MSA UNIVERSITY ENGINEERING JOURNAL

Application of Analysis of Variance and Taguchi Method for the Identification of Key Parameters and their Impact on Sound Measurement.

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Abstract

This work is done to measure the sound density and improve its quality. And this is done by measuring the sound intensity in different situations and surroundings. To determine the effect of significant parameters throughout the sound measurement. The results of the various experiments of the sound measurement are viewed by applying some tools in Design of Experiments (DOF), Such as Taguchi method and Analysis of Variance (ANOVA) [1]. In these experiments there are four factors considered, they are temperature, distance, wind speed and angle of the sensor. These factors were chosen because they are the most parameters that can affect the quality of the sound. The results show that the factor speed is the most significant factor with percentage 1.79% according to the ANOVA table. Therefore, this work is considered as an effective tool to find the important parameters and their effect in sound measurement.

Keywords: sound density, Design of Experiments (DOF), Taguchi method, Analysis of Variance (ANOVA), wind speed.

1. Introduction

The statistical procedure that is most frequently used to analyses experiment findings to ascertain the relative percent effect of a single factor and to distinguish between important and inconsequential factors is called an analysis of variance (ANOVA) [1].

To investigate how different process variables, affect the machining process, analysis of variance (ANOVA) is employed. The Taguchi method-based technique uses the signal-to-noise ratio and analysis of variance (ANOVA) to examine performance characteristics [2].

It is commonly used in experiments to compare the means of different groups, such as the means of different treatments or groups of subjects. In the context of sound measurement, ANOVA can be used to determine which parameters (e.g., frequency, intensity, duration) have the greatest impact on the measured sound levels [3].

The Taguchi method, also known as the "robust design method," is a systematic approach to design and analysis that is used to improve the quality and reliability of products and processes [4]. It was developed by Japanese engineer Genichi Taguchi in the 1950s and has since been widely used in a variety of fields, including engineering, manufacturing, and quality control [5]. In the context of sound measurement, the Taguchi method can be used to identify the significant parameters and their contributions to the measured sound levels, as well as to optimize the design of the measurement system [6].

Both ANOVA and the Taguchi method are powerful tools for understanding the factors that contribute to the measured sound levels and for identifying ways to improve the accuracy and precision of sound measurement [7].

2. Selection of parameters:

When using ANOVA and the Taguchi method to determine the significant parameters and their contributions in sound measurement, the selection of parameters is an important consideration [8]. In the case of sound measurement in an outdoor setting, the following parameters might be considered:

Wind speed: The speed of the wind can have an effect on the measured sound levels, as it can carry away or scatter sound waves. The wind speed should therefore be included as a parameter in the analysis [9].

Direction of sound: The angle at which the measurement device is oriented relative to the sound source can also affect the measured sound levels. Including the angle of inclination as a parameter in the analysis can help to account for this effect [10].

Table 1. Selected parameters and their levels.

Levels	A-wind speed [rpm]	B-Angle of Inclination [degree]	C- Distance [cm]	D- Temperature [Celsius]
level 1	0	0	3	22.3
level 2	1100	90	10.5	31
level 3	2200	180	18	40

Distance: The distance between the sound source and the measurement device can also affect the measured sound levels. It is important to include the distance as a parameter in the analysis in order to account for this effect.

Temperature: The temperature of the air can also have an effect on the measured sound levels, as it can affect the speed of sound waves. Including the temperature as a parameter in the analysis can help to account for this effect [11].

In addition to these parameters, it may be useful to consider other factors that could affect the measured sound levels, such as the type of sound source, the characteristics of the measurement environment (e.g., humidity, atmospheric pressure), and the characteristics of the measurement device (e.g., sensitivity, frequency response) [5].

Regardless of the specific parameters chosen, it is important to ensure that they are relevant to the measurement task at hand and that they are measured with sufficient accuracy and precision. This will help to ensure that the results of the analysis are reliable and meaningful.

L9 orthogonal array of Taguchi was chosen as indicated in Table 2 based on the quantity of parameters chosen and their levels [12]. The Taguchi approach reduces the number of tests, which saves time and money, in accordance with the chosen orthogonal array. This specific orthogonal array design covers all parameters with a limited number of trials, assigns control parameters and design variables to an array's columns, and converts the integers in the array columns into the actual parameter setting [13].

The factors taken for the sound sensor are: 1- the wind speed, 2- angle of inclination, 3- the distance, 4- temperature. As the wind speed is made by small 3 fans directed to the sensor. Also, angle of inclination is the inclination of the sound source referenced to the sensor, the distance referenced to the distance between the source and the sensor and the temperature is produced by lamp. All of these factors made by the following pictures.

Table 2: L9 orthogonal array of Taguchi for data collection

No. of experiment	A-wind speed [rpm]	B-Angle of Inclination [degree]	C- Distance [cm]	D- Temperature [Celsius]
1	0.0	0	3.0	22.3
2	0.0	90	10.5	31.0
3	0.0	180	18.0	40.0
4	1100 rpm	0	10.5	40.0
5	1100 rpm	90	18.0	22.3
6	1100 rpm	180	3.0	31.0
7	2200 rpm	0	18.0	31.0
8	2200 rpm	90	3.0	40.0
9	2200 rpm	180	10.5	22.3

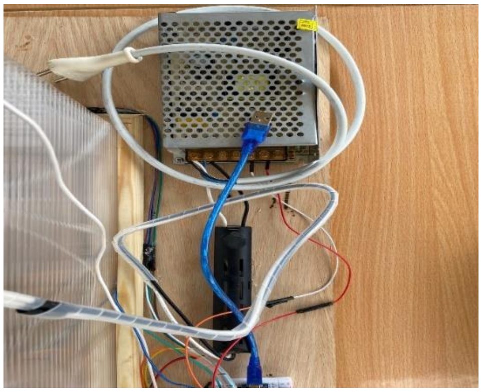

Fig (1). Power supply and potentiometer

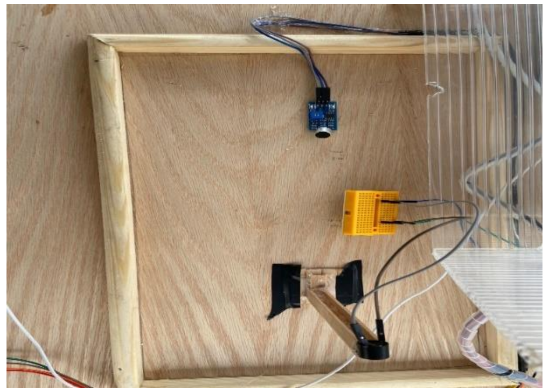

Fig (2). Sound sensor and sound source

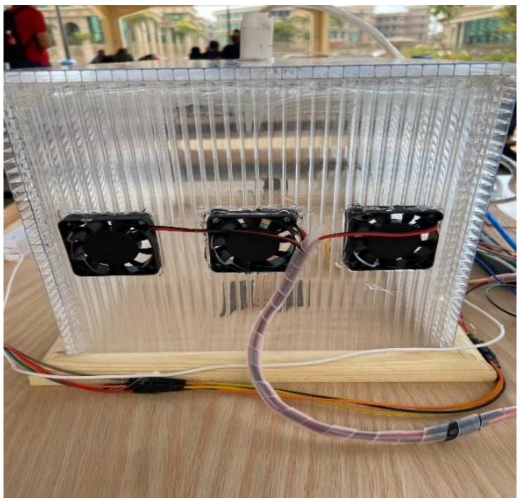

Fig (3). 3 fans 4X4

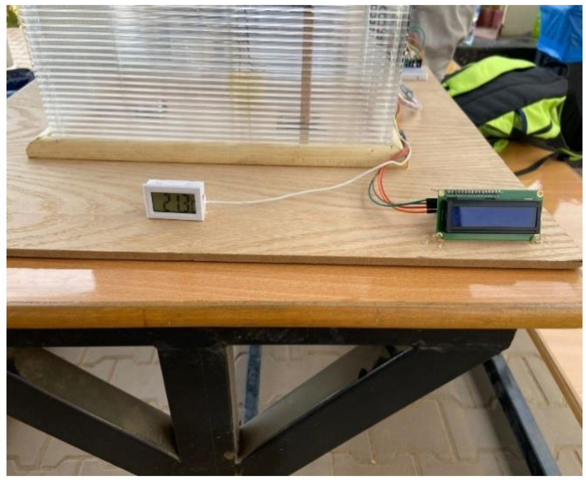

Fig (4). The temperature sensor and LCD

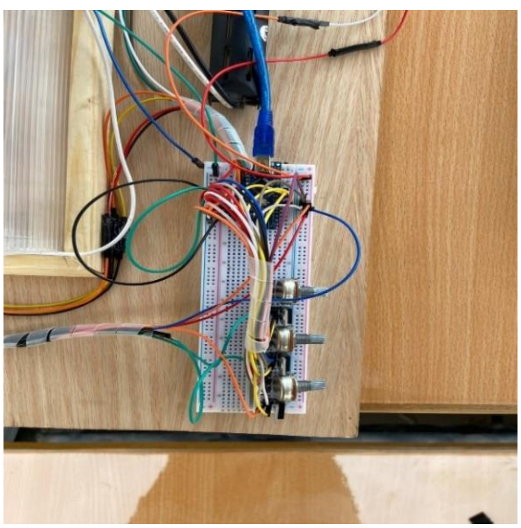

Fig (5). Bread board and connections

Fig. (6). General photo for the project (assembly)

3. Equation and sound measurements

To ascertain the quality features taken into account for any issues in engineering design, Taguchi suggests using the S/N ratio [14]. There are three options for S/N ratio: lower is better, nominal is best, and greater is better [15]. The S/N ratio uses average values to translate experimental data into a number that is practical for evaluating an element of Study of the ideal parameters [15]. Since the goal of this study is to use optimal parameters to keep the observed value as close as possible to the target value, the nominal best quality characteristic, which is specified in Eq. 1 and Eq.2, has been chosen.

$$\bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i,$$

$$s^2 = \frac{1}{n-1}\sum_{i=1}^{n}(y_i - \bar{y})^2,$$

Eq.1

$$S/N = 20\ \mathrm{Log}\left(\frac{\bar{y}}{s}\right)$$ [16]

Eq.2

Table 3: S/N calculations

Average Q	S^2	S	S/N
82.0	4.0	2.0	32.3
84.0	13.0	3.6	27.3
79.0	16.0	4.0	25.9
73.0	9.0	3.0	27.7
83.3	17.3	4.2	26.0
85.3	12.3	3.5	27.7
80.0	1.0	1.0	38.1
81.7	2.3	1.5	34.6
82.0	7.0	2.6	29.8

Then the calculations for the S/N table as shown in table 4:

Table 4: S/N table

	A-wind speed [rpm]	B-Angle of inclination [degree]	C- Distance [cm]	D- Temperature [Celsius]
level 1	28.50	32.68	31.51	29.37
level 2	27.15	29.31	28.30	31.04
level 3	34.15	27.82	30.00	29.40

From these calculations it can be concluded that the most significant factor is A-wind speed, (Highest difference). The best set of combination: A- wind speed at 2200 rpm, B- direction of sound at 90-degree, C- distance at 15 cm and D- temperature at 22.3 C (room temperature).

Then the ANOVA table is calculated from Eq.3 as the following:

Total sum of squares:

For the $S_t = ({Q_{Q1}}^2 + {Q_{Q2}}^2 + \cdots + {Q_{Q8}}^2 + {Q_{Q9}}^2) - \frac{(Q_{Q1}+Q_{Q2}+\cdots+Q_{Q8}+Q_{Q9})^2}{N}$ **Eq.3**

Table 5: ANOVA table

factors	**ST**	**104.4691358025**	**PC%**
factor A	SA	1.87654321	1.796265658
factor B	Sb	36.83950617	35.26353108
factor C	Sc	17.28395062	16.54455212
factor D	Sd	48.4691358	46.39565115

4. Conclusion:

The effect of the operators, wind speed, inclination angle, distance and temperature have been investigated in this paper throughout the sound measurement. Design of experiment (DOE) and related tools, namely Taguchi method, Signal to Noise (S/N) ratio and Analysis of Variance (ANOVA) were applied to reduce the noise from the controllable parameters. Hence, the optimal levels of selected parameters were identified including their percentage of contribution to improve the quality of the measurement process. The result demonstrates that wind speed is the most significant parameter followed by angle of inclination, temperature, and distance and the optimum set of parameters are wind speed at level 3, direction of sound at level 2, distance at level 3 and temperature at level 1. Finally, based on the ANOVA, the distance has the highest percentage of contribution 53.1% followed by the wind speed with 22.59%, direction of sound level with 15.613% and temperature with 8.692%.

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