Investigation of CO$_2$Welding Arc Sound [†]

Correlation of Welding Arc Sound Signal with Welding Spatter

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Abstract

A computer detection and analysis system has been developed and the correlation of CO$_2$ welding arc sound with spatter loss as well as other affecting factors was studied. The results show that the welding spatter loss is proportional to the arc sound energy produced at the end of short circuit transfer. Based on this discovery, a new sensing method is proposed to characterize the CO$_2$ welding spatter loss on line by means of the arc sound energy signal.

KEY WORDS: (Welding spatter) (Arc sound energy) (CO$_2$ welding) (Short circuit transfer)

1. Introduction

It is well known that CO$_2$ arc welding is of high efficiency, low cost and widely used in industrial production of welding structure. However, it has the defects—serious welding spatter and thus bad weld appearance. In order to control the welding spatter effectively, it is necessary to use a sensor, which can indicate exactly the signal of welding spatter on-line. We have known that during welding, a welder with experience can distinguish large or small welding spatter through the arc sound signal and relevantly adjust the welding parameters. This means that there is a close relationship between the arc sound and the welding spatter. So far there are some reports on the study of welding arc sound [2,3,4,5], but no investigation about the relationship between the arc sound and welding spatter has been published. The authors of this paper have studied the spattering process by means of high-speed cine films synchronized with the arc sound and arc voltage signals, and discovered that a special arc sound signal occurred at the moment when welding spatter occurred [1]. In this paper, the authors devoted their efforts to find the relationship between the arc sound signal and the welding spatter loss and its influencing factors so that a new sensing method could be proposed with which we can dynamically control the welding spatter.

2. Experimental method

2.1 Structure of the experiment

The whole system is shown in Fig.1. During CO$_2$ welding process, the welding arc sound signal was received by two microphones and then amplified and filtered. A 586 computer through a data acquisition board collected the voltage, current and arc sound signals after a converter. The stored data were processed by specially developed statistical analyzing software. Thus the frequency of short circuit transfer, the synchronous wave patterns and characteristics of the arc voltage, current and arc sound could be obtained. The statistical results could be used on-line to train a neural network controller.

2.2 Welding Arc Sound Receiving with Two Microphones

In the previous work, only one microphone was used to receive the welding arc sound signal. Therefore, the
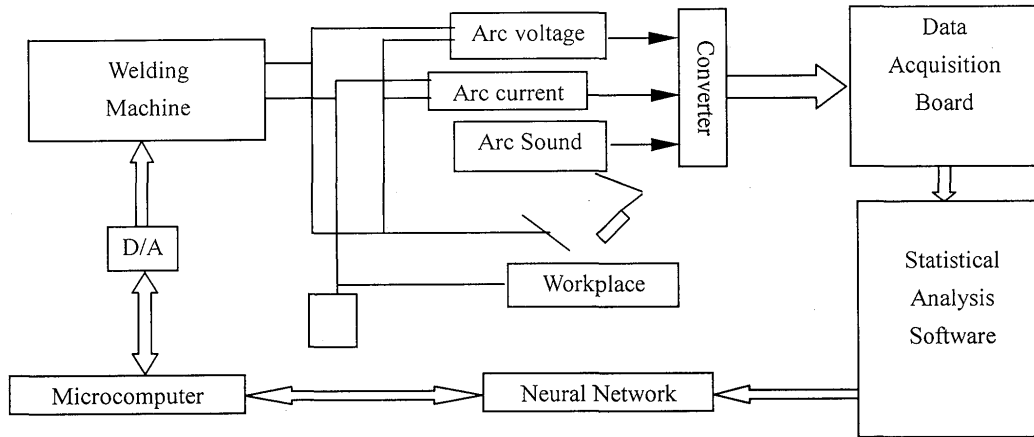
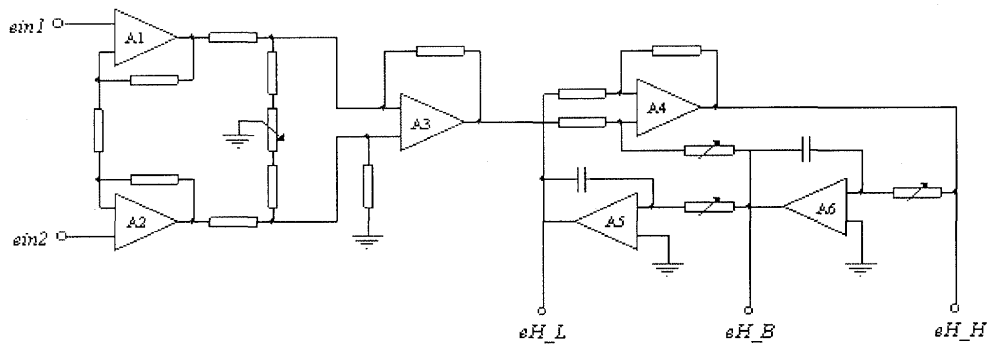**Fig.1** The construction of experiment system

Fig. 2 The amplifier and filter circuit for arc sound signals

noise could not be avoided to confuse the arc sound signal. In order to eliminate the influence of the noise, a new method that uses two microphones to receive the welding arc sound signal was utilized here.

Table 1 Welding conditions for experiments

Gas flow rate (l/min)	Electrode extension (mm)	Arc current (A)
15	15	160,200,250,280
5,10,15,20,25	15	250
15	10, 15, 20	250

The electric circuit is shown in Fig.2. One microphone was directional to the welding arc; the other microphone was directional to the surrounding.

Because we used a differential amplifier and the noise signals that were received by the two microphones were of the same module, so the noise signals were reciprocally cancelled out while the arc sound signal was amplified. The low-pass, band-pass and high-pass filters were also used to eliminate noise.

The experimental results showed that the frequency band of welding arc sound was wide. For the low-pass, band-pass and high-pass filters sections, all had welding arc sound signals. However, the effect of the low-pass filter section was best with regard to short-circuit transfer.

2.3 Analysis Software

The software was programmed by Turbo C 2.0 with menu interface. The welding voltage, current and arc sound signals can be synchronously displayed, and transformed by FFT or statistically analyzed.
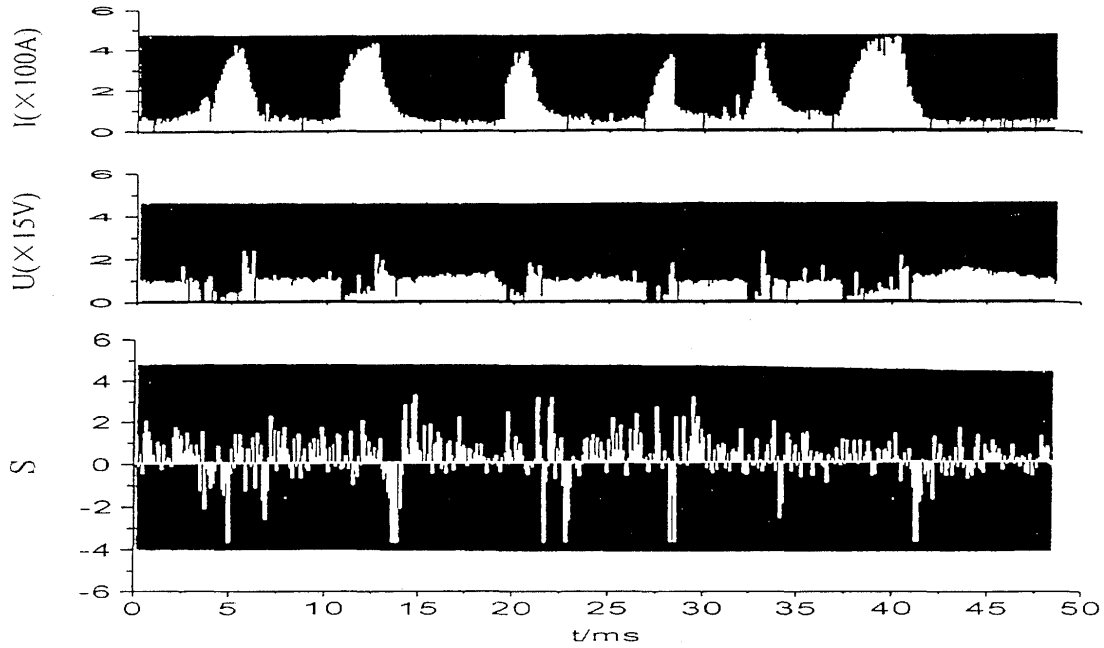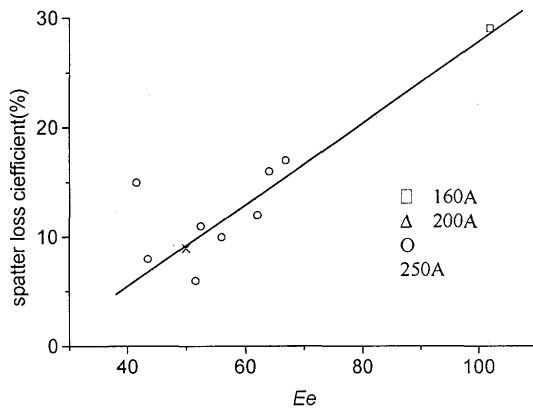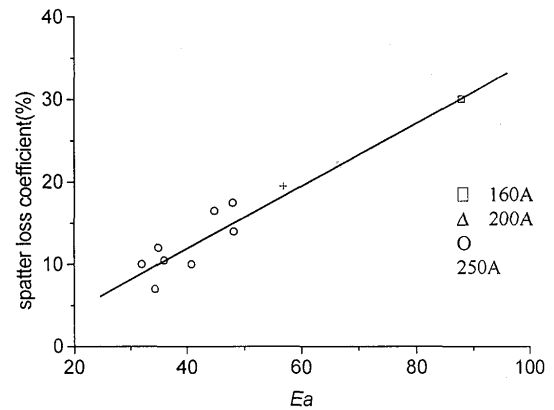
3.   Experiment Results

3.1 Experiment Condition

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Fig. 3 Welding arc sound and voltage and current signals

Fig.4 The relation of Ee and
Welding spatter loss

Fig.5 The relation of Ea and
Welding spatter loss

Welding machine: ZXB-500.

Test sample: 250mmx42mmx7mm(A3 steel).

The distance between the microphones and the welding arc was 450mm. The diameter of welding wire was 1.2mm.

According to the difference of the welding current, gas flow rate and electrode extension, the experiments were divided into 11 groups (see Table 1).

3.2 Synchronous Wave Form

The synchronous waveform is shown in Fig.3. We can see that it takes about 2~3 ms to finish one short circuit transfer. The voltage immediately reaches the maximum at the end of the short circuit transfer. The arc

sound signal lags a little behind the voltage and current signals. The reason is that the arc sound signal takes some time to reach to the microphone from the arc source. Just after a short circuit transfer, the amplitude of the arc sound signal increases immediately and is much higher than that at other times. Therefore, the change of the arc signal shows not only instantaneous amplitude variation but also the variation during some time.

3.3 FFT Transformations

The FFT transforming results of the arc sound signals show that there were three peak values. The first peak related to the direct component, the second peak related to the frequency of short circuit transfer, and the
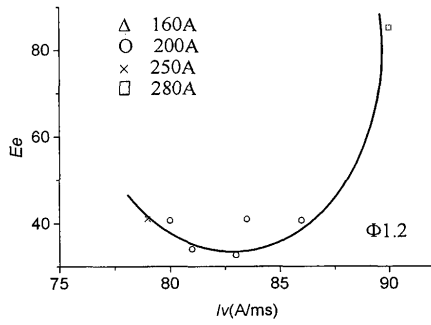
Fig.6 The relation of
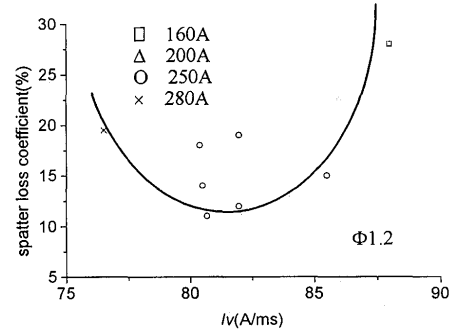*Ee* and *Iv*

Fig.7 The relation of *Iv* and
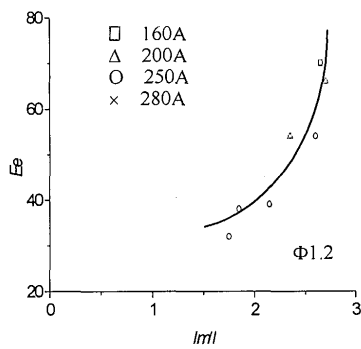welding spatter loss

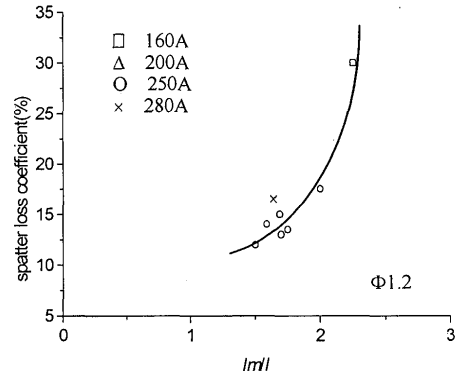**Fig.8** The relation of *Im/I*
and arc sound energy *Ee*

Fig.9 The relation of *Im/I*
and welding spatter loss

third peak associated with the frequency of the arc sound produced at the end of short circuit transfers. These peak values were volatile and there was no obvious correlation.

4. Results of Statistical Analysis

The authors studied the relation of welding spatter with each term of arc sound energy, short circuit peak current (I_m), ratio of (I_m) and average welding current (I), the rising rate of short circuit current (I_v), and short circuit average electric power individually. For each term, a straight-square chart of probability distribution was made. But no obvious correlation was found.

4.1 Relationship Between Welding Arc Sound and Spatter loss

It was found that the frequency and the amplitude of arc sound individually could not finely reflect the effects of arc sound signals. So a parameter that is called arc sound energy (Es) is defined. It is the integral of squared arc sound signals to the time as follows.

$$Es = a \int_{t_0}^{t_0 + \Delta t} s^2 dt \qquad (1)$$

a- the linear transform coefficient

S- the acquired welding arc sound signal.

Δt- the time delay and the value is 1.44 micro second

t_0 - the time at the begin or end of the short circuit transfer.

The arc sound energy at the beginning of a short circuit transfer (Eb) is defined as the integral of squared arc sound signal from the time at the beginning of the short circuit transfer to 1.44 microsecond after that. The arc sound energy at the end of a short circuit transfer (Ee) is defined as the integral of squared arc sound signal from the time at the end of the short circuit transfer to 1.44 microsecond after that. The average arc sound energy (Ea) is defined as the average value of (Eb) and *(Ee)*. From Fig.4 and Fig.5, we can see that both *(Ee) and (Ea)* have a linear relation with the welding spatter loss coefficient. Therefore, both the end arc sound energy and the average arc sound energy can be used as the feedback

signals to indicate the welding spatter.

4.2 Influence of Current Wave on Arc Sound Energy

The short circuit peak current, the rising rate of short circuit current and the ratio of I_m and I have great influences on the arc sound energy, and the experimental results are shown in Fig.6,7,8 and 9. In Fig.6, there is a best region in which, the end arc sound energy, and therefore, the welding spatter loss is minimum. The associated rising rate of short circuit current is 83A/ms.

5. Discussion

The welding arc sound is a kind of energy wave, and it is generated through a vibration. During a welding process, the welding arc sound in some frequency region is generated for continuous changes of the arc. The energy of a molten metal bridge will increase with the increasing of short circuit current during a short circuit transfer. When the energy reaches some degree, the metal bridge will explode. At the same time, a very violent vibration of arc plasma is generated. Thus it causes a violent arc sound. A part of the explosion energy is released in the form of arc sound energy. At the same time, welding spatter is produced. The more violent the molten metal bridge explosion, the greater is the arc sound energy, and therefore, the more spatter is produced. Here we can see clearly the linear relation between the end arc sound energy and the welding spatter loss.

The vibration of arc sound at the beginning of a short circuit transfer is generated by the arc extinction or the contact between droplet and molten pool, and this

process will also cause welding spatter.

6. Conclusion

(1) The arc sound energy at the end of short circuit transfer is proportional to the welding spatter loss for CO_2 arc welding process.

(2) In the parameters of arc current waveform, the short circuit current rising ratio and the current ratio have greater influence on welding spatter.

(3) The method of using two microphones to receive the arc sound signals is very effective.

(4) Based on the results of this study, a new method is proposed to sense the spatter loss by means of arc sound signal for CO_2 arc welding process.

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