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Monitoring the quality of welding based on welding current and ste analysis

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Abstract. Qualities of welding play an important part in industry especially in manufacturing field. Post-welding non-destructive test is one of the importance process to ensure the quality of welding but it is time consuming and costly. To reduce the chance of defects, online monitoring had been utilized by continuously sense some of welding parameters and predict welding quality. One of the parameters is welding current, which is rich of information but lack of study focus on extract them at signal analysis level. This paper presents the analysis of welding current using Short Time Energy (STE) signal processing to quantify the pattern of the current. GMAW set with carbon steel specimens are used in this experimental study with high-bandwidth and high sampling rate oscilloscope capturing the welding current. The results indicate welding current as signatures have high correlation with the welding process. Continue with STE analysis, the value below 5000 is declare as good welding, meanwhile the STE value more than 6000 is contained defect.

1. Introduction

Quality of welding is a critical role in most industries, especially in manufacturing and automotive [1], where strict procedures are in place to produce the best product with little to no flaws. Many innovations have been developed in the welding quality inspection. Post-welding non-destructive test is one of familiar process in term of inspection in quality of welding. There are several types of non-destructive test, for example visual inspection [2], radiographic inspection [3] and ultrasonic inspection [4]. Each type of testing have different process, but they have similar problems regarding to the time consumed and high cost. This is due to the post-process nature of the tests, where they can only be carried out after the welding were completed and the weld were cooled down.

In previous literatures, researchers have suggested another way to reduce welding flaws by continuously monitor the welding process via online monitoring system. Monitoring in welding is refer to several signals as the reference before summary the information of process. In past researches, radiography information analysis has been used to determine the defect while welding process is carried out [5]. On the other hand, sounds was used as reference to analyse and identify the quality control of welding [6]. The arc light spectrum also gives signal as reference in the analysis of welding process [7]. That can state the welding signal can use as one of source information of welding process. In the same



time, in this paper is purpose to monitoring the welding process as other way to detect the quality of welding.

One of common signal can be used as the signal is welding current. From the previous research, welding current was used as a reference signal because it is sensitive to any changes in the welding process. The welding current are rich of information and have own pattern to describe the welding process [8-9]. In other meaning, current signal can be utilized to determine the stability of welding process [10] and to evaluate the quality of welding [11]. The signal from a welding current can be referenced if any disturbance or spike happens when the process detect defects. Hence, it is a viable candidate of main variable in the online monitoring of welding process. Motor current signature analysis (MCSA) is one of successful research use current signature analysis to detect fault when motor running [12-14]. It is expected that method can be applied in the welding current signature analysis.

Raw welding current need to be analyzed before one can extract the welding process information inherently embedded in its shape. For example, welding current was previously processed using Artificial Neural Network (ANN) in welding control and quality estimation [11]. But the complex nature of ANN prohibits its application in real time online monitoring. Simple statistical analysis had been proven to successfully extract some of the information [15]. However, the research has tended to focus on macro level analysis, rather than on micro level analysis which hypothetically contain richer information. In this paper, we embark on an investigation of welding current analysis using Short Time Energy (STE) signal processing technique.

STE was originally intended to separate voice and unvoice segments of speech signal. It is effective in real time analysis due to its simple working principle [16]. Theoretically, it is based on short time energy calculation, short time magnitude calculation, autocorrelation of different segment of speech and zero crossing rate calculation [17]. Zero crossing rate (ZCR) provide the frequency information from signal voice[18]. When the zero crossing rate is less, the signal contain low frequency. Meanwhile in short time energy is especially use to frame the voice, unvoiced and silence signal[19]. The frame will transform to some of energy value. Until now, STE has always been applied to only speech processing application.

The objective of this paper is to predict the quality of welding based on welding signal. The welding current signal was interpret to new data information by STE analysis. In this paper, Short Time Energy is used to seperated the smooth current and disturbance current. The smooth current is created the good welding meanwhile the disturbance current made the defect in welding. The differentiate is presented in energy value. Based on the result, short time energy provides the value of energy in the welding process. Then the value is determined the condition on welding process. In this paper, the experiment of welding and analyse data using STE is presented.

2. Methodology

The workstation is carried out in Laboratory Welding at Faculty of Mechanical, Universiti Malaysia Pahang with room temperature. Figure 1 shows the workstation set up for experiment in this paper. The main of the experiment is welding machine and generate the data collection.

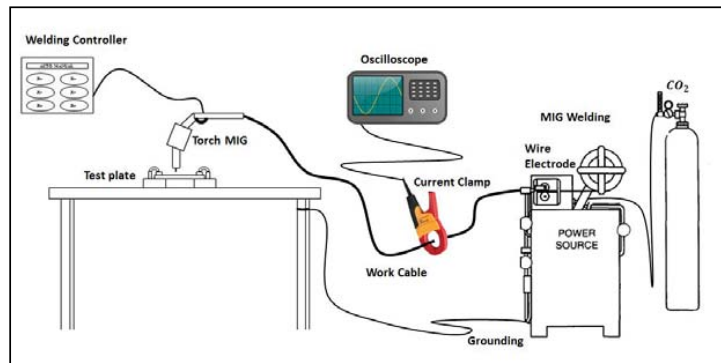


Figure 1. The workstation set up for the experiment of welding.

Present in this experiment is Gas Metal Arc Welding (GMAW) welding machine and controlled via a semi-automatic handler. Meanwhile, during the welding process, the welding current was captured on Keysight Oscilloscope DSOX3024A via Fluke i400 current probe. The semi-auto torch was 90° perpendiculars with the surface plate that was fixed to the table by clamps. The torch was fixed on a set of support with an x-axis, y-axis and z-axis adjustment. This ensures accurate control of the distance between the torch and plate. The welding parameters setting is shown in Table 1.

Table 1. List parameter in the experiment.

Parameter	Welding condition
Plate (mm)	80 × 50 carbon steel (thickness: 2.0)
Shielding gas	100% CO ₂
Welding current (A)	180
Travel speed (mm/Sec)	13
Electrode type	ER70S-6 (DIA=1.2mm)

Carbon steel plate with 2.0mm thickness is used in this experiment. Each specimen uses 2 plates to weld. Carbon dioxide used as to prevent the air in welded. ER 70S-6 is an electrode type with diameter is 1.2mm. The welding power supply was operated in constant voltage mode. In this research, the current signal was captured at a very high sampling rate (200,000 samples per second) in order to preserve the current shape for further analysis.

The welding current signal was then analysed in MATLAB/Simulink using STE signal processing technique. The result of STE analysis and the welding specimen will be compared visually. The experiment repeated for three times for three different specimens with same parameter.

3. Results and discussion

After finishing the experiment, the result divide by two parts. The first part is about the welding specimen. The welding specimen was given in to Qualified Inspection Team to investigate the result of welding. In other hand, the welding current data are analysed in MATLAB/Simulink. In the MATLAB/Simulink, data are processed in Short Time Energy data.

Figure 2 shows the result of the experiment for all three specimens A the same time, from top to bottom, In the Figure 2, that consists the photos of welding specimens, the raw signals of welding current

and the processed signals using STE, respectively.

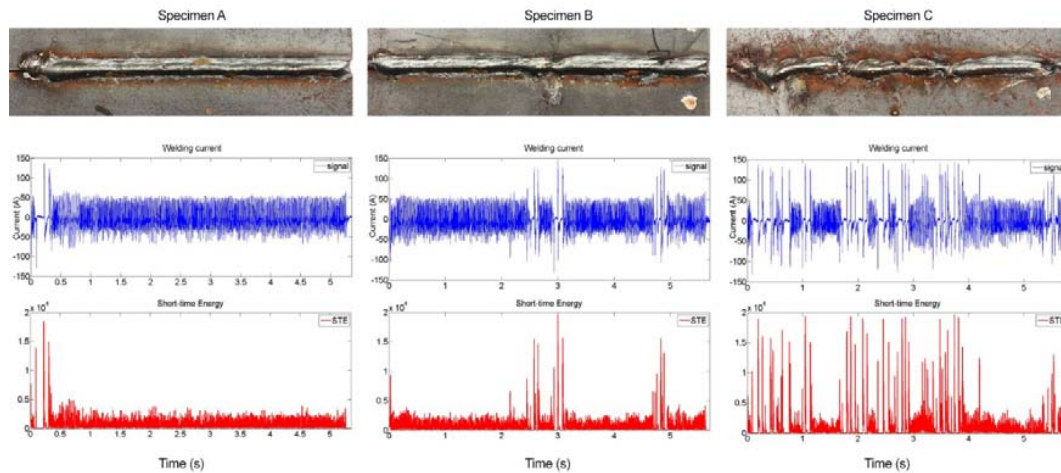


Figure 2. Welding specimens, the raw signals of welding current and the signals using STE.

From Figure 2, the specimens and the data are arranged from the best (Specimen A) on the left to the worst on the right (Specimen C). In the visual inspection report for Specimen A, on the starting welding point have the defect. It is visually apparent that the welding current “spikes” to close to 100 A. The effect of defect, cause the disturbance in welding current waveform. In the same time, the current generates maximum energy in the few second. After that, the welding is run smoothly. In this part, that is clear the current is stable and the energy in constant value. It is observed that during good welding process, the welding current waveform is in the range of ± 70 A.

In the Short Time Energy (STE) signals, the contrast between good specimen and bad specimen is even clearer. In Specimen A, the welding joint looks good excepts at its starting point, where it has small defects. This defect manifests itself as a short series of spikes in welding current. Comparing this with the STE pattern, the waveform reaches more than 6000. This is obviously different from the rest of Specimen A’s STE signal, where the amplitude of STE is always lower than 5000.

In visual for Specimen B, the welding contains more defects than Specimen A. The defect is captured at middle and near to end. Compare to the welding current, at the same time the current is sudden up and down. That effect on STE which is the energy is increasing in that area. Just as Specimen A, the reading of Specimen B’s STE is lower than 5000 when the welding quality is good. Then, there have three defect location. Three series of spikes occurred at around 2.5 s, 3.0 s and 4.8 s, directly corresponds to the welding specimen’s condition.

The worst of all three specimens is Specimen C where a lot of defects can be seen in the photo. As previously discussed, the defect can cause the disturbance on the current. That can see the unstable current waveform which define that a lot of defects is detected. At the same time, the similar pattern can be observed in the heavily spiky pattern of STE of Specimen C. In the analysis show mostly value STE is more than 6000.

It should be noted that there are several points which are the highlights of the experiment. First, the study is still an ongoing investigation where the results presented here are preliminary. Second, it is found that STE can be used to analyse welding current in the effort to differentiate between the moment of good welding joint and the moment of welding defects. In this particular experiment, welding current STE of 6000 is the threshold where any numbers below than that signifies good welding, whereas higher than that

represents risks of defects. The third point is with segmented analysis such as STE, one can determine directly the moment of the defects. This is one of the great advantages of using STE instead of simple statistical analysis such as mean and variances. Simple statistical analysis evaluates the specimen as a whole rather than the process.

4. Conclusions

In this paper, the experiment is carried out to support the research. Three specimen are present with different result. The specimen from experiment is compared with welding current and STE to form the correlation between them.

As a conclusion, the welding current signal contains information of welding process, inherently embedded into its shapes and pattern. By using Short Time Energy (STE) analysis, the information of good welding and welding defects can be extracted. For further investigation, welding specimens will be processed in microstructural analysis to confirm the correlation.

Acknowledgments

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