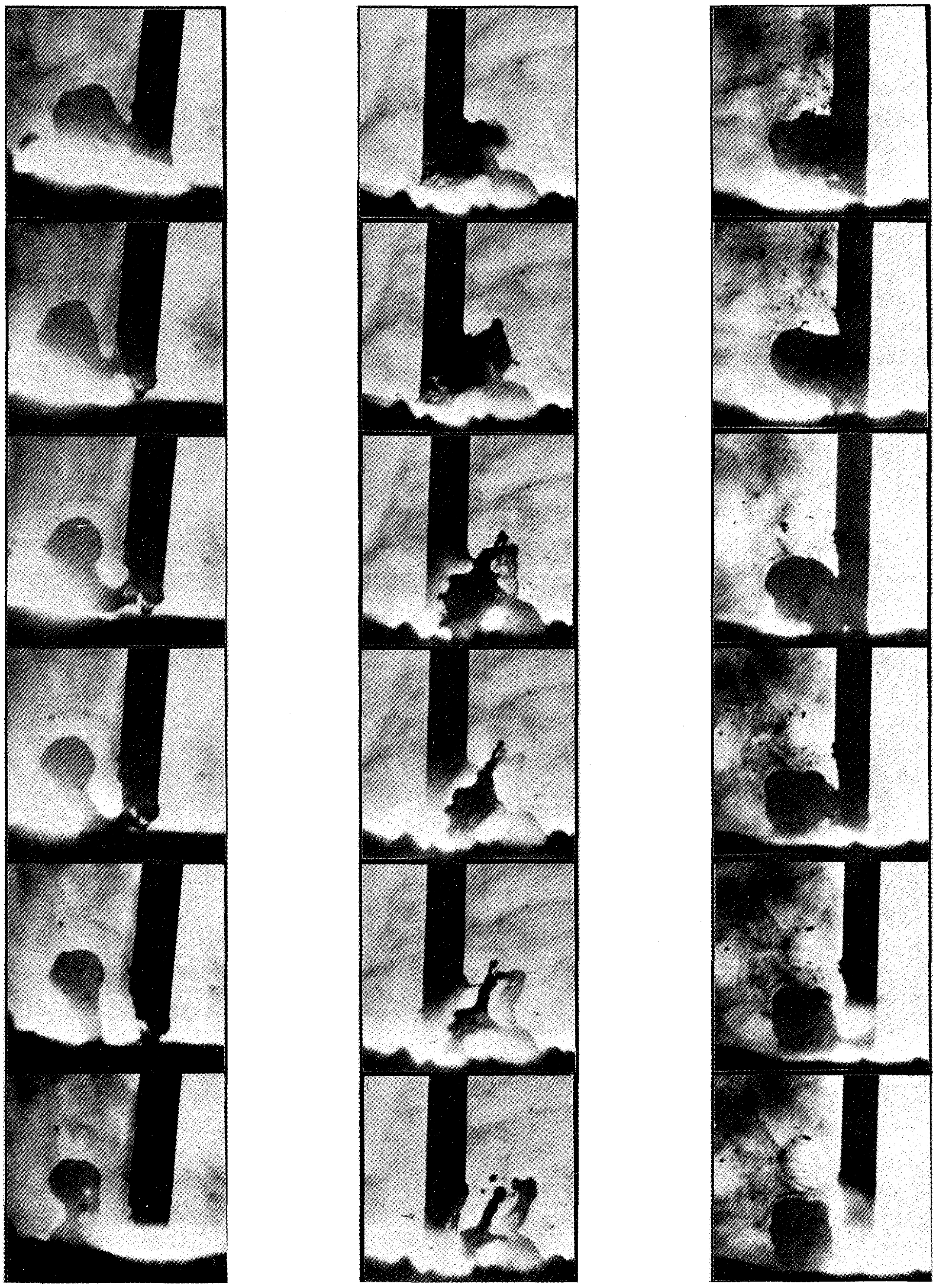


Fig. 5 Change in proper welding condition area for three wires E, F and G.



(a) Wire E
the addition of Ba

(b) Wire F
the addition of Na

(c) Wire G
the addition of $CaCO_3$

Fig. 6 Typical photographs of metal transfer behavior of wires E, F and G.

hatched lines and is found mainly in Ia region.

Wire E has relatively wide Ia region, due to the low voltage of stick-our boundary. The more content of Ba in flux resulted in the less voltage of stick-out boundary. The proper welding conditions are localized in a narrow region, resulted from the increase in spattering and porosities. In the cases of wire F and G, the area of proper welding condition are comparatively wide.

Typical photographs of metal transfer behavior of these wires are shown in **Fig. 6**. In wire E, the droplet becomes large and it looks like to be pushed up by arc force particularly in lower voltage. It can be seen in the high speed cine films the droplet fluctuates and swings violently as if the arc force slaps various places of the lower surface of droplet and is retained for rather long time without detaching. This is considered to be the main reason of low voltage of stick-out boundary.

On the other hand, at the wire tip of F wire, droplets were formed in the relatively small size and detached more frequent and regularly. In the case of wire G, the droplet became large as shown in Fig. 6 and the explosion of droplet could be seen occasionally.

Figure 7 shows typical current and voltage waveforms for the three types of wire. Apparently in the figure there are many spikes in the current waveform of wire E, but contrarily they are less for wire F. These spikes are considered to correspond to instantaneous change in electrical load resulted from detaching of the droplet at the occurrence of spattering and/or partial short-circuitting due to the violent movement of droplet, as is evidently shown in Fig. 6 also. These spattering and short-circuitting phenomena might disturb the completeness of shielding effect of molten pool. The narrower area of proper welding condition in the case of wire E is considered to be due to the reason above mentioned.

4. Conclusions

The effects of killing agents, Al, Mg and Al-Mg on the metal transfer phenomena were studied for the self shielded flux cored wire of basic type flux.

(1) Aluminum made the droplet size large in comparison

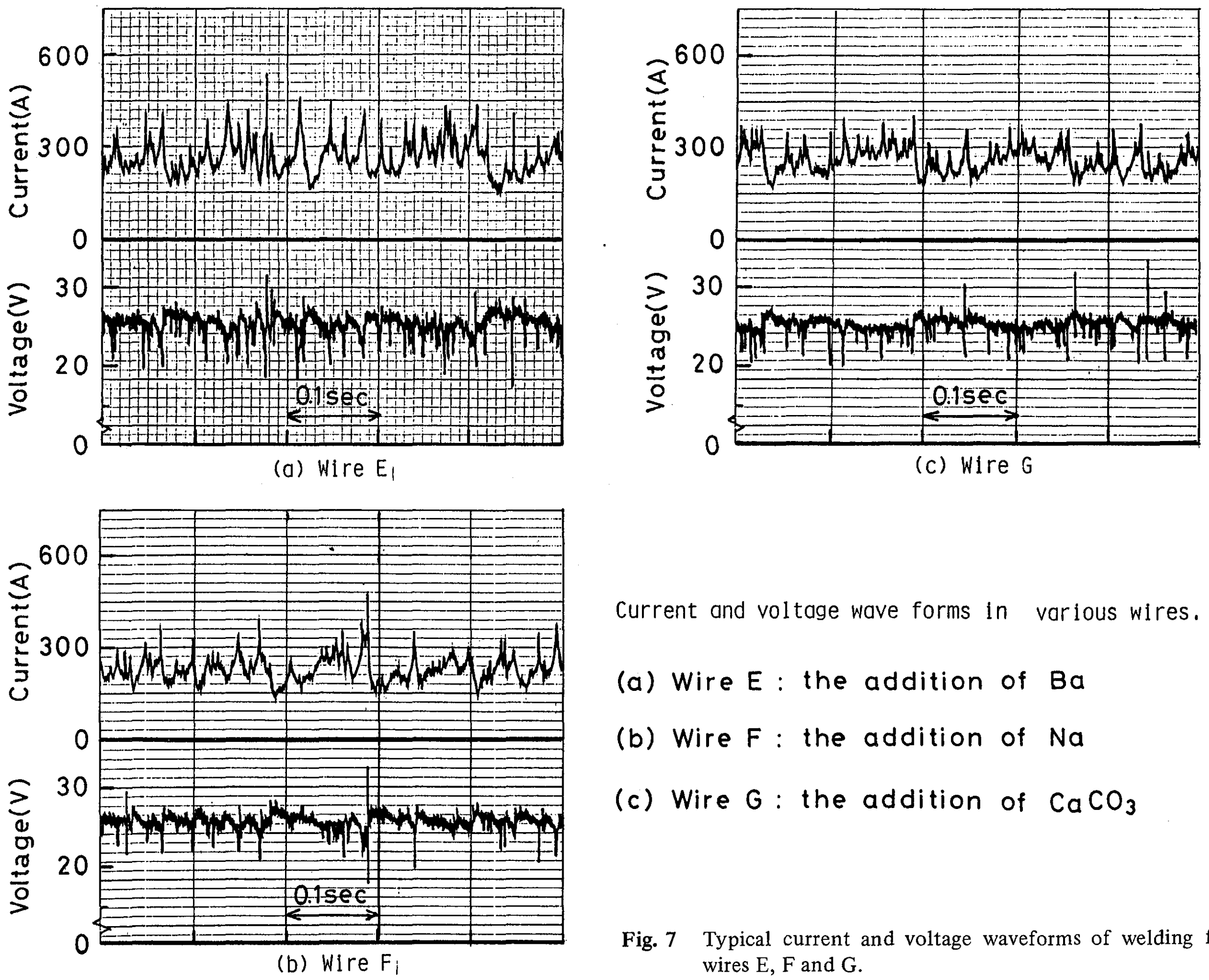


Fig. 7 Typical current and voltage waveforms of welding for wires E, F and G.

with that of magnesium. In the wire using magnesium as killing agent, the spattering occurred frequently.
(2) The area of proper welding condition was widened by applying of aluminum and the stability and regularity of metal transfer was improved by adding magnesium to aluminum.

Moreover the effects of minor element Ba, Na and $CaCO_3$ in CaF_2 type flux on the metal transfer phenomena were examined by the use of Al-Mg killing agent wire.
(1) Addition of Ba resulted in the increasing droplet size and the irregular transfer of droplets. On the other hand the addition of Na made the droplet size comparatively small and improves the stability and regularity of metal transfer. (2) The area of proper welding condition was widened by the use of Na, but it became narrow in the case of Ba.

References

1) F. Matsuda, M. Ushio, N. Kuwayama and K. Koyama: Trans. JWRI, Vol. 12, No. 1 (1983).