Current Measurement of Resistance Spot Welding Using DSP

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Abstract

This study aims to calculate the resistance spot welding current digitally at a fast speed. The conventional open-loop spot welding machine cannot measure the current, thus the welding quality varies. The welding time of spot welder is very short, but the welding current is strong and it is hard to be measured, thereby resulting in the uncontrollability of welding quality. This study uses a high speed, low price and high-performance 32-bit ADSP21065 SHARC digital signal processor (DSP) as the core to measure the welding current in real time. The experimental results are compared with the commercial welding current meter to prove that the proposed method can quickly and accurately calculate the welding current.

***Key Words*:** Resistance Spot Welder, Welding Current, Digital Signal Processor, Current Measurement

1. Introduction

At present, the resistance spot welding is widely applied, 95% for industrial purposes. The advantages of spot welders include short welding time, fast working speed, few energy consumption, simple structure, and easy operation [1]. On the contrary, the disadvantages are strong welding current, electrode consumption, and electrode size restricted by the materials and thickness of welding parts. When the welding current passes through the electrodes, the welding current is very strong (as high as 250 K amperes), while the welding time is too short. Welding two 2 mm thick metal plates needs only 0.5 s [2]. Thus, it is very difficult to accurately measure the welding current in a short time.

The principle of the resistance spot welding is that the strong current passes through two metal plates via the electrodes, as shown in Figure 1. The contact area is heated up for its contact resistance, which melts the metal plates and joins two metal plates together by the electrode force. Most of the heat concentrates on the contact surface because the resistance value is the largest in the contact area. The main functions of the electrodes are to supply the welding current at the welding part, to impose high pressure on the welding parts, and to cool down the welding parts.

The conventional open-loop spot welding machines do not measure welding current as the feedback signal. The open-loop welding process is fixed by setting the current and the heating time prior to welding. Therefore the welding quality might vary due to the metal thickness change, electrode force change or machine temperature rising [3,4]. Thus, this study attempts to measure the

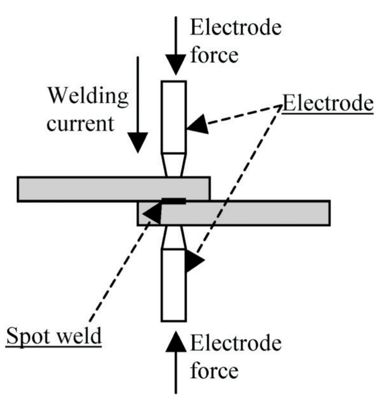

Figure 1. Illustration of resistance spot welding.

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welding current digitally in real time which is necessary for future development in closed-loop controller of spot welding for better welding quality.

2. The Resistance Spot Welding System

The equivalent circuit of the resistance spot welder is as shown in Figure 2 [2]. The controller in the figure is used to control the power into the welder. The secondary winding of the transformer is only two or less than ten turns. Therefore, the secondary side has low voltage but extremely high current. The strong current and even small contact resistance between two metal plates would cause huge heat to melt and join the metal plates together.

The heat generated during the spot welding is transformed from the electric energy as follows:

$$H = 0.24\, I^2\, RT \tag{1}$$

where H is welding heat (caloric), I is welding current (ampere), R is contact resistance (ohm), and T is welding time (second).

The three factors influencing the spot welding quality are described in the following [2,5–7]:

(1) Electrode force: If the electrode force is proper and the contact area size is adequate, the current will concentrate in the contact area and produce a proper nugget. If the electrode force is too small, the contact area of two contact plates will be too small, and the resistance becomes bigger, and thus, the current distribution is uneven, easily cracks and has surface flashing. If the electrode force is too large, the contact area will be too big. The resistance becomes smaller, and thus, the current density is too low, resulting in a big dent and small nugget.

(2) Welding current: If the welding current is too weak, the nugget will be too small or even cannot adhere. If it is too strong, the nugget may be too big, and the transformer becomes too hot.

(3) Welding time: If the welding time is too short, the nugget may be too small, vice versa. Moreover, attention must be paid to the welding time, so as to prevent that the electrode becomes too hot and adheres to the work pieces, and that the service life of the electrode is shortened.

3. Methodology and Experimental Design

The main hardware for the proposed method was the SHARC ADSP-21065 EZ-Kit, as shown in Figure 3. Its high-performance 32-bit DSP chip has an operation frequency of 60 MHz, and is able to conduct 198 mega floating/fixed point operation per second and implement an instruction (assembly language) in a clock. The chip is built in with a 544 K bits SRAM memory for storing programs and collected voltage/current data. The DSP chip can be externally connected to a 1 M × 32 bit SDRAM memory.

The structure of the welding current measurement is shown in Figure 4. The RMS value of welding current is calculated by the following formula:

$$I_{RMS} = G_I \cdot \sqrt{\frac{\sum_{k=1}^{N} {i_k}^2}{N}} \tag{2}$$

where G_I is the scale of the current transformer and N is the number of sampled data i_k for half cycle.

This study used the single-phase DC resistance spot welder for the measurement test, and analyzed its perfor-

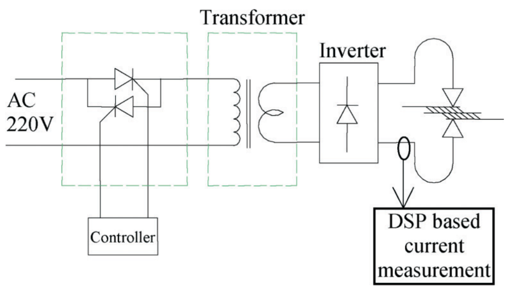

Figure 2. The spot welder equivalent circuit and the proposed current meter.

Figure 3. SHARC ADSP-21065 EZ-Kit.

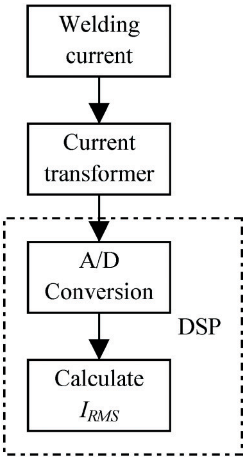

Figure 4. The structure of the welding current measurement.

mance characteristics according to the actually measured results. During the process of welding, the time when the current passes through two metal plates is very short. The welding time is generally one cycle to tens of cycles (a cycle is 16.67 ms). Traditionally, the resistance welding current meter commonly seen on the market often takes half cycle (8.33 ms) for one measurement. However, this study adopted the rapid DSP chip, thus 1 ms is taken for the measurement, and there are 16 outputs of measured current within a cycle. Therefore, it can rapidly respond and accurately output the calculated welding current.

The measurement is updated every 1 ms. Therefore, we need to reduce the calculation load while conducting sum of square in the RMS calculation. As shown in Figure 5, to obtain the sum of square of the present 8.33 ms raw data, the sum of square of the A-area raw data (1 ms) is subtracted from the previous sum of square of 8.33 ms raw data and then plus that of the C-area raw data (1 ms). Because the B-area raw data are the same for both the

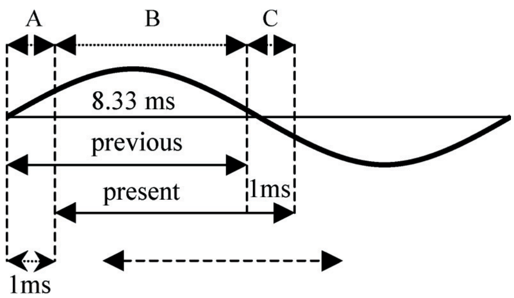

Figure 5. Illustration of reducing calculation load for RMS value.

previous and the present RMS calculation, the sum of square of this area can be reused. This method will save more than 80% calculation time.

4. Experimental Results

The proposed welding current measurement featured with high-efficiency RMS calculation is implemented in a DSP board. This DSP based welding current meter is connected to the welder probe through a current transform to measure the welding current. The heating time of the welder is set as 3 cycles, 5 cycles, and 10 cycles; the corresponding welding current is set as 2 KA, 8 KA, and 17 KA, respectively. Table 1 is the measurement result of the proposed method and the commercial CHUO SEISAKUSHO WM-3UP welding current meter as a reference. Table 1 lists the measured current for 10 cycles in 17 KA, in which the error is beneath 3% showing high accuracy performance. The proposed method outputs the current measurement every 1ms; however, in the table we provide the measurement only for every half cycle in order to compare to the reference which outputs every half cycle.

Table 1. 10-cycles welding current measurement comparison

Meters / Cycle	Reference	Proposed	Error
	Welding current (KA)	Welding current (KA)	(%)
1	16.4	16.1	1.83
1.5	16.5	16.4	0.61
2	16.7	16.8	0.59
2.5	17.0	16.9	0.58
3	16.8	17.0	1.19
3.5	17.1	17.1	0
4	17.2	17.1	0.6
4.5	17.8	17.3	2.8
5	17.4	17.2	1.15
5.5	16.7	17.1	2.39
6	16.7	16.9	1.19
6.5	16.7	16.7	0
7	17.5	17.3	1.14
7.5	16.8	17.0	1.19
8	16.7	16.8	0.59
8.5	17.0	16.9	0.58
9	16.5	16.7	1.21
9.5	16.8	16.8	0
10	16.6	16.5	0.60

The measured welding currents of 3-cycle, 5-cycle and 10-cycle heating are shown in Figures 6, 7, and 8, respectively. The figures shows that the used welder takes around 1.5 cycles to achieve the required welding current (2, 8, 17 KA), then the current keeps at the required current till the required heating cycles. After the required heating cycles, the welding current drops drastically, and the welding work is completed. The curve of the pro-

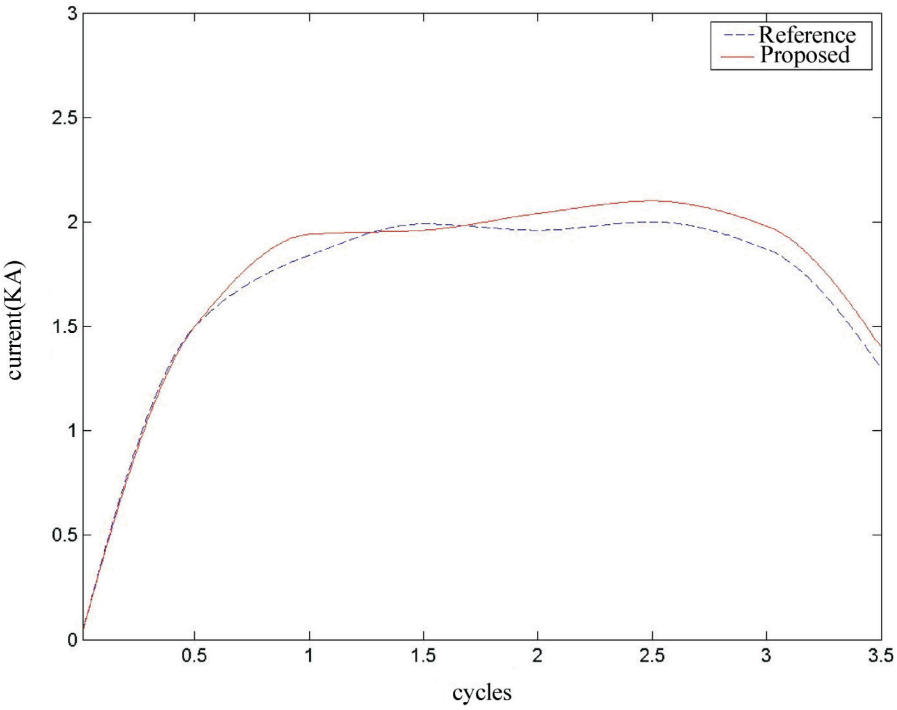

Figure 6. Welding current measurement of 2 KA and 3-cycle heating.

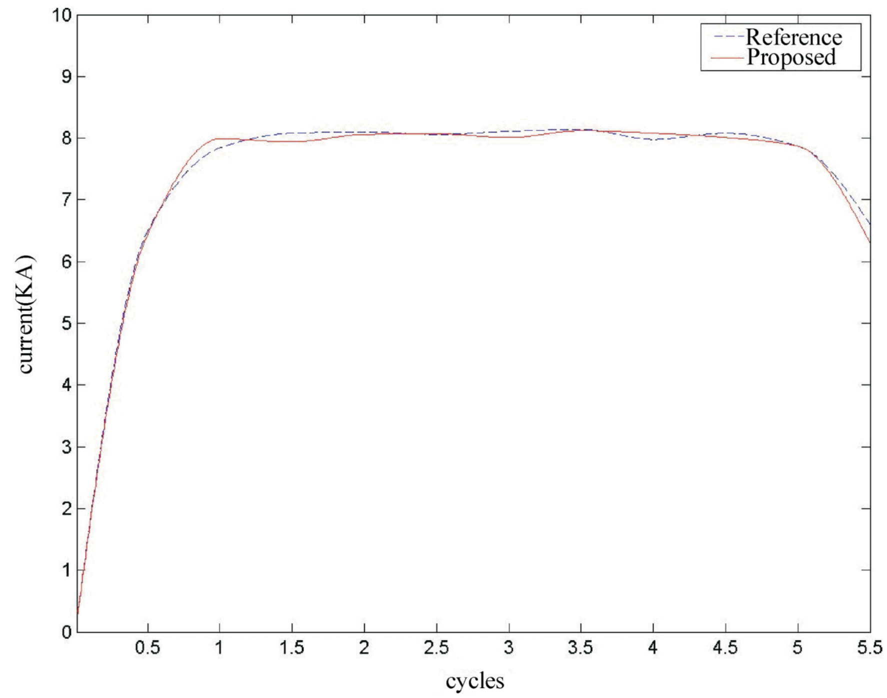

Figure 7. Welding current measurement of 8 KA and 5-cycle heating.

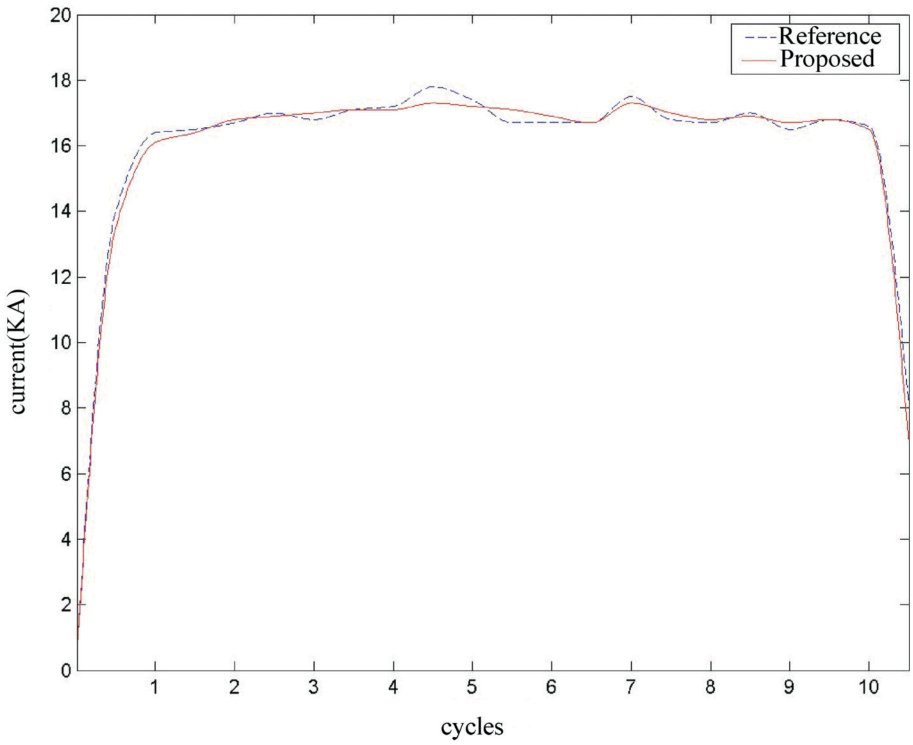

Figure 8. Welding current measurement of 17 KA and 10-cycle heating.

posed method is very closed to that of the reference. The measurement results reveal that the proposed method is feasible to implement a fast-calculation and high-accuracy welding current meter based on a DSP.

5. Conclusion

This study successfully calculates the welding current rapidly by a DSP. The proposed method outputs the measured current every 1 ms. It is tested under various welding processes. The experimental results are also compared with the advanced commercial welding current meter, and the error of measurement is within 3%. Therefore, the proposed method can measure the welding current rapidly and accurately. This study can be used as the feedback signal of the closed-loop welding controller to improve the welding quality in the future.

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