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SIGNAL ANALYSIS OF VOLTAGE NOISE IN WELDING ARCS

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ABSTRACT

Gas tungsten arc welds have been made on low alloy steel plates to which intentional defects (discontinuities) have been imposed. Disruption of shielding gas, welding over surface films, tack welds etc., all produce changes in what is otherwise a relatively uniform voltage signal. The arc voltage was 15 volts ± 2 volts with 300 mV ripple noise from the power supply. The changes in this steady noise voltage varied from 50 mV to less than one millivolt depending on the severity and the type of change experienced. In some instances the changes are easily detected by analysis of the signal in real time, while in other cases the signal had to be transformed to the frequency domain in order to detect the changes. Although use of frequency spectrum analysis is currently too expensive for any but the most critical welding applications, the promise of low cost computation in the next decade makes even this complex technique potentially attractive in the future.

The technique has detected discontinuities as small as 1.5 mm in length. The ultimate sensitivity and reproducibility of the technique is still being investigated.

INTRODUCTION

Automation of welding is essential for improved productivity and reliability, yet one of the major problems

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associated with automation is development of low cost, rugged sensors. In the present study the noise voltage from a gas tungsten arc has been monitored as a means of detecting changes in the process. An advantage of this type of sensor is that the probe is simple and inexpensive. Indeed, the two voltage leads are probably the simplest of all possible probes.

The probe actually being used is the welding arc plasma itself. The plasma has the advantage of responding to both chemical changes and geometric changes on a time scale of microseconds. Chemical changes in the plasma are caused by vaporization of impurities on the surface or by vaporization of metal from the weld pool or by disturbances in the shielding gas. These ions alter the electrical conductivity of the gas, thereby altering the voltage. High speed spatially resolved spectroscopy indicates that the ions traverse the arc in a time of ten microseconds or less (1).

Geometric changes in the workpiece change the shape of the plasma, which in turn causes a change in the arc voltage. These changes also occur on a microsecond time scale. This voltage fluctuation with changes in joint geometry has been used commercially to control the length of the gas tungsten arc and to track a weld seam in a groove. Neither of these uses, however, has exploited time resolution of the changes above approximately 100 Hz. This is due primarily to the slow speed of the mechanical systems needed to move the electrode. In the present study, changes in the voltage signal have not been used to control the arc, but rather to determine if a disturbance has occurred. Mechanical restrictions do not apply, with the result that oscillations to 50 kHz or higher may be studied.

It is well known that an experienced welder listens to the arc to determine if it is operating properly. In many instances, disturbances in the process may be detected by this acoustic signal before their effects are seen in the weld pool. Partial loss of shielding gas may produce crackling sounds without altering the visual appearance of the weld at all, yet the resulting contamination from the atmosphere may reduce the mechanical properties of the joint significantly. Shaw has correlated the light emission from the plasma with the arc voltage fluctuations to frequencies of 20 kHz (2). It is likely that the acoustical signals detected by the welder are also correlated with the noise voltage. For these reasons, it was decided that fluctuations between 60 Hz and 10 kHz represented a useful starting point for the signal analysis. Voltage was chosen since it responds more rapidly than current to changes in an inductive system. Acoustic techniques were not used as they are susceptible to interference from extraneous sources.

The major disadvantage to using the arc itself as the sensor is that the plasma responds to many different things. Reduction of the signal to a useable form is the most significant problem encountered. The purpose of the present study was to determine if intentional disturbances to a gas tungsten arc could be detected in the welding noise voltage signal.

EXPERIMENTAL

The measuring circuit for the welding voltage noise is shown in Figure 1. The welds were made with an SCR transformer-rectifier power supply at 100 amperes and 15 volts electrode negative. The signal was monitored on an oscilloscope and recorded on an open reel AM tape recorder. A high pass filter with a cutoff of 20 Hz was used to reduce the low frequency noise coming from the power supply. The high frequency rolloff of the tape recorder was measured at approximately 24 kHz which is much higher than the frequencies of interest.

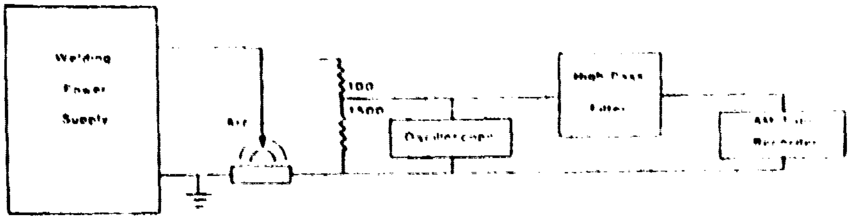

Figure 1

The base metal was sand blasted carbon steel plate. Argon gas at a flow rate of 30 CFH was used for shielding. Disturbances were introduced both by turning on a transverse

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air jet and by welding over copper inserts in the steel plate. The inserts were brazed in place and machined smooth prior to welding. The second channel of the stereo tape recorder was used to mark the location of the disturbed signal on the first channel of the magnetic tape by imposing a constant frequency sinusodial input during the time of the disturbance.

Considerable attention was given to detection of a reproducible signal. Several grounding and voltage lead configurations were tested until the background noise was reduced to several millivolts peak to peak. The remaining noise was periodic in time, and since only relative changes were of interest, this small noise signal was thought to be insignificant.

The recorded waveforms were transferred to a PDP 11/45 computer in the MIT Digital Signal Processing Laboratory. These signals could then be studied at length in either the time domain or the frequency domain by performing a Fast Fourier Transform (FFT).

RESULTS

Figure 2 shows several periods of a weld over a clean steel plate with no disturbance imposed. The period of these oscillations is 120 Hz with a range of 350 mV peak to peak. Numerous welds made at different times and different conditions confirmed that this signal was uniform and consistent provided the arc was not disturbed. Indeed, the signal in Figure 2 is very similar to that obtained by running 100 amperes through a 0.3 ohm carbon block resistor using the same power supply. It was concluded therefore that the signal in Figure 2 is essentially the noise voltage generated within the power supply. These fluctuations are not due to changes in the welding arc plasma, yet they do induce a

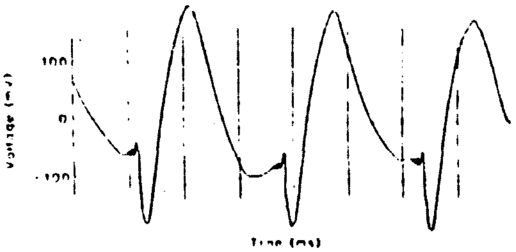

Figure 2

disturbance at the arc itself.

Figure 3 shows the same signal with a disturbance in the arc caused by a transverse jet of air. It should be noted that the disturbance was minor, with little variation as perceived by the operator. The signal has changed noticeably, nonetheless, portions of the power supply noise voltage (cf. Figure 2) may still be detected.

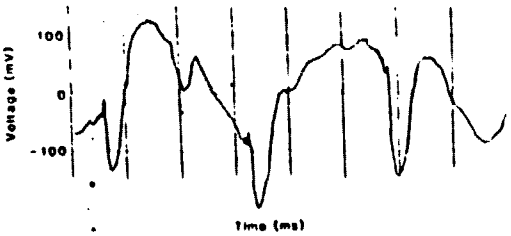

Figure 3

Figures 4 and 5 show "good" and "bad" welds produced by welding on a steel plate contaminated with a 3 mm bead of

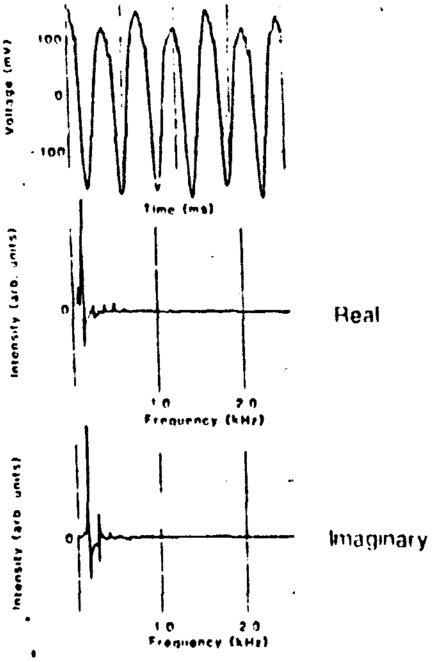

Figure 4

copper. Figure 4 shows both the time domain and frequency domain signals for the good weld made on the steel alone, while Figure 5 shows the same signals in the contaminated regions. It will be noted that the changes in the time domain are barely discernable while the frequency domain shows a significant difference.

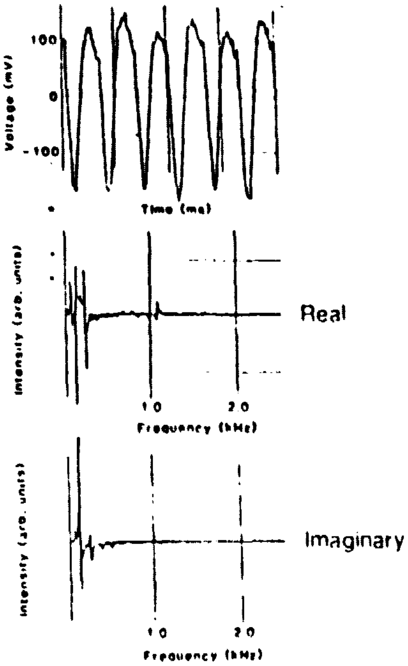

Figure 5

DISCUSSION

These studies have shown that disturbances in the welding arc plasma may be detected in the welding noise voltage signal. In some instances the changes are readily seen in the time domain, while in other cases, the change is more readily distinguished in the frequency domain.

The specific reasons for the changes are not well understood at this time. One observer has suggested that the arc oscillates about the electrode tip and that the period of this oscillation is a function of the arc length (3). This could easily explain the disturbance caused by the transverse air jet, yet it does not explain the distinct frequency observed when welding over the copper contamination at constant arc length.

Several important problems remain to be studied before this technique can be developed further. First, it is desirable to improve the signal to noise ratio. The power supply oscillations are many times greater than the disturbances which are of interest. Fortunately, at least for the gas tungsten arc process, the power supply fluctuations are periodic and may be subtracted from the total signal by using more complex signal analysis techniques. Alternatively, transistorized power sources can produce much cleaner signals.

Secondly, it is necessary to develop an understanding of the form of the voltage disturbance produced by a given disturbance in the weld. It is not clear at this point whether disturbances in the weld zone will produce characteristic signatures in the voltage wave form. If the response is not predictable, all that this technique can do is determine that some change has occurred. It would be much more valuable if the type of change could also be determined.

Thirdly, the process, if feasible, must be performed in real time. The off line analysis used in this study provided a number of simplifications. If the process is to be used in production, special equipment must be used. The prospect of very large scale integrated (VLSI) circuitry coupled with the speed of a hardwired FFT program at least yields the promise that the technique may be practical in future years. For the present, it is necessary to demonstrate the full potential of the signal analysis before contemplating the development of real time equipment.

It is unlikely that consumable electrode processes will be amenable to this technique of analysis unless the droplet formation and detachment is made more uniform. Pulsed current welding machines may provide the necessary uniformity.

SUMMARY

Signal analysis of the high frequency voltage fluctuation in gas tungsten arc welds has shown that disturbances in the process may be detected. It remains to be shown whether these fluctuations are specific enough to use as a means of controlling the welding process. If several remaining problems can be solved, noise voltage signal analysis could provide a sensitive technique for monitoring many changes in the welding process.

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