PROCESS STABILITY CRITERION FOR MIG WELDING

by

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ABSTRACT

The term "Process stability" refers to the dynamic behaviour of the welding arc. In MIG welding process it depends on number of factors like power source characteristics, shielding gas, welding conditions, mode of metal transfer and wire chemistry etc. However the influence of each of these factors on the process stability is reflected in the current and voltage waveform of the welding arc. Since the current and voltage signals of an arc welding process are stochastic signals by nature, it requires statistical signal theory for evaluating the process stability. Therefore the current and voltage signals are measured using high speed data acquisition system and analysed. This paper presents the results of the investigation carried out on the influence of shielding gas mixture on the process stability in solid wire MIG welding under short circuit and spray transfer conditions, using statistical approach.

INTRODUCTION

The Gas Metal Arc Welding (GMAW) process is finding increased use in fabrication industries, particularly in the automobile industries due to its advantageous features like all position welding capability, ease of automation, higher welding speed etc. The quality of the weld is greatly determined by the stability of the arc. The GMA welding process stability is influenced by a number of factors such as shielding gas, welding conditions, mode of metal transfer, power source characteristics and wire chemistry etc. In this investigation the influence of shielding gas on the process stability has been studied for both short circuit and spray transfer mode, keeping other things like power source etc. constant.

EXPERIMENTAL CONDITIONS

For this study 1.2 mm dia. carbon steel electrode wire conforming to AWS E70s-6 gas has been used. The welding trials were conducted with 100% CO_2 shielding gases. The investigations on the process stability have been carried out both for short circuit and spray transfer modes. The carbon steel base plate used for welding trials have all been milled and cleaned thoroughly. The welding parameters used for the short circuit and spray transfer conditions are given in **Table I**.

The Analyser Hannover AH- XII has been used for data acquisition and process stability. The Analyser Hannover AH-XII is a computer aided monitoring and analysing hardware and software for data acquisition, data processing and documentation for industrial applications. The AH-XII is built up for amplitude analysis of welding current and voltage. For amplitude analysis the class range and width are

Table I : Parameters used for short circuiting transfer and spray transfer welding trials (Wire 1.2 mm ϕ) Type : E 70S-6

PARAMETER	VALUE	
	Short circuiting	*Spray*
Current	120-130 A	280-300 A
Voltage	17-18 N	33-35 V
Stand-off distance	17 mm	20 mm

programmable. For the time analysis the voltage threshold and class width are preselectable. The AH-XII evaluates the amplitude of arc voltage, current, short circuiting time, arc burning time, weighted burning time and cycle time on line and also using the time functions of the process signal it determines the probability density distribution of the above parameters. The minimum class width for the voltage is 0.2 volts and for the current is 2 Amp. From the current and voltage PDD function the program determines the statistical parameters such as mean, standard deviation, modal value etc. **Fig.1** shows the schematic picture of the AH-XII and the method of measuring the voltage and current signals. **Fig. 2**. shows the process of data reduction by classification.

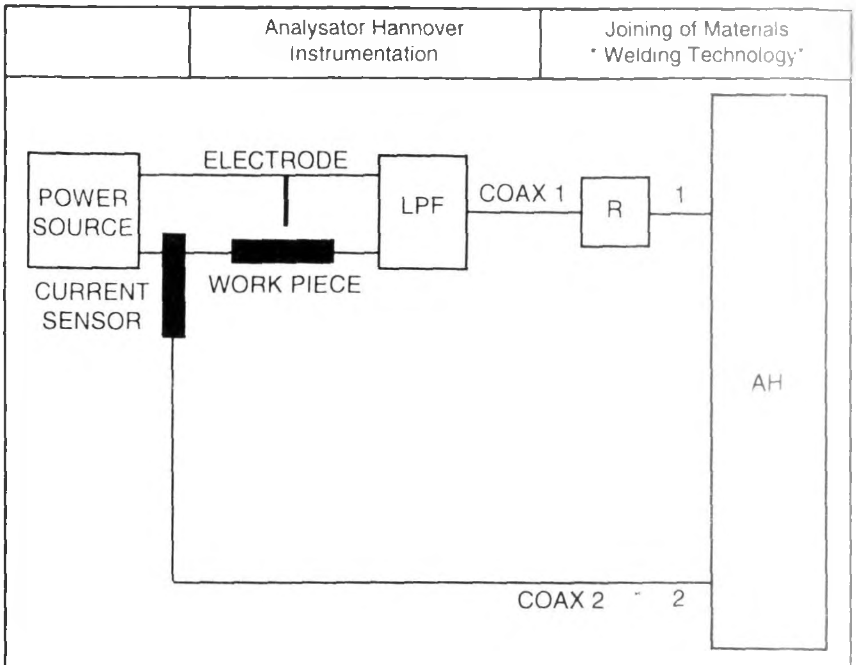

Fig. 1 : Schematic diagram of AH-XII Instrumentation system

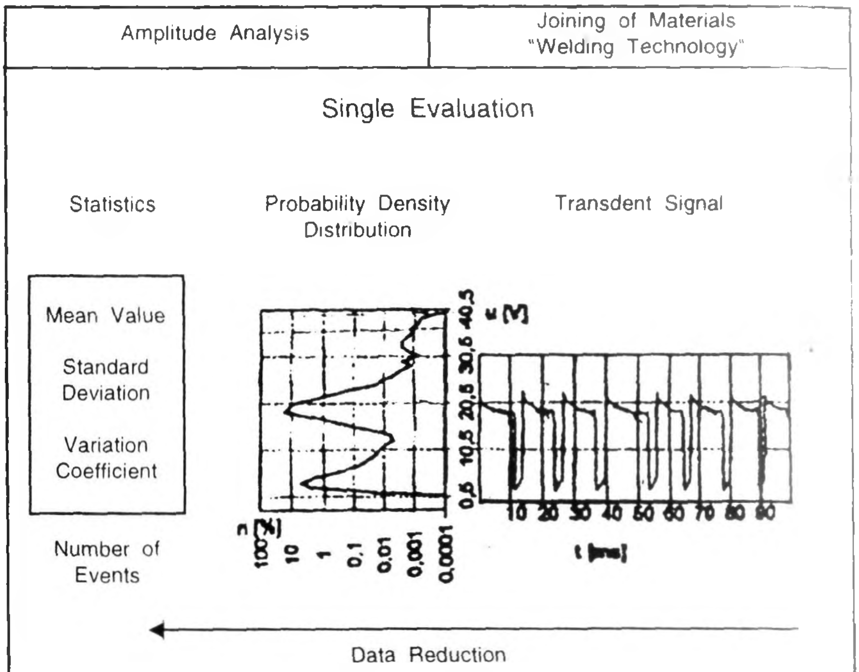

Fig. 2 : Signal Evaluation and Probability Density Distribution (PDD)

ARC STABILITY

The term "Arc Stability" refers to the dynamic characteristics of the welding arc. Rehfeldt et.al. [1] have stated the following as the characteristics of an ideal arc.

- The arc should burn with a constant arc length
- It should have uniform metal transfer.
- Low spatter.
- Quick reignition of the arc after every short circuit.

The above characteristics are only qualitative description of the arc stability. However, some kind of quantitative description of the arc stability would be better. In this direction, Orszagh et al. [2] have proposed stability index [W] as given below :

$$W = Ts\,Vs + Ta\,Va + To\,Vo$$

where Vs, Va and Vo are the variation coefficients from a short circuit arcing and arc absence phases and Ts, Ta and To are the relative proportion of these phases in the welding process respectively.

On expending Vs, Va and Vo and rearranging we get

W = Fs ms + Fa ma + Fo mo

where Fs and ms are frequency and standard deviation of short circuiting phase and Fa ma and Fo mo are similarly for the arc burning and arc absence phases.

It shows that the stability index is the sum of the products of frequency and standard deviation of the three different phases. While the physical significance and validity of such an index is still to be clearly understood and verified. It can easily be shown that the above index is inapplicable for spray arc conditions, as both Fs and Fa become zero during spray arc welding. Hence such a simplified index can not be universal covering all ranges of metal transfer modes.

Mita et al. [3] using a multiple regression technique, have identified four waveform factors viz. standard deviation of short circuiting time S [Ts], standard deviation of arcing time S [Ta], standard deviation of average short circuit current S[Ts] and standard deviation of average arcing current S[Ia] to have a strong correlation with arc stability and obtained and arc stability index [W] in terms of the above factors after introducing some dividing constants and correction terms for arc extinction and arc flare-up as given below :

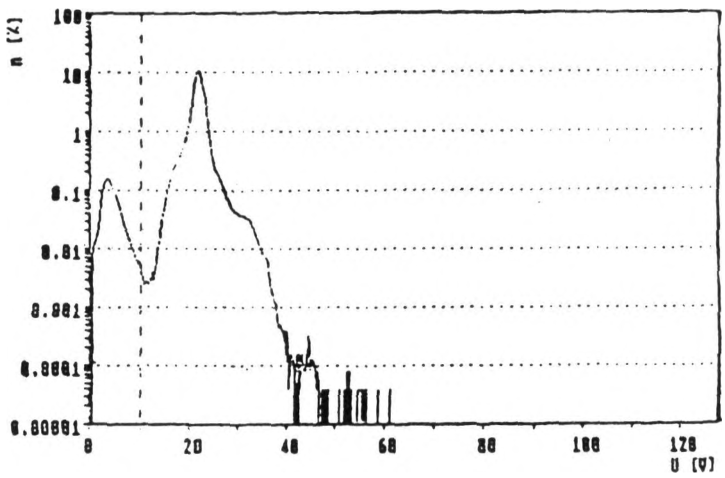

Fig. 3 : PDD of arc voltage for short circuit transfer

W = Wa + WR + Wp

where

$$Wa = Ln \frac{S[Ts]}{1.3} \times \frac{S[Ta]}{3.8} \times \frac{S[Ia]}{24} \times \frac{S[Ia]}{23.6}$$

WR = Z Ln[Ra/Ri]

where,

Ri = Mean resistance during arc period under optimum condition

Ra = Mean resistance during the arc period

Wp = Ln[Pa/Pi]

Pa = power during arcing period

Pi = power during arcing period under optimum conditions.

In this, although identification of the contribution factors is based on statistical concept, further treatment adopted to arrive at the stability index appears to be arbitrary. For instance the standard values used may be applicable only for the wire type and power source employed in their experiments. Further the arc stability index obtained, does not convey any recognisable physical behaviour of the process to suggest some corrective action.

RESULT & DISCUSSION

The current and voltage signals have been measured simultaneously using the Analyser Hannover AH-XII. The current signal is converted by a Gall effect sensor LEM module with an isolated output signal of ±10 volts for ±1000 Amps. The arc voltage signal is given to a signal conditioner which produces ±10 volts corresponding to ±128 volts.

The process signals have been measured for a period of 20 secs, taking a total of one million samples. Because of the large size of the sample, the statistical parameters obtained closely represents the actual behaviour of the process.

Figs. 3 and **4** show the Probability Density Distribution (PDD) of voltage for short circuit and spray transfer welding conditions. The PDD of current and voltage signals are considered to be the finger prints of the process. since the various factors that influence the process stability find a place in the PDD. It can be seen from **Figs. 3** and **4**, that while the PDD voltage for short circuit transfer has a bimodal distribution the PDD for spray arc has only a single modal distribution. The bimodal distribution in case of short circuit transfer welding represents the short circuiting phase and arc burning phase. The stability of the process is evaluated based on the statistical parameters of the PDD such as standard deviation, variation coefficient, mean value etc. For a stable process in short circuit transfer welding, the standard deviation and variation coefficient have to be minimum for each phase. Besides, it should have a uniform short circuiting time and

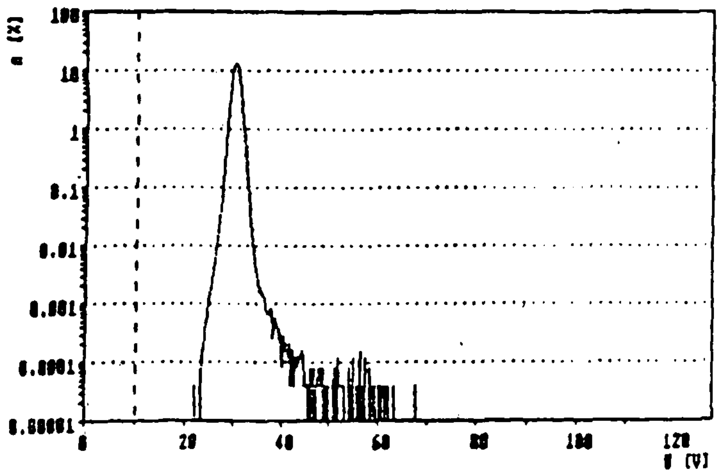

Fig. 4 : PDD of arc voltage for spray arc transfer

Table II : Statistical Parameters

Shielding Gas	Mode of metal transfer	Signal	SHORT CIRCUITING PHASE Mean Value	SHORT CIRCUITING PHASE Std. Deviation	SHORT CIRCUITING PHASE Variation Co-efficient	ARC BURNING PHASE Mean Value	ARC BURNING PHASE Std. Deviation	ARC BURNING PHASE Variation Co-efficient
100% CO_2	Short circuiting transfer	Voltage	4.3 V	1.4 V	0.33	24.9	1.9	0.08
		current				138.4	55.1	0.4
		Short circuiting time	2.5 m sec	1.7 m sec	0.69			
		Arc burning time				5.3 m sec	3.07 m sec	0.58
	Spray transfer	Voltage	10.9	2.9 V	0.26	35.8 V	2V	0.06
		current				277.2 A	44.5 A	0.16
80% Ar + 20%CO_2	Short circuiting transfer	Voltage	4.5	1.3	0.29	21.9	2	0.09
		current				143.4	42.2	0.29
		Short circuiting time	2.32 m sec	1.11 m sec	0.48			
		Arc burning time				7.7 m sec	4.5 m sec	0.59
	Sparay transfer	Voltage				33 V	1.4 V	0.04
		current				304 A	37.9 A	0.12

arc burning time. For stable process in spray arc welding, the standard deviation and variation coefficient have to be minimum and there should be no short circuiting events as short circuiting is a process disturbance in spray arc welding.

The results of the investigations carried out are summarised in **Table II**. It can be seen from the table that the process stability is better with 80% Ar+20%Co_2 gas mixture compared to 100%CO_2 as is evident from the standard deviation and variation co-efficient.

CONCLUSION

The PDD of voltage and current along with Class Frequency Distribution of short circuiting time, arc burning time and cycle time and the statistical parameters obtained from these PDDs provide a better means of assessing the process stability of any arc welding process than any of the so called stability indexes available. Further the PDDs and statistical parameters generated on line can be used for in process quality monitoring and control.

ACKNOWLEDGMENT

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OBITUARY

With profound grief and sorrow, we acknowledge the sudden and sad demise of our respected member, Mr. K. Thariani on 18th October '96.

His services to The Indian Institute of Welding were commendable. The Delhi Chapter has lost a guide and dedicated member. He was the first Hony. Secretary of IIW, Delhi Branch and was Chairman for 2 years from 1982 to 1984. He was a member of Delhi Chapter's Building committee and a permanent invitee of the Executive Body of Delhi Branch. He also served as a Council Member for several years representing Delhi Branch. His association, contribution and guidance shall be remembered by all members of IIW. We send our heart felt condolence to the agrieved members of the family.

May his soul be rest in peace.