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# Dynamic Characteristics of Short Circuit in Pulse Gas Metal Arc Welding of Aluminum

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## ABSTRACT

**In this paper, dynamic behaviour of short circuit occurring in Pulse Gas Metal Arc Welding (GMAW-P) is investigated. Welding experiments with different values of pulsing parameters, high speed camera pictures and welding signals such as current and voltage were acquired to identify short circuit conditions in GMAW-P.**

## 1. Introduction

GMAW-P is widely used in various industrial welding applications for thin metal because of low average heat input and periodical metal transfer using pulsing of current between higher and lower values. Determination of the proper welding condition is an important and a time consuming task in the GMAW-P [1]. As short-circuiting is common between the welding electrode and the work piece in GMAW-P, understanding dynamic behaviour of short circuit behaviour in GMAW-P will be useful to ensure stable GMAW-P.

Several researchers in the past have studied the short circuit behaviour in GMAW and for monitoring weld quality online for welding steel. Previous research effort have conducted both theoretical analysis of the welding process [2,3,4] and statistical analysis of real welding signals [5,6,7] to analyse short circuit phenomenon in case of steel. However, in case of aluminium hardly any attempt is made to analyse the dynamic behaviour of short circuit in GMAW-P. This paper analyses the short circuit phenomenon in GMAW-P and their behaviour with varying pulsing parameters.

## 2. Welding Technology

### 2.1 Short Circuit Metal Transfer

Short circuit metal transfer occurs at the lowest range of welding current. It is characterized by periodic contact between the electrode and the weld pool. A short circuit begins with an electric arc formed by the potential difference between the electrode and workpiece. Droplet growth occurs in the arcing period and the arc diminishes when the filler wire makes contact with the weld pool resulting in short circuit. During the contact period, welding voltage decreases to almost zero, current reaches maximum value and metal transfer from the electrode to the workpiece takes place. The actual welding voltage and current

### 2.2 Pulse Metal Transfer

During the mid 1960's, an alternative transfer technique of GMAW-P was invented. This mode of metal transfer overcomes the drawbacks of globular mode while achieving the benefits of spray transfer. This mode is characterized by pulsing of current between low-level background current and high-level peak current in such a way that mean current is always below the threshold level of spray transfer. The purpose of background current is to maintain arc where as peak currents are long enough to make sure detachment of the molten droplet

## 3. Experiments

In the welding experiments, the shielding gas 100% Argon with a flowrate 23 L/min, and the electrode wire was Al 4047 with a diameter of 1.2 mm. The workpiece was C119T6 with a thickness of 6 mm. The welding speed was set at 8 mm/s and bead on-plate was performed for total welding time of 120 secs. Table 1 shows the actual levels of pulsing parameters used for the experimentation. The wire feed rate and contact tip-work distance (CTWD) was set at 4 m/min and 20 mm.

Table. 1 Experimental design plan

| Level | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Peak Current (A) | 250 | 280 | - | - | - |
| Base Current (A) | 40 | 50 | 60 | 70 | 80 |
| Peak Time (ms) | 2 | 4 | 6 | 8 | 10 |
| Base Time (ms) | 6 | 11 | 17 | 21 | 27 |

The experimental set-up used in this study is shown in Figure 1. It consists of a welding robot, a welding power source, sensing for the welding variables, A/D and D/A converters and a computer for analysing the welding variables.

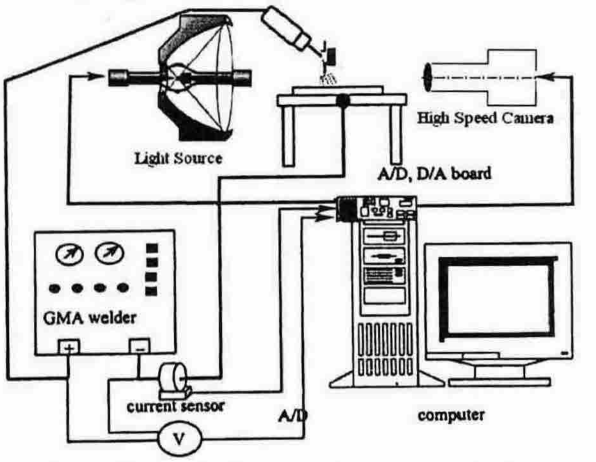



Fig. 1 Schematic diagram of experimental setup

The pulsing parameters were used as setting variables. The welding current was measured with a Hall sensor, which was attached to the earth cable, and the arc voltage between the output terminals of the wirefeeder was measured. The data sampling rate for the signals was 10000 samples/s. The waveform signals were collected during a 2 s period after 10 s elapsed from the start of welding. The threshold voltage and the average voltage were used to distinguish the pulsing region and the short-circuit region from the filtered signals. Then, the factors (the waveform elements and their average values) were extracted from the results.

## 4. Results

### 4.1 Different Forms of Short Circuit in GMAW-P

Short circuit is a very dynamic process. Major problem occurring during short circuit is unstable process behaviour accompanied by the formation of spatter. When considering short circuit in GMAW-P, we can easily define three types of short circuit behaviour in GMAW-P:

1) Instantaneous Shorts
2) Base Shorts
3) Peak Shorts

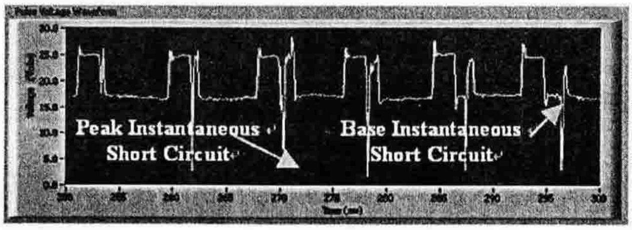



Fig. 2 Voltage waveform of instantaneous short circuit condition in GMAW-P

#### 4.1.1 Instantaneous Shorts

In instantaneous shorts, the electrode touches the weld pool for a very short period (< 5 ms in this case) of time, but no metal transport takes place. When considering instantaneous short circuit in GMAW-P, it occurs in two forms: Peak instantaneous short circuit and base instantaneous short circuit. Both of these, peak and base instantaneous short circuit occur during peak and base time of the one pulse cycle and are shown in Figure 2 on a voltage waveform.

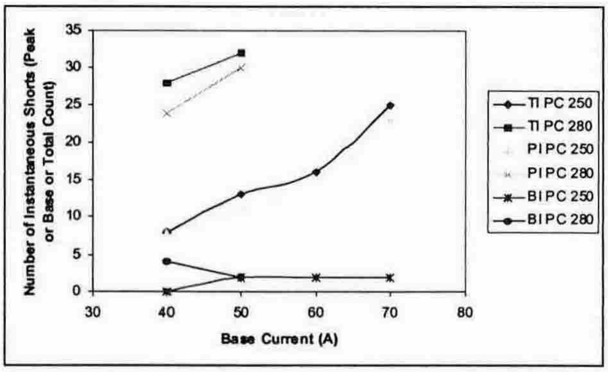
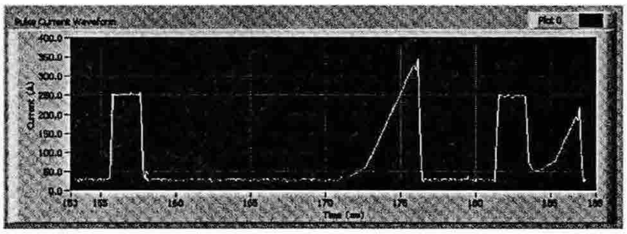
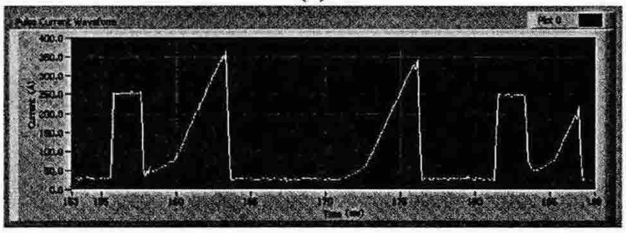



Fig. 3. : Variation in Different Types of Instantaneous Shorts (Total, Peak and Base) at Peak Time 2 ms and Base time 17 ms with Increasing Base Current and Peak Current *(* TI Total Number of Instantaneous Short Circuit, PI - Total Number of Peak Instantaneous Shorts, BI - Total Number of Base Instantaneous Shorts, and PC Peak Current)*

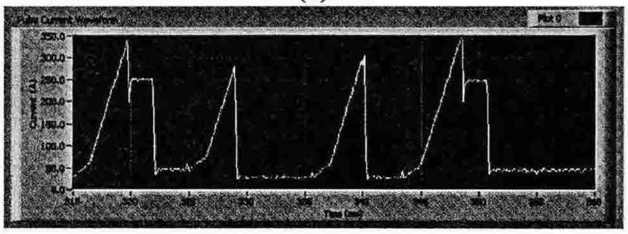
Figure 3 shows the trend of variation of instantaneous shorts with increasing peak current and base current. Instantaneous shorts were found to be more predominant during peak current phase and almost negligible during the base current phase. If the peak current, peak time and base time is kept constant and only base current is varied, then number of instantaneous shorts is found to be increasing as depicted in Figure 3. If peak current is further increased keeping base time and peak time constant and base current is varied, then numbers of instantaneous shorts are found to increase as depicted in Figure 3.



(a)



(b)



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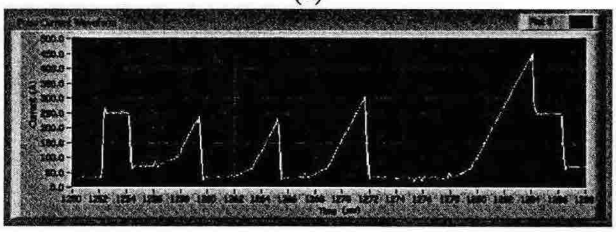
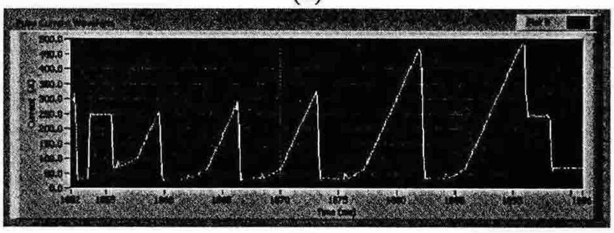


(d)

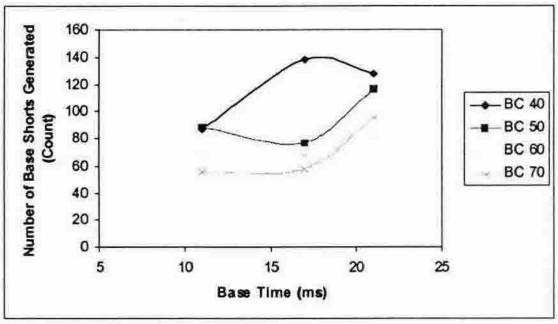


(e)

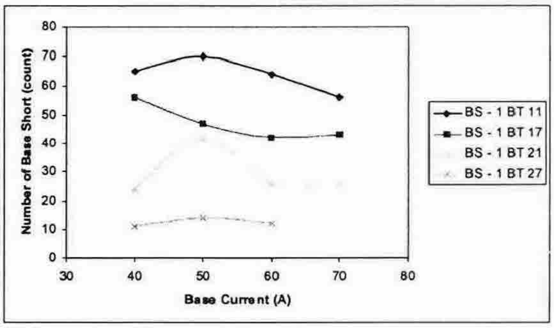
Fig. 4: Various forms of shown on current waveform when short circuit occurs during base time (a) Single base short, and Multiple base shorts - (b) Two base shorts, (c) Three base shorts, (d) Four base shorts, and (e) Five base shorts

### 4.1.2 Base Shorts

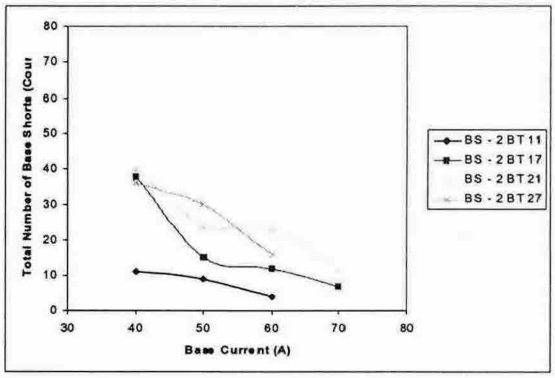
In base shorts, the electrode touches the weld pool for a period (> 5 ms in this case) of time during the base time of pulse and actual metal transport takes place.



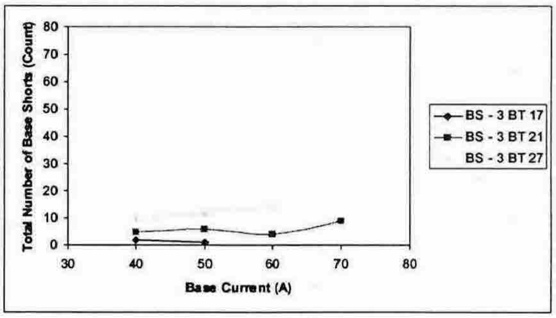

(a)




(b)




(c)




(d)

Fig. 5: Variation with increasing base current and base time (at peak current 250 A and peak time 2 ms) of (a) Total number of base shorts, (b) Single base short, and Multiple base shorts - (c) Two base short, and (d) Three base shorts *(* BC Base Current, BT Base Time, BS - 1 Single Base Short, BS-2 Two Base Shorts, and BS-3 Three Base Shorts)*

When considering base short circuit in GMAW-P, it occurs in two forms depending upon he number of times short phenomenon occur during the base time: Single base short, and multiple base shorts (two, three, four or five base short circuits). All of these base short circuits can be detected on current waveform as shown in Figure 4.

Figure 5 shows the trend of variation of base shorts with increasing base current and base time. Number of base shorts was found to be increasing with increasing base current and base time as depicted in Figure 5 (a). With increasing base time, the tendency for formation of multiple base shorts was found to increase. However, with increasing base current, decrease in number of base shorts was found.

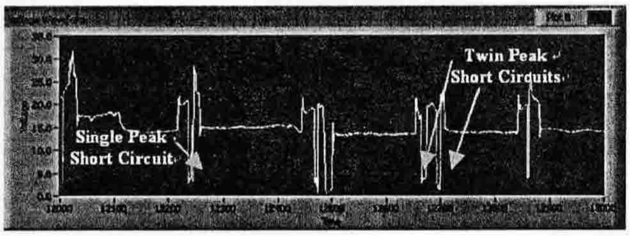



Fig. 6: Various forms of peak short circuit (a) Single peak short, and Multiple peak shorts - (b) Twinpeak shorts

### 4.1.3 Peak Shorts

In peak shorts, the electrode touches the weld pool for a period (> 5 ms in this case) of time during the peak time of pulse and actual metal transport takes place. When considering peak short circuit in GMAW-P, it occurs in two forms depending upon the number of times short phenomenon occur during the peak time: Single, and multiple peak shorts (Twin peak short circuit). All of these peak short circuits can be detected on voltage waveform as shown in Figure 6.

Figure 7 shows the trend of variation of peak shorts with increasing peak current and peak time. Peak shorts were found to be increasing with increasing peak current and peak time.

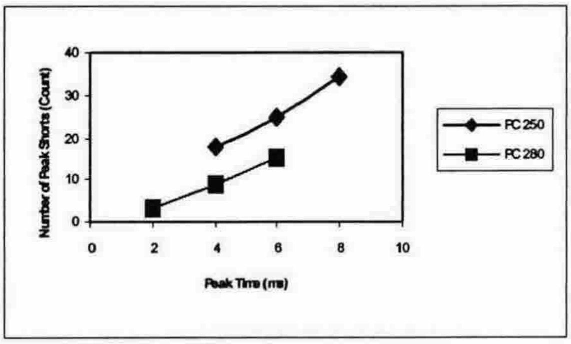



Fig. 7: Variation with increasing peak current and peak time (at base current 40 A and base time 27 ms) of total number of peak shorts *(* PC Peak Current)*

## 5. Conclusion

The results show the dynamic behaviour of short circuit in GMAW-P. Various forms of short circuit occurring in the GMAW-P of aluminium namely peak, base and instantaneous short have been identified and shown on welding current and voltage signals. Instantaneous shorts were found to be more predominant during peak current phase and showed an increasing trend with increasing peak and base current. Number of base shorts was found to be increasing with increasing base current and base time. Peak shorts were found to be increasing with increasing peak current and peak time.

References

1. Subramaniam, S., White, D. R., Jones, J. E., and Lyons, D. W. : Experimental Approach to Selection of Pulsing Parameters in Pulsed GMAW, Welding Research Supplement, May (1999), 166-172
2. Kisselevski, F., Shvydkii, N., Dolinenko, V. : Mathematical Simulation of Scanning Arc in MIG-Welding, Proceedings of the International Conference (1985), Strassbourg.
3. Amson, J. C. : Loretz Force in the Molten Tip of an Arc Electrode, British Journal of Applied Physics, 16 (1965), 1169-1179
4. Allum, C. J. L Metal Transfer in Arc Welding as a Varicose Instability: I. Varicose Instabilities in a Current-Carrying Liquid Cylinder with Surface Charge, British Journal of Applied Physics (1985), 18-35.
5. Leino, K., Nikkola, A., Vartianen, L. : Prediction of Weld Defects using Welding Condition Data, Technical Research Center of Finland,Research Report (1984), 264-267.
6. Lucas, W., Ahmed, N., Hutt, G. A. : Process Stability in MIG Welding, The Welding Research Institute Bulletin, October (1984)
7. Liu, S., Siewart, T. : Metal Transfer in Gas Metal Arc Welding: Droplet Rate, The Welding Journal, 2 (1990) 68