Arc stability evaluation in Gas Metal Arc Welding process, Using Acoustic data and Signal Processing

[*]Mohsen Ghofrani[1], Farhad Kolahan[2]
[1]M.sc. Student, mohsenghofrani.ma@gmail.com
[2]Associate Professor, kolahan@um.ac.ir
Department of Mechanical Engineering, Ferdowsi University of Mashhad (FUM), 9177948974, Mashhad, Iran,
(Phone: (98) 511 8805075; fax: (+98-511) 8436432)

Abstract

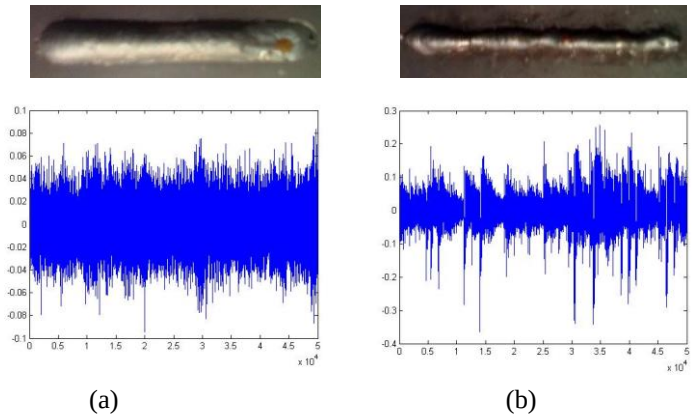
The weld quality depends on many factors and parameters, Stability of the arc welding is one of the most important parameters to evaluating the weld quality. All these parameters have to be after the welding process (Off-line) examined. Since Welding sound signal is an important feedback, In this research it is used as a (On-line) Criterion to determine the arc stability evaluation. The purpose of this investigation is Arc stability evaluation in Gas Metal Arc Welding process, Using Acoustic data and Signal Processing. For this purpose, Acoustic signals is recorded in the laboratory during the welding process. Acoustic parameters of the process is extracted by the signal processing. Acoustic parameters of welding process are; The Average of Fast Fourier Transform – FFT coefficients, Standard deviation of FFT coefficients, Standard deviation of DCT coefficients and Standard deviation of DWT (Haar wavelet – level 2) coefficients. The selection process for this study is The gas-shielded welding process (MIG), One of the most commonly used types of welding. In this research, in order to evaluating stability of the arc welding, a criteria based on the Acoustic parameters from the signal processing is introduced.
Finally, the relationship between the stability of the arc welding and acoustic parameters can be studied and after data analysis, the results are presented.

Keywords: Metal inert gas (MIG), Acoustic data, Stability of the arc welding, Fast Fourier Transform (FFT), Discrete cosine transform (DCT), Discrete Wavelet Transform (DWT), On-line Criterion, Signal processing.

1. Introduction

Welding is one of the means of production, Its purpose is the permanent connection of engineering materials (metals, ceramics, polymers, composites, etc) to another So that the binding properties of the base material properties. Due to the extensive application in various industries such as steel, automotive, machinery, oil industry, shipbuilding industry, Certain industries Aerospace and Airlines, Various techniques such as non-destructive tests to check the quality of welding is proposed and used [1,2] .At present, evaluation and control of production processes is one of the most common engineering research .So research on weld quality of welding processes is very important to pay special attention to it. The weld quality depends on many factors and parameters, Stability of the arc welding is one of the most important parameters to evaluating the weld quality. All these parameters have to be after the welding process (Off-line) examined. The purpose of this research to determine the arc stability evaluation is to find a (On-line) criterion during welding. In this context, Welding arc sound signal includes information from a wide range of boiling behavior is [3,4]. Features and behavior of the sound spectrum is closely related to the quality and texture of the weld [5]. Professional welders have learned this, by experience and training [6]. They actually listen to the voice signal welding, are set The welding parameters to achieve the desired geometry and quality.

For example, to better understand See the figure 1, Represent two types of welding, A weld with stable arc welding and a weld with unstable arc welding With their audio signal.



(a) (b)

Figure 1: (a) stable arc welding, (b) unstable arc welding

So in this study as a criterion to determine the arc stability evaluation, sound of Arc welding is selected. Sound of arc welding can be used as a controller for controlling weld quality can be used in the welding process. For this purpose the techniques of signal processing will use.

2. Materials and Methods

The selection process for this study is The gas-shielded welding process (MIG), One of the most commonly used types of welding.
Acoustic signals is recorded in the laboratory during the welding process. Acoustic parameters of the process is extracted by the signal processing. In this research, in order to evaluating stability of the arc welding, a criteria based on the acoustic parameters from the signal processing is introduced.
Finally, the relationship between the stability of the arc welding and acoustic parameters can be studied and after data analysis, the results are presented.

2.1 The gas-shielded welding process (MIG)

In this process, the arc of electrical energy is heat source and shielding gas to protect the electrode tip, the droplet transfer during melting in the arc and molten metal pool against to atmosphere used. In some processes, the inert gas, and in others, an inactive gas such as carbon dioxide are used. In some processes from a mixture of gases used. In this process, creating an arc, the electrode(welding wire) is constantly melting and is added to the welding area. Proportional to the electrode melting rate, The electrode enter to the weld pool with Certain speed [1,2].(Figure 2)

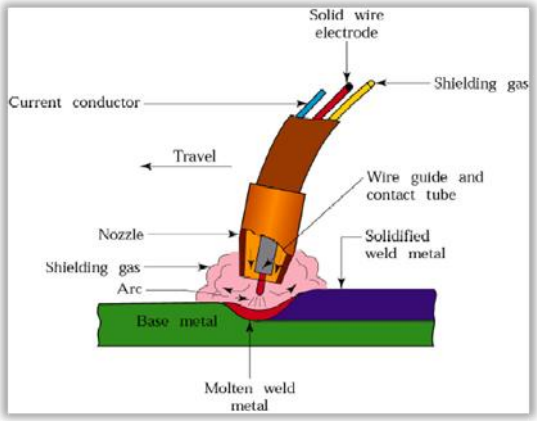


Figure 2: Schematic of the welding process, (MIG)

Process variables are; Welding current, Welding voltage, Welding speed, The type of electrode and electrode feed rate, Type, purity and pressure of the gas [1].

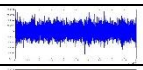
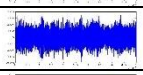
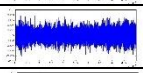
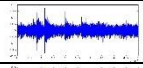
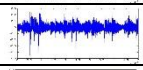
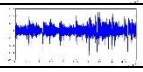
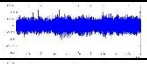
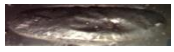
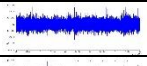
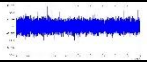
2.2 signal processing

Signal processing is the science that focuses on the analysis of signals. In this study, Welding sound is sampled via a microphone and using the Matlab environment. For each experiment, the signal is processed to obtain the characteristics of the signal. Signal processing task is to identify the characteristics of the signal. For this purpose, Acoustic characteristics of welding process are; The Average of Fast Fourier Transform – FFT coefficients, Standard deviation of FFT coefficients, Standard deviation of DCT coefficients and Standard deviation of DWT(Haar wavelet – level 2) coefficients. These characteristics are obtained from the signal processing and FFT, DCT and DWT transform in Matlab software.

2.3 Design of experiments

The welding parameters such as welding voltage, wire feed rate and welding speed are most important. For the experiments, four levels for welding voltage [20-24-28-32 (v)] because the most important, three levels for wire feed rate [6-8-10 (m/min)] and three levels for welding speed [145-290-435 (mm/min)] has been considered. According to the number of parameters and their levels, 36 experiments done and the outputs are measured. In table 1, the tests, Acoustic signals and welding shape for each test is shown.

Table 1: Matrix experiments, Acoustic signals and welding shape

Test	Voltage(v)	Wire feed rate(m/min)	Welding speed(mm/min)	Acoustic signals	Welding shape
1	20	6	145		
2	20	6	290		
3	20	6	435		
4	20	8	145		
5	20	8	290		
6	20	8	435		
…	…	…	…	…	…
…	…	…	…	…	…
34	32	10	145		
35	32	10	290		
36	32	10	435		

2.4 Acoustic parameters of welding process

A fast Fourier transform (FFT) is an algorithm to compute the discrete Fourier transform (DFT) and its inverse. Fourier analysis converts time (or space) to frequency and vice versa.
A discrete cosine transform (DCT) expresses a finite sequence of data points in terms of a sum of cosine functions oscillating at different frequencies. In particular, a DCT is a Fourier-related transform similar to the discrete Fourier transform (DFT), but using only real numbers. DCTs are equivalent to DFTs of roughly twice the length, operating on real data with even symmetry (since the Fourier transform of a real and even function is real and even), where in some variants the input and/or output data are shifted by half a sample.
The Haar wavelet is also the simplest possible wavelet. The technical disadvantage of the Haar wavelet is that it is not continuous, and therefore not differentiable. This property can, however, be an advantage for the analysis of signals with sudden transitions, such as monitoring of tool failure in machines. In mathematics, the Haar wavelet is a sequence of rescaled "square-shaped" functions which together form a wavelet family or basis. Wavelet analysis is similar to Fourier analysis in that it allows a target function over an interval to be represented in terms of an orthonormal function basis.
After processing the signals obtained from the laboratory, Acoustic parameters of welding process are obtained. Acoustic parameters of welding process, resulting from Signal processing are shown in table 2.

Acoustic parameters of welding process are:
1. The Average of Fast Fourier Transform – FFT coefficients
2. Standard deviation of FFT coefficients
3. Standard deviation of DCT coefficients
4. Standard deviation of DWT (Haar wavelet – level 2) coefficients

Table 2: Acoustic parameters of welding process

Test	Average of FFT	Std of FFT	Std of DCT	Std of DWT
1	0.7925	3.1799	0.0166	0.0292
2	0.8263	3.5263	0.0189	0.0324
3	0.8522	3.8725	0.0204	0.0355
4	0.9535	3.5259	0.0212	0.0329
5	1.6976	7.5718	0.0466	0.0707
6	1.7690	7.2572	0.0446	0.0679
…	…	…	…	…
…	…	…	…	…
34	1.0538	4.1079	0.0246	0.0384
35	1.0722	3.8415	0.0242	0.0361
36	1.0193	3.7591	0.0229	0.0352

3. Results and Discussion

In order to find a criterion based on acoustic parameters for stability of the arc welding, diagram is drawn in Figure 3. In this diagram, Number of tests from 1 to 36 on the horizontal axis and the values of each Acoustic parameter is shown on the vertical axis. Almost all parameters show a similar trend as shown in Fig 3.

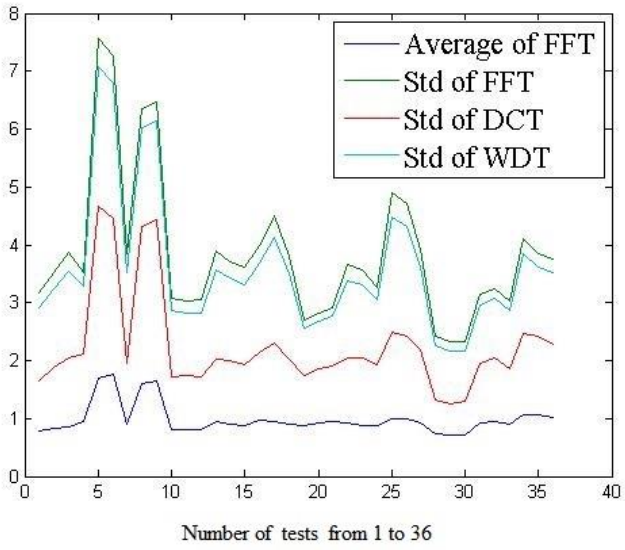


Figure 3: The values of each Acoustic parameter from test 1 to 36

We define a parameter includes all of the acoustic parameters and called (M):

$$M = (\text{Average of FFT}) \times (\text{Std of FFT}) \times (\text{Std of DCT}) \times (\text{Std of DWT})$$

In other words, (M) is equal to the product of the four acoustic parameters. Now look at the chart in Figure 4, that Number of tests from 1 to 36 on the horizontal axis and the values of (M) is shown on the vertical axis.

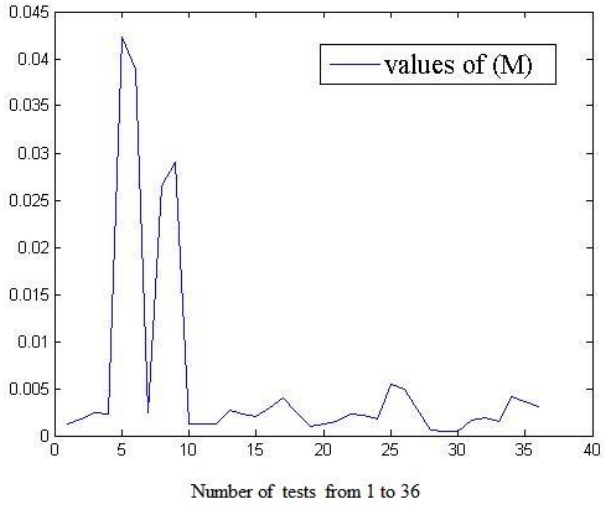


Figure 4: The values of (M) from test 1 to 36

According to the results of laboratory, Tests: 5, 6, 8 and 9 have an unstable arc welding, that the extent of this instability is higher than other tests. And as you can see in figure 5, the value of (M) for these tests are located on the top of the charts.

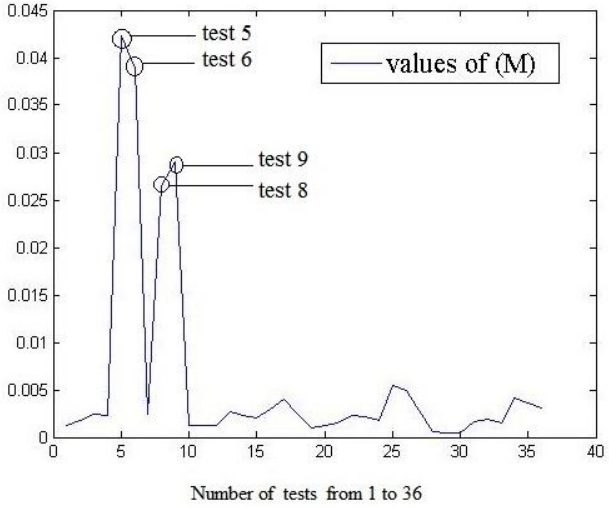


Figure 5: The values of (M) from test 1 to 36

4. Conclusion

Stability of the arc welding can be expressed very well by acoustic signals. The selection process for this study is The gas-shielded welding process (MIG). Acoustic signals is recorded in the laboratory during the welding process. Acoustic parameters (The average of Fast Fourier Transform – FFT coefficients, Standard deviation of FFT coefficients, Standard deviation of DCT coefficients and Standard deviation of DWT (Haar wavelet – level 2) coefficients) of the process is extracted by the signal processing. In order to evaluating stability of the arc welding, a criteria based on the Acoustic parameters from the signal processing is introduced. We define a parameter includes all of the acoustic parameters and called (M). This parameter is a criterion for stability of the arc welding. The value of (M) is much lower, stability of the arc welding is higher. In other words, by increasing the value of (M), stability of the arc welding is reduced and vice versa. Figures 4 and 5 show this results as very well.

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