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Fast fourier transformation of emitted noises from welding machines and their classification with acoustic method

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1. Introduction

The enhancement of operating performance in the industry is directly related with the provision of proper working environment to the workers. The studies conducted about work safety and the improvement of working conditions reveals that one of the factors influencing the labour motivation of workers is the noise in the working environment. In literature, noise is defined as the jarring sound [1-3]. While the sound is described as a measurable objective term, noise is however defined as a subjective term. The qualification of sound as a noise changes from person to person. In today's rapidly growing cities, with the expansion of residence and industrial zones, the increase of traffic intensity, and with the more inclusion of electrical appliances and mechanical devices in our life, the factors causing noise rise [1]. Noise is also particularly disturbing in the working environment of workers as well as in intense traffic, and the health of people working all day in a noisy environment is endangered.

The Noise Criteria Measurement is decibel (dB) based on the level of sound pressure [4]. In the detection of noise level measurement, the used weight is designed as dBA or dBC according to its curve. The sensitivity of human ear to sound depending on frequency is best represented by A weight curve. For this reason, dBA is usually measured as grading in the industrial working environments. C weight curve dBC is used in the measurement and evaluation of impulse noise [1-5].

In today's industry, a large variety of materials are manufactured in automotive, ship building, architectures, transportation and many other sectors [4-10]. Metal materials are used in the manufacture of these buildings. Metal materials and the manufactures performed through their resources have a considerable place in industry [5-11]. These manufactures are made in the open air, laboratory or industry installations. Technical staff operating with welding machines during these production stages use a lot of chemical agents breathing or touching them. Besides the negativities posed by these chemical agents, technical staff are also adversely influenced by the noise coming out of the materials they are operating on and with. The noises coming out of the materials affect the motivation of workers and labour productivity negatively.

Although the chemical effects that technical staff are exposed while welding materials in the industry have been examined in many studies, this study is a research on the noise coming out of welding machines during welding. There are a large number of studies carried out on welding machines and welding processes in literature [11-14]. In particular, there are quite many studies about the roughness on which welding is applied and the chemical analyses of these materials [1, 5]. However, it hasn't been encountered many studies in literature regarding the research of the sound coming out of the welding machine during welding and the welding of two pieces. Even though it has a really common field of application in the industry, researchers investigated acoustic observation techniques and welding processes very little [1, 5].

In this study, the emitted sounds of machines were investigated in off and on positions using Arc welder, Gas metal arc welder and Spot welder, furthermore, an analysis was performed with regard to predicting the types of welding machines with acoustic method using Fast Fourier Transformation (FFT) and Artificial Neural Networks (ANN).

2. Welding methods

In many fields of industry, welding is an indispensable application used for bonding. In today's big industries, even if welding robot is commonly used, manual welding has a substantial field of application in small scale industry and repair at the stage of production. Bonding metallic materials using heat or pressure or both heat and pressure using a material whose melting range is the same or approximate is called metal welding. If an extra material is used in bonding two pieces, this material is named additional metal. As welding process is a sort of undetectable bonding, it requires much more attention and carefulness, besides that, trained technical staff and device and etc. are needed to apply welding process. Welding methods are more than the 3 methods analysed in this study. These are welding methods such as braze welding, resistance welding, thermite welding, solder, solid state welding, laser welding, but, only three common applications have been analysed in this study [1,11-14].

2.1. Arc welding

It is a form of bonding by making use of the heat to occur with the constant electric arc between at least two metal pieces to be bonded and using an extra electrode. In the Arc Welding, power is the transformation speed of energy from one form to another. On examining a welding arc, it is observed that almost all of the electric energy is converted into heat. While a very small rate of this generated heat is used to produce ultraviolet radiation and bright light radiated by arc, the remaining major share generates the heat needed for welding. As the current and voltage passing through electrodes during welding can easily be measured, the power input can be counted as Watt [1, 11-14].

2.2. Gas metal arc welding

Gas metal arc welding occurs via the arc way formed between the necessary temperature, a wire electrode that melts and is fed perpetually and welding bath and via the resistance heating that the welding current passing through electrode generates in the electrode. Electrode is a bare conductive wire and an electrode is dispatched to welding zone with feeding mechanism in a constant speed. Bare electrode, welding bath, the neighbouring parts to arc and basic metal are formed through blowing gas org as mixture that is provided from outside against atmosphere pollution and is suitable for the area Because of the melting electrode and use of inert gas, the method is called Metal Inert Gas (MIG) welding. Thanks to this welding method, all industrially and commercially important metals such as unalloyed steels, low alloyed steels, stainless steels, aluminium, copper, titanium and nickel alloys can be welded on the condition that proper protective gas, electrode and welding variables are chosen. The reason why inert-gas welding is commonly used is the superiorities it naturally provides. It is the sole welding method with melting electrode that can be used in all of the industrial metals and alloys. It has abolished the problem of electrode which is faced in electric arc welding and used in limited length. These superiorities made inert-gas welding method quite appropriate especially for high production rates and automatic welding applications. [11-14].

2.3. Spot welding

Spot welding is the most used type within the resistance welding types. The pieces to be welded are taken between two copper electrodes and electric current is enabled to pass with the application of a certain pressure. Spot welding can be defined as the process of fixing work pieces at certain intervals so that they can remain within proper measurements. To complete welding process successfully, the angles of work pieces and the distance among those during welding should not change. A serial point welding is used in the bonding of sheet metals. The size of spot must be the four times of a work piece thickness. Spotting must be made with the same kind of electrode whichever is used for welding. Sheet metal is widely used in the mass production of automobile, household appliances and other products which are manufactured from metal. The choice of electrode according to piece thickness and type in spot welding is one of the significant elements determining welding quality [15, 16].

3. Mathematical basis

In this study, the harmonic compositions of the emitted sounds recorded from welding machines with FFT were ascertained and using these compositions, they were classified with ANN.

3.1. Fast fourier transformation (FFT)

Discrete Fourier Transformation (DFT) is a method transforming the discrete time signal used in many fields of engineering into frequency period [17-20]. $s(n)$ shows discrete signal as:

$$S(k) = \sum_{n=1}^{N-1} s(n)\omega_N^{n.k} \ , \tag{1}$$

here n and k are whole numbers, N is the length of discrete signal and is

$$\omega_N = e^{(-2\pi i)/N} \ .$$

The Fast Fourier Transformation (FFT) which is obtained by making use of DFT's periodical characteristic and performs transformation with a less processing is however obtained as [1-6];

$$S(k) = \sum_{n=0}^{\frac{N}{2}-1} s(2n)\omega_{\frac{N}{2}}^{n.k} + \omega_N^k . \sum_{n=0}^{\frac{N}{2}-1} s(2n+1)\omega_{\frac{N}{2}}^{n.k} \ . \tag{2}$$

3.2. Artificial neural networks (ANN)

Artificial neural networks is the mathematical method that imitates the data exchange of human brain cells, and is used in a large number of scientific fields such as predicting result, classification and control [21, 22]. While in a three layered feed-forward ANN model (Fig. 1), the mathematical correlation between the input and output of neuron in the input layer is:

$$n_i = o_i \tag{3}$$

the neuron input expressions in the output layer are found as [21, 22];

$$n_k = \sum_{j=1}^{Nj} w_{kj} o_j \ , \ \ k = 1, 2, 3, ..., N_k \ . \tag{4}$$

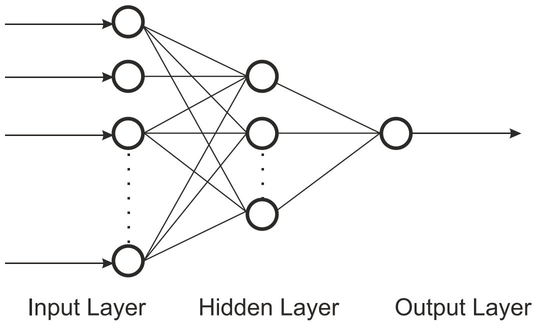

Fig. 1 Three layer feed-forward neural network [21]

The weight of connection function of w_{kj} ; j; neuron with k neuron is shown by, N_j and N_k neurons in the input and output layers [22]. The neuron outputs in the secret layer are however found as; the weight of connection function of w_{kj}; j neuron with k neuron is shown by, N_j and N_k neurons in the input and output layers [22]. The neuron outputs in the secret layer are however found as:

$$o_k = \frac{1}{1+e^{-(n_k+\theta_k)}} = f_k = (n_k, \theta_k) \qquad k = 1,2,3,...,N_k\,, \quad (5)$$

where θ_k , k expresses the threshold value of neuron, f_k, and expresses activation function [22].

The error function between the input and output data of the formed model, output neurons' output and target E_p is tried to be minimized by updating again the weight of connection function among neurons at the stage of training in each iteration [23]:

$$E_p = \frac{1}{2}\sum_{k=1}^{N}(t_{pk} - o_{pk})^2 \qquad (6)$$

where t_{pk} , k are the target set for output neuron, o_{pk} is the one determined by the model, k is the value of output neuron. The total error for all neurons is however found [22]:

$$E = \sum_{p=1}^{N_p} E_p\,. \qquad (7)$$

3. Data collection system

The data collection system seen in Fig. 2 consists of a microphone, a recorder and a computer. The emitted sounds of three different welding machines were recorded with 44100 Hz sampling frequency and analysed with MATLAB program. So that it could be convenient for real working conditions, no ambient temperature was created. Thanks to Active Noise Cancellation System, the environment noises were decreased as much as possible. The study was achieved in the Welding Laboratory of Kirklareli Vocational High School [1, 23].

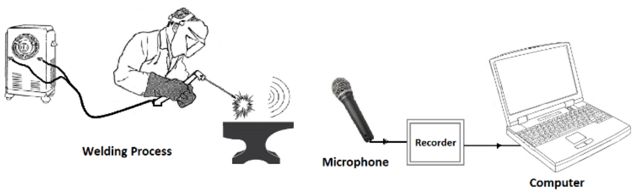

Fig. 2 Schematic appearance of testing set

Fig. 3 A View from welding machine and application [1]

4. Application and analysis

So as to conduct FFT analysis of the recorded signals, 15 different signals with 5000 samplings of each welding machine were used. The emitted sounds of arc welding machine, inert-gas welding machine and spot welding machine were respectively given in Figs. 4, 5 and 6.

When the FFT analysis given in Eq. (2) is applied to these emitted sound signals, a great majority of high amplitude frequency components is observed to be between 0 and 4401,18 Hz. Using more component will decrease ANN performance. The amplitudes of frequency components of three welding machines have values different from each other. It is seen that the value of the smallest one is $1{,}3308.10^{-6}$ dB and the value of the biggest one is 0,0184 dB. Normalization is needed to be performed in order to increase ANN performance. Using the equation given in Eq. (8), the data range is taken between 0,1 and 0,8985 [1, 23].

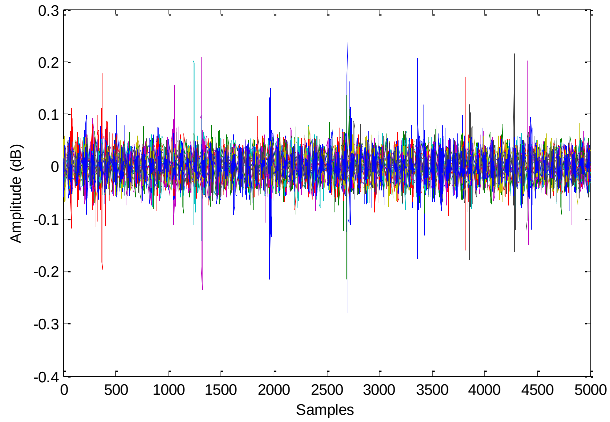

Fig. 4 The sound pressure level of emitted sound from arc welding machine

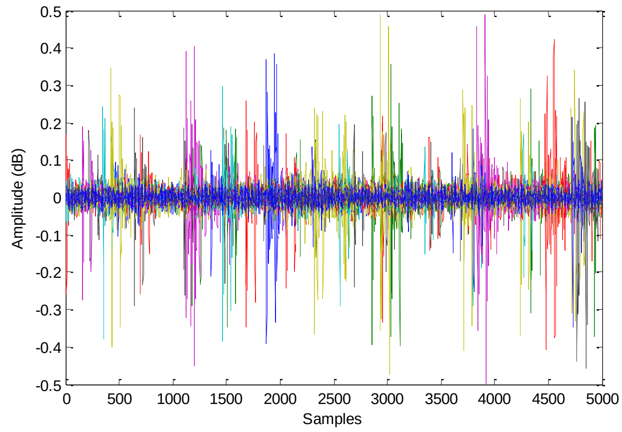

Fig. 5 The sound pressure level of emitted sound from inert-gas welding machine

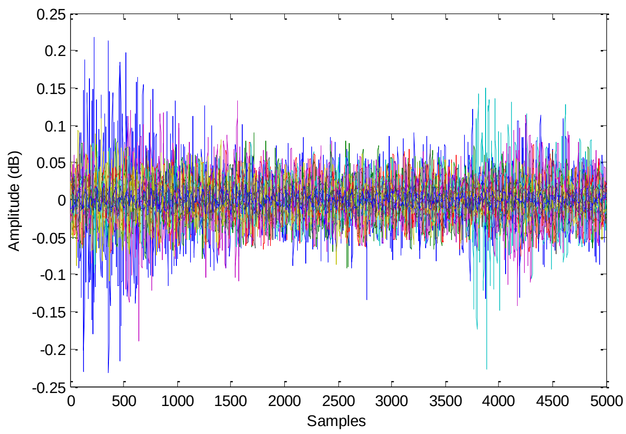

Fig. 6 The sound pressure level of emitted sound from spot welding machine

$$S_N(k) = 0{,}8\left(\frac{S(k)-S(k)_{min}}{S(k)_{max}-S(k)_{min}}\right)+0{,}1 \qquad (8)$$

In Figs. 7, 8 and 9 normalizations is realized and FFT analysis results are given. In Figs. 7-9, amplitudes are sound pressure level in dB.

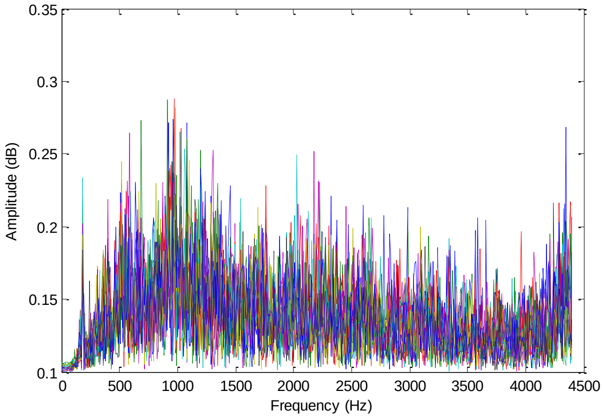

Fig. 7 FFT Analysis of arc welding machine

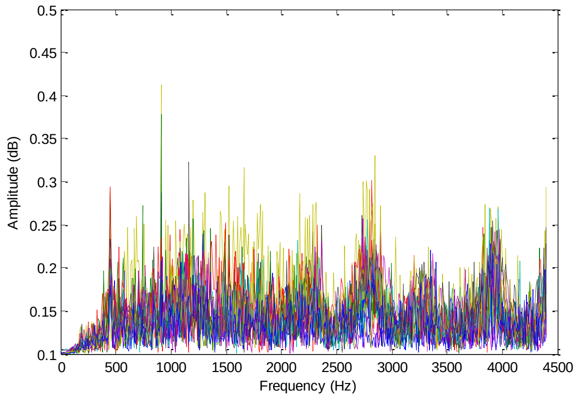

Fig. 8 FFT analysis inert-gas welding machine

The results of normalized FFT analysis were used for classification by forming ANN model. By applying FFT to the emitted sounds signals recorded to extract feature, frequency components are adopted. The sampling frequency of microphone is 44100 Hz and Nyquist frequency becomes 22050 Hz which is half of this frequency. Due to the involvement of three welding machines in the same ambient noise and high amplitude components' taking part in low frequency values, the first 500 components of FFT results were chosen for the extraction of feature.

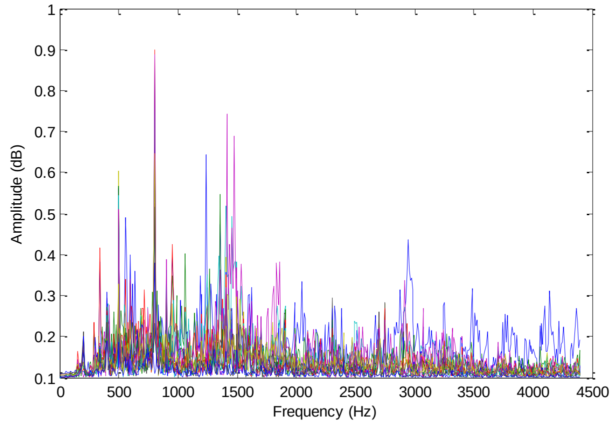

Fig. 9 FFT Analysis of spot welding machine

15x500 data was chosen for Arc welding machine, 15x500 for Inert-gas welding machine, 15x500 for Spot welding machine and 45x500 data in total for the input data of ANN model. Thus, there are 500 neurons in the input layer (Fig. 10).

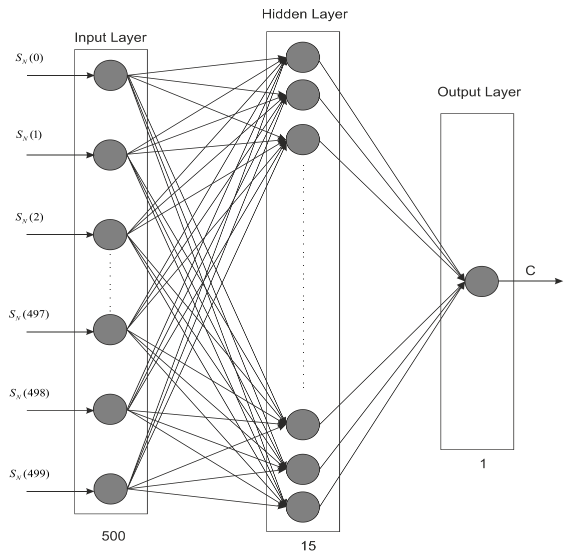

Fig. 10 The designed ANN model

Table

Inputs and targets of ANN for training

$S_N(0)$	$S_N(1)$	$S_N(2)$	$S_N(3)$	.	$S_N(497)$	$S_N(498)$	$S_N(499)$	C
0.1007	0.1005	0.1003	0.1006	.	0.1355	0.1602	0.2065	1
0.1051	0.1014	0.1062	0.1032	.	0.1951	0.1455	0.1591	1
0.1021	0.1012	0.1004	0.1011	.	0.2174	0.1192	0.1366	1
.	.	.	.	.	.	.	.	.
0.1040	0.1021	0.1022	0.1022	.	0.1241	0.1209	0.1221	1
0.1021	0.1004	0.1015	0.1008	.	0.1231	0.1226	0.1522	2
0.1025	0.1007	0.1010	0.1013	.	0.1754	0.1348	0.1760	2
0.1025	0.1019	0.1015	0.1019	.	0.1831	0.1397	0.1810	2
.	.	.	.	.	.	.	.	.
0.1001	0.1015	0.1012	0.1013	.	0.1977	0.1504	0.1342	2
0.1008	0.1009	0.1010	0.1012	.	0.1713	0.1930	0.1933	3

$S_N(0)$	$S_N(1)$	$S_N(2)$	$S_N(3)$	.	$S_N(497)$	$S_N(498)$	$S_N(499)$	C
0.1060	0.1043	0.1044	0.1044	.	0.1239	0.1666	0.1097	3
0.1032	0.1018	0.1019	0.1018	.	0.1140	0.1150	0.1139	3
.	.	.	.	.	.	.	.	.
0.1034	0.1026	0.1027	0.1025	.	0.1010	0.1005	0.1022	3

According to the test results accomplished, it was decided to have 15 neurons in the secret layer and 1 neuron in the output layer. As an activation function, logarithmic sigmoid function was chosen because there was not negative value. Three different values were chosen for the target in the output layer. “1” value represents arc welding machine, “2” represents inert-gas welding machine, “3” represents spot welding machine.

The constituted ANN model was trained according to Levenberg-Marquardt method. The 70% of the input data was used for training 30% for validation and 30% for test. The performance of ANN model was given in Fig. 11.

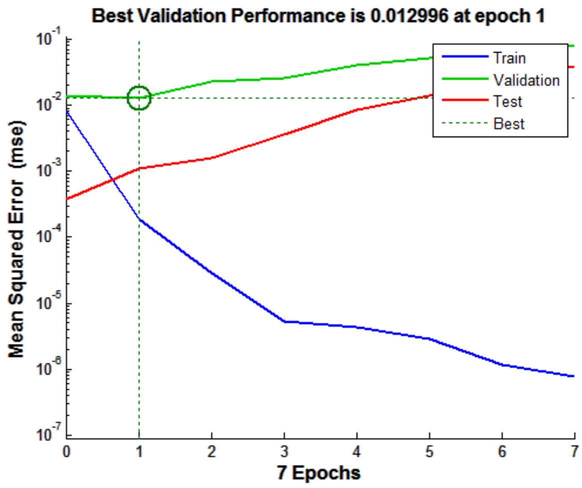

Fig. 11 The performance of the designed ANN model

Examining the regression results given in Fig. 12, it is seen that classification was achieved successfully. It was obtained 99.98% for test 98.86% for validation and 99.91% for test and 99.82% in total.

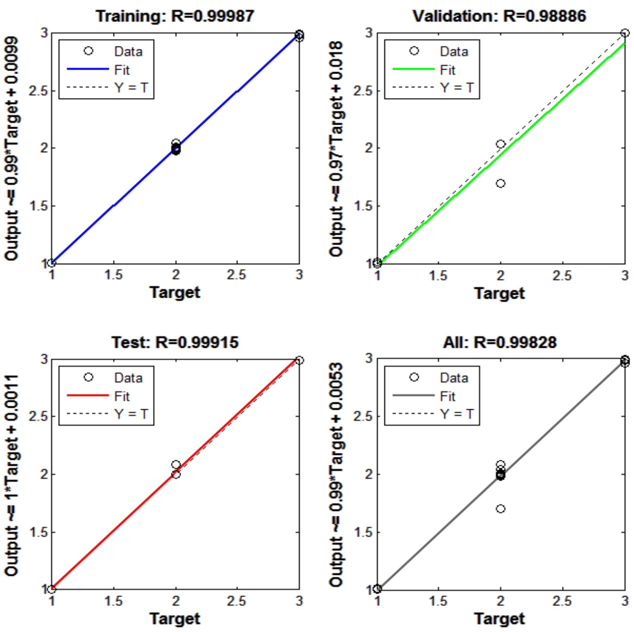

Fig. 12 The regression results of the designed ANN model

When the target set and ANN results are compared, it is obvious that there is a successful relationship between the target and ANN model (Fig. 13). However, the biggest error occurred at 0.4078 value and in the prediction of inert-gas welding machine. The biggest error value for arc welding machine is -0.0146, but for spot welding machine it is 0.1129. The reason why the error occurred relatively high in the prediction of inert-gas welding machine is that frequency values are closer to arc welding machine.

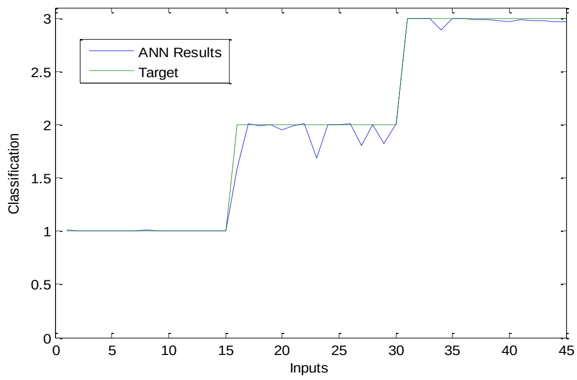

Fig. 13 The classification results of the designed ANN model

5. Conclusions

In this study, a method that can identify the types of three welding machines through only recording the emitted sounds of them without connecting any measuring device or tool has been developed.

In this study, FFT was used for feature extraction of signals and also used for ANN classification. It was observed that ANN model can classify welding machines at the rate of 99.82%. The biggest disadvantage of this method is the jamming of emitted sounds when more than one machine works simultaneously and classification’s getting difficult.

This study can be evaluated as the first step that determination and classification of welding problem originated from chosen not suitable electrical parameters such as current, power etc. In future studies, it can be used three dimensional sound intensity measurement technique.

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G. Gokmen, O. Akgun, T.C. Akinci, S. Seker

FAST FOURIER TRANSFORMATION OF EMITTED NOISES FROM WELDING MACHINES AND THEIR CLASSIFICATION WITH ACOUSTIC METHOD

S u m m a r y

In this study, a method that determines the welding machine types using acoustic method and Fast Fourier Transformation (FFT) and Artificial Neural Networks (ANN) has been suggested. FFT was used in order to bring out the characteristics of welding machines and ANN to classify them. To this end, the sounds of three arc, gas metal arc and spot weld machines were transferred to a computer during welding process via a microphone and recorded separately and then, by applying FFT, discrete frequency components were ascertained. The selected 500 frequency components were normalized and used as an input of an ANN model. It was observed that ANN model could classify welding machine types following training, validation and test stages, through the recorded sounds with a great success.

Keywords: classification, sound of the welding machine, fast fourier transform, artificial neural network.

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