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OPTIMIZATION USING TAGUCHI METHOD TO INVESTIGATE THE EFFECTS OF PROCESS PARAMETERS ON THE HARDNESS OF DEVELOPED ALUMINIUM ROOFING SHEETS

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Abstract: This study focused on the optimization using taguchi method to ınvestigate the effects of process parameters on the hardness of developed aluminium roofing sheets. Maximizing process variables like manufacturing temperature, manufacturing pressure, cooling time, and percentage of magnesium in aluminium, the Taguchi Method, a statistical method, was used to enhance the manufacturing quality of aluminium roofing sheets. Using an orthogonal array, a signal-to-noise ratio, and an analysis of variance, the effects of process variables on the hardness of the produced aluminium roofing sheets were examined. In this analysis, four factors; manufacturing temperature, manufacturing pressure, cooling time, and the precentage of magnesium in the aluminium roofing sheet were investigated. Thus, a suitable orthogonal array was selected, and experiments were conducted. Following the trial, the process parameters were evaluated, and the signal-to-noise ratio was calculated. The best parameter values were determined with the use of graphs, and confirmation trials were performed. The results showed that an aluminium roofing sheet's maximum hardness of 65.0kgf was obtained at a manufacturing temperature of 1250 °C, a manufacturing pressure of 65 GPa, a cooling period of 95 seconds, and a magnesium content of 0.5%. The most important influences on the hardness of aluminium roofing sheets was found to be the precentage of magnesium in aluminium roofing sheets followed by manufacturing pressure and manufacturing temperature. The cooling time was found to be the least efficient one. The obtained results in this study were used to improve the material property (hardness) of aluminum roofing sheet and investigate the effects of production factors in aluminum production industries.

Keywords: Aluminium sheets, Design of experiments, Hardness, Manufacturing, Signal-to-noise ratio

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1. Introduction

Most technical applications that demand outstanding mechanical properties require the development of metal matrix composites. Moreover, applications requiring low weight, such as in the aerospace and automotive sectors, use aluminium alloys (Altan, 2010). This is because aluminium alloy has great qualities such as increased stiffness (a higher strength-to-weight ratio), increased heat conductivity, and corrosion resistance. However, compared to steels, it has a lower melting point, less temperature stability, and a lower tensile and fatigue strength (Fratilia and Caizar, 2011; Zitoun, 2019). Aluminium alloy composite materials were created with increased strength and without changing the fundamental characteristics of aluminium alloys (Zitoun, 2019; Foster, 2000). The matrix phase makes up the majority of a composite substance while the reinforcement makes up the minority (Friend, 1987). Here, the matrix phase and reinforcement phase combine to create a composite substance. Various reinforcements, including Silicon carbide (SiC) (Joardar et al., 2012), Titanium diboride (TiB_2), Titanium carbide (TiC), Boron Carbide (B_4C), *Aluminium oxide (*Al_2O_3), Magnesium oxide (MgO), and fly ash (Kok, 2004; Manigandan et al., 2011), can be mixed with an aluminium matrix. Several techniques, including powder metallurgy, spray coating, electroplating, and stir casting, are used in the production of aluminium metal matrix composites (Singla et al., 2009). The production technique known as stir casting is more cost-effective and ideal for mass production. The metal matrix composite is primarily reinforced with whiskers and other particulate types using the stir casting method (Meena and Manna, 2013). Due to the lower density difference and greater wetability of Silicon carbide (SiC) compared to aluminium, it is frequently used as reinforcement in aluminium metal matrix composites (Olodu, 2018; Olodu, 2021). Prior to casting, the reinforcement and matrix were preheated individually (Osarenmwinda and Olodu, 2018; Rao et al., 2019). Aluminium- Silicon carbide (Al/SiC) composite is created by pouring reinforcement into a molten metal matrix that has reached its melting point and is being stirred with a motorized stirrer (Sozhamannan et al., 2012; Srinivas and Venkatesh, 2012; Saravanan et al., 2015).

Taguchi and Konishi created a statistical technique in 1987 known as the Taguchi method (Taguchi and Konishi, 1987). It was uesd to achieve the best results from the process, the Taguchi Method entails the identification of suitable control parameters. In Taguchi Method, a series of tests are carried out using orthogonal arrays (OA). These experiments' findings are used to assess the data and forecast the quality of the components that will be made (Taguchi and Konishi, 1987). The development of production processes was initially established to increase the quality of manufactured goods, but later its application was expanded to many other engineering fields, such as biotechnology (Fratilia and Caizar, 2011). The creation of analysis of variance schemes was one of Taguchi's contributions that was particularly valued by statisticians in the field. To effectively achieve the desired results, precise process parameter selection and their separation into control and noise components are essential (Taguchi and Konishi, 1987; Vaatainen and Pentti, 2016). It is important to choose the control in such a manner that the sound source has no effect. The Taguchi method entails selecting the proper control parameters in order to obtain the best process outcomes. There have been several orthogonal network (OA) experiments (Olodu, 2018). The findings of these investigations are used in data analysis and component quality prediction techniques (Friend, 1987). Foster (2000) looked into how five input parameters affected the refined goods' surface quality. Mold temperature, melting temperature, packing pressure, packing duration, and injection time were the input factors. The Taguchi method was used to lessen shrinkage in polypropylene (PP) and polystyrene (PS). In addition, Foster (2000) decreased PP and PS by 0.937% and 1.224%, respectively, using neural networks to simulate the process. The Taguchi technique was used by Vaatanen et al. (2016) to examine how injection molding parameters affected the aesthetic appeal of cast parts. The decrease of three other quality attributes; weight, welding, and kiln marks was a priority. They can optimize a variety of high-quality features that can result in cost savings with very little expertise. Economic growth is fueled by the discovery of new materials through research and design (Singla et al., 2009). That is, contemporary technology is heavily reliant on material research, which advances the economies of all nations. The mechanical characteristics of vortex-produced alloys of 2024 aluminium alloy enhanced with Al_2O_3 particles were examined by Kok (2004). The optimum melting temperature, mold preheating temperature, mixing speed, particle addition speed, mixing time, and contact pressure for the production process are 700 °C for casting, 550 °C for mold preheating, 900 rpm, 5 g/min., or 6 MPa. According to Friend (1987), the hardness and toughness of MMC A359/Al_2O_3 increase with increasing temperature. In addition, the research showed that the use of electromagnetic agitation during production leads to smaller particles and better adhesion from the interface of the particles to the matrix. Aluminium-Silicon carbide (Al/SiC) composites produced by powder metallurgy were studied by Venkatesh and Pentti (2016) to obtain the required properties and improve the mechanical properties of aluminium. Meena and Manna (2013) and Friend (1987) reported that aluminum strength, fatigue strength, modulus, wear resistance, and creep are improved by reinforcement. In comparison to the standard aluminium alloy, composites reinforced with Titanium diboride (TiB_2) particles showed a 30% increase in stiffness and a nearly doubling of tensile strength (Olodu, 2021). Meena and Manna (2013) looked at the effect of mixing time and speed on particle distribution in Silicon carbon-aluminum metal matrix composite (SiCAMC). The aluminium material's strength, durability, and stability, according to Meena and Manna declined (Meena and Manna, 2013). Early processing observations revealed a persistent uneven distribution of reinforcement in the form of groups or clumps of reinforcement with associated porosity. In addition, for a particular matrix alloy, raising the volume fraction reduces the break length (Singla et al., 2009). According to Fratilia and Caizar (2011) investigation on the effects of reinforcing particle shape and interface strength on the deformation and fracture behavior of an Al/Al_2O_3 composite observed two processes for particle failure which are cracking and separation at the interface.

This study therefore, focused on the optimization using Taguchi method to investigate the effects of process parameters on the hardness of developed aluminium roofing sheets

2. Materials and Methods

5052 aluminium sheet was used in this study. it is the strongest non-heat treatable sheet and plate in common use. Versatility and strong value make it one of the most serviceable alloys. When alloyed with magnesium, 5052 aluminium can be anodized. It shows good welding characteristics, and demonstrates moderate-to-good strength. It has good drawing properties and a high rate of work hardening. 5052 aluminium is resistant to saltwater corrosion, making it appropriate for roofing sheet applications. There are various types of long-span aluminium roofing products used in Nigerian construction industry. These products was analysed based on their hardness. Samples of aluminium material used for the tests were obtained from two Longspan aluminium manufacturing companies namely; AGEN Aluminium and Differential Aluminium Company all located in Benin City, Edo State, Nigeria. This material was exposed to a range of temperatures and pressures, from 30 GPa to 65 GPa and 905°C to 1250°C, respectively. In order to regulate the grain structure, limit grain growth, and avoid recrystallization following heat treatment in aluminium roofing sheets, magnesium (Mg) was added at different percentage to the aluminium. The magnesium (Mg) added was used to improve toughness and reduces susceptibility to stress corrosion. After cooling, the mechanical properties of these materials, which were created at different pressures and temperatures, were evaluated.

2.1 Types of Hardness Testing Methods

The Brinell Hardness Test was used in this study due to its economic adavantage over other methods. The following are other types of hardness testing methods used to determine the hardness of materials: Rockwell Hardness Test, Vickers Hardness Test, Shore Scleroscope Hardness Test, Knoop Hardness Test, Mohs Hardness Test, and Barcol Hardness.

2.2. Evaluation of Developed Aluminium Roofing Sheets for Hardness

The Brinell hardness test was used in this study, it involves the application of a constant load, usually in the range 500–3000 N, for a specified period of time (10–30 s) using a 5 or 10 mm diameter hardened steel or tungsten carbide ball on the flat surface of longspan aluminium roofing sheet. The Brinell hardness number (BHN) was then obtained using Equation 1 (Rao et al., 2019) (Figure 1 and 2).

$$\mathrm{BHN} = \frac{2F}{\pi D[D - \sqrt{D^2 - d^2}]} \quad (1)$$

where F is the load in kilogram, D is the steel ball diameter in millimeter, and d is the depression diameter or indentation diameter.

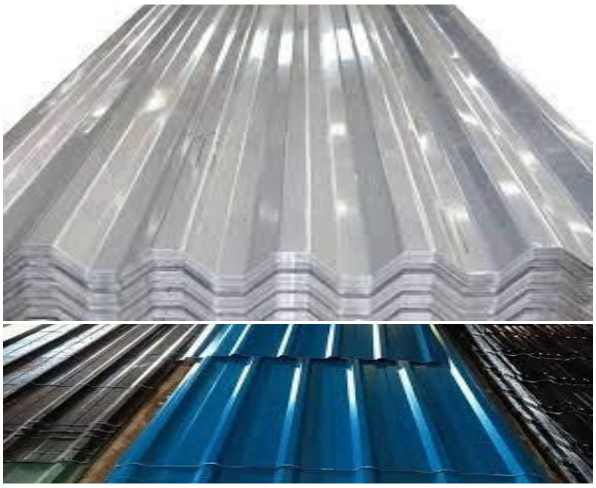

Figure 1. Samples of longspan aluminium roofing sheets.

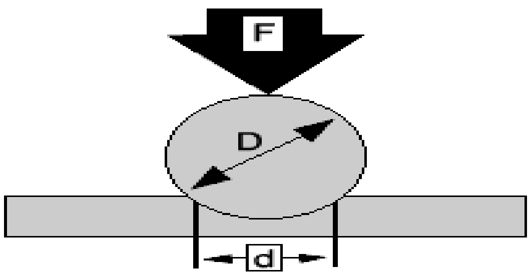

Figure 2. Impact force using brinell hardness method.

2.3. Optimization of Aluminium Roofing Sheets Process Parameters Using Taguchi Method

2.3.1. Experimental plan

In this study, experimental design was considered as one of the most comprehensive approaches to product/process development. This statistical approach attempts to provide predictive knowledge about a complex, multifactorial process through multiple trials.

2.3.2. Application of Taguchi method

A complete factorial design necessitates a great deal of testing. The more variables there are, the more complicated and time-consuming this becomes. Taguchi proposed an innovative method using an orthogonal array to explore the complete parameter space with fewer experiments to address this issue. To measure performance that deviates from the intended target value, Taguchi advises using a loss function. A signal-to-noise (S/N) ratio is then created from the value of this loss function. The signal-to-noise (S/N) ratio used by the Taguchi method shows both the mean and variability of quality characteristics. It is a metric of effectiveness for creating systems and procedures that are resistant to noisy influences.

2.4. Types of Signal-Noise (S/N) Ratio

The following are types of signal to noise ratio:

(i) Smaller-the-better: In Smaller-the-better (Equation 2),

$$Signal\ to\ noise\ ratio, \eta\left(\frac{S}{N}\right) = -10Log_{10}\{\frac{1}{n}\sum_{i=1}^{n} y_i^2\} \quad (2)$$

when a characteristic's minimization is desired, it is utilized.

(ii) Larger-the-better: In Larger-the-better (Equation 3),

$$Signal\ to\ noise\ ratio, \eta\left(\frac{S}{N}\right) = -10Log_{10}\{\frac{1}{n}\sum_{i=1}^{n} \frac{1}{y_i^2}\} \quad (3)$$

where i ranges from 1 to n, and n is the number of iterations used to complete tasks that call for optimizing the quality traits of interest.

with S/N (signal-to-noise ratio), n (number of observations), and yi (i-th number of observations).

(iii) Nominal-the-best: Equation 4 is used to determine the signal ratio for Norminal-the-best (Equation 4):

$$Nominal - the - best\left(\frac{S}{N}\right) = -10Log_{10}\{\frac{\mu^2}{\sigma^2}\} \quad (4)$$

when the mean, μ and standard deviation, σ are given. It is applied while attempting to reduce the RMS error near a particular target value. Matching the mean to the objective transforms the issue into a constrained optimization problem, regardless of the approach.

2.4.1. Selected Signal Ratio

In thie study, the smaller-the-better was used. This is because production temperature (°C), production pressure (GPa), cooling time (second) and percentage of magnesium in aluminium roofing sheet (%) are intended to be lower in order to produce aluminium roofing sheets with good hardness.

2.5. Identifying the Control Factors and their levels

Three levels of processing parameters and L9 orthogonal array were selected. The process parameters and levels are shown in Table 1 and L9 orthogonal array is shown in Table 2.

3. Results and Discussion

The factors and levels listed in Table 1 were used in the trials, per the orthogonal table (OA) above. Table 3 presents the trial configuration with the chosen factor values. Each of the aforementioned 9 trials was carried out. 36 experiments were conducted a total of 4 times to account for potential variations brought on by noise variables. The measured values of the process parameters acquired from different tests are displayed in Tables 4 through 7.

3.1. Determining the Experimental Matrix

The orthogonal table (OA) above indicates that the factors and levels used in the trials were those listed in Table 1. Table 3 displays the experimental configuration with the chosen numbers for the factors. Each of the aforementioned 9 trials was carried out. 4 times (total of 36 trials) to account for potential variations brought on by noise elements. The measured values of the process parameters derived from various tests are displayed in Tables 4 through 8.

Table 1. The process parameters and their levels

Serial Number	Factors	Level 1	Level 2	Level 3
1	Manufacturing Temperature (°C)	905	1100	1250
2	Manufacturing Pressure (GPa)	30	50	65
3	Cooling Time (second)	50	70	95
4	Percentage of magnesium in Aluminium Sheet (%)	0.2	0.3	0.5

Table 2. The orthogonal array for L9

Experiment Number	Control Factors			
	Manufacturing Temperature (°C)	Manufacturing Pressure (GPa)	Cooloing Time (second)	Percentage of magnesium in Aluminium Sheet (%)
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Table 3. Orthogonal array (OA) with control factors and hardness for aluminium roofing sheets

Experiment No.	Control Factors				Brinell Hardness (N/mm^2)
	Manufacturing Temperature (°C)	Manufacturing Pressure (GPa)	Cooling Time (second)	Percentage of magnesium in Aluminium Sheet (%)	
1	780	42	54	0.20	45.4
2	1022	55	70	0.22	48.0
3	1100	60	75	0.30	54.7
4	1110	65	70	0.50	65.0
5	1250	45	95	0.40	60.0
6	890	40	54	0.20	40.0
7	905	30	85	0.33	38.5
8	1005	58	60	0.42	50.4
9	850	35	65	0.38	44.0

Table 4. Measured values of manufacturing temperature for aluminium roofing sheets

Experiment No.	Manufacturing Temperature (°C)					
	1	2	3	4	5	Mean
1	786	785	775	770	784	780
2	1022	1020	1024	1015	1025	1022
3	1080	1120	1100	1130	1070	1100
4	1105	1115	1100	1130	1100	1110
5	1250	1270	1230	1260	1240	1250
6	870	900	900	900	880	890
7	900	900	915	900	910	905
8	790	790	760	790	770	780
9	1022	1024	1020	1021	1023	1022

Table 5. Measured values of manufacturing pressure for aluminium roofing sheets

Experiment No.	Manufacturing Pressure (GPa)					
	1	2	3	4	5	Mean
1	42	43	40	42	43	42
2	54	53	56	56	57	55
3	57	62	62	61	58	60
4	65	68	65	63	64	65
5	42	48	43	45	47	45
6	41	38	42	37	42	40
7	28	32	30	28	32	30
8	41	40	45	44	40	42
9	50	60	55	50	60	55

Table 7. Measured values of percentage of magnesium in aluminium roofing sheets (%)

Experiment No.	Percentage of magnesium in Aluminium Roofing Sheet (%)					
	1	2	3	4	5	Mean
1	0.20	0.15	0.20	0.20	0.25	0.20
2	0.22	0.21	0.22	0.22	0.23	0.22
3	0.30	0.29	0.30	0.30	0.31	0.30
4	0.50	0.40	0.50	0.50	0.60	0.50
5	0.40	0.39	0.40	0.40	0.41	0.40
6	0.20	0.25	0.20	0.20	0.15	0.20
7	0.33	0.31	0.33	0.33	0.35	0.33
8	0.42	0.44	0.42	0.42	0.40	0.42
9	0.38	0.36	0.38	0.38	0.40	0.38

Table 8. Tabulated signal-to-noise (s/n) ratios for of aluminium roofing sheets

Experiment No.	S/N Ratio (dB) for Manufacturing Temperature (°C)	S/N Ratio (dB) for Manufacturing Pressure (GPa)	S/N Ratio (dB) for Cooling Time	S/N Ratio (dB) for Percentage of magnesium in Aluminium Roofing Sheets
1	-57.8489	-32.4679	-34.5579	13.8722
2	-62.7618	-34.8419	-36.9108	13.1480
3	-61.6731	-35.5683	-37.5028	10.4556
4	-60.9069	-36.2611	-36.9048	5.9517
5	-61.9388	-33.0753	-39.4100	7.9577
6	-58.9887	-32.0531	-34.6509	13.8722
7	-59.1332	-29.5578	-38.5889	9.6233
8	-57.8430	-32.4758	-35.5669	7.5311
9	-60.1890	-34.8389	-36.2603	8.3995

The S/N ratio (η) for the individual control factors are calculated as given below (Equations 5-16):
Sum of Squares for manufacturing temperature for 1 to 3

$S_{T1}=(\varphi_1+\varphi_2+\varphi_3)$ (5)

Sum of Squares for manufacturing temperature for 4 to 6

$S_{T2}=(\varphi_4+\varphi_5+\varphi_6)$ (6)

Sum of Squares for manufacturing temperature from 7 to 9

$S_{T3}=(\varphi_7+\varphi_8+\varphi_9)$ (7)

Sum of Squares for manufacturing pressure from 1 to 3

$S_{P1}=(\varphi_1+\varphi_4+\varphi_7)$ (8)

Sum of Squares for manufacturing pressure from 4 to 6

$S_{P2}=(\varphi_2+\varphi_5+\varphi_8)$ (9)

Sum of Squares for manufacturing pressure from 7 to 9

$S_{P3}=(\varphi_3+\varphi_6+\varphi_9)$ (10)

Sum of Squares for cooling time from 1 to 3

$S_{T1}=(\varphi_1+\varphi_5+\varphi_9)$ (11)

Sum of Squares for cooling time from 4 to 6

$S_{T2}=(\varphi_2+\varphi_6+\varphi_7)$ (12)

Sum of Squares for cooling time from 7 to 9

$S_{T3}=(\varphi_3+\varphi_4+\varphi_8)$ (13)

Sum of Squares for percentage of magnesium from 1 to 3

$S_{C1}=(\varphi_1+\varphi_4+\varphi_7)$ (14)

Sum of Squares for percentage of magnesium from 4 to 6

$S_{C1}=(\varphi_2+\varphi_5+\varphi_8)$ (15)

Sum of Squares for percentage of magnesium from 7 to 9

$S_{C1}=(\varphi_3+\varphi_6+\varphi_9)$ (16)

See Table 9 to choose values for φ_1, φ_2, φ_3, etc., and to calculate S_1, S_2, and S_3. The average S/N ratio for level 1 manufacturing temperature is $\frac{S_{T1}}{3}$. The average S/N ratio for level 2 manufacturing temperatures is $\frac{S_{T2}}{3}$. $\frac{S_{T3}}{3}$ is the average S/N ratio for level 3 manufacturing temperature. Similar formulas are used to determine the manufacturing pressure, cooling time, and magnesium content of aluminium roofing sheets, respectively. Table 9 displays the average of the signal-to-noise ratios (S/N).

Table 9. The response table for S/N ratio for aluminium process parameters

Serial Number	Manufacturing Temperature (°C)	Manufacturing Pressure (GPa)	Cooling Time	Percentage of Magnesium in Aluminium Sheet (%)
Level 1	-60.7613	-34.2927	-36.3238	+12.4919
Level 2	-60.6115	-33.7965	-36.9886	+9.2605
Level 3	-59.0551	-32.2908	-36.8054	+8.5180
DELTA	1.7062	2.0019	0.6648	3.9739
RANK	3	2	4	1

*DELTA= absolute highest signal noise ratio - absolute lowest signal noise ratio

3.2. Confirmation Experiment

The confirmation experiment, which was performed using manufacturing temperature of 1250°C, manufacturing pressure of 65 MPa, 95 s of cooling time, and 0.5% magnesium in aluminum roofing sheets, as shown in Table 11. A total of five sets of experiments were run in the confirmation experiment, and their hardness was assessed. It is evident that the outcomes were reliable.

Table 9 displays the response Table for the S/N ratio. The level with the highest value for each factor was chosen as the ideal set of combination parameters. For aluminium roofing sheets, LEVEL 1 for percentage of Magnesium, LEVEL 2 for manufacturing pressure, LEVEL 3 for manufacturing temperature, and LEVEL 4 for cooling time respectively, are the best process parameter combinations. The factor that has the greatest impact on the hardness of aluminium roofing sheets is depicted by the Delta value in Table 9. It was discovered that the factor having the greatest impact on the hardness of aluminium roofing sheets had a Delta value of 3.9739 for percentage of magnesium. This was followed by manufacturing pressure with a Delta value of 2.0019, manufacturing temperature with a Delta value of 1.7062, and cooling time with a Delta value of 0.6648 (Table 9). Figures 1 to 4 depict a response diagram for the S/N ratio that was created. The ideal process condition relates to a manufacturing temperature of 1250°C, a manufacturing pressure of 65 GPa, a cooling time of 95 seconds, and a percentage of magnesium of 0.5%, and was determined by the maximum S/N ratio for each factor (Table 10). To improve the situation, the factor levels with the highest S/N ratio were picked.

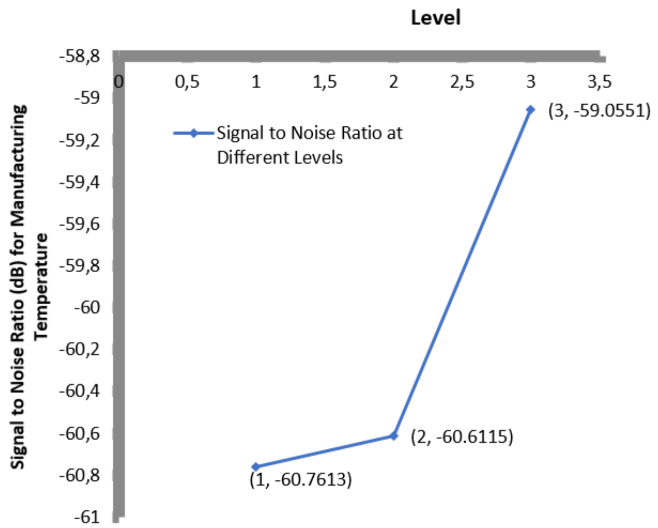

Figure 3. Signal to noise ratio (dB) for manufacturing temperature.

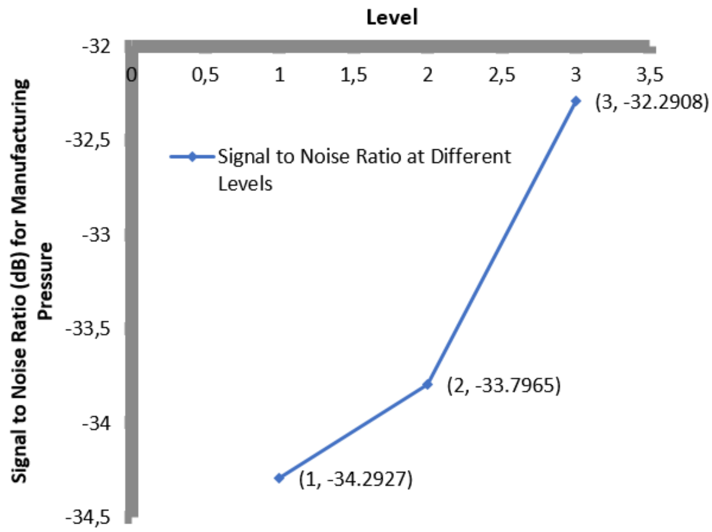

Figure 4. Signal to noise ratio (dB) for manufacturing pressure.

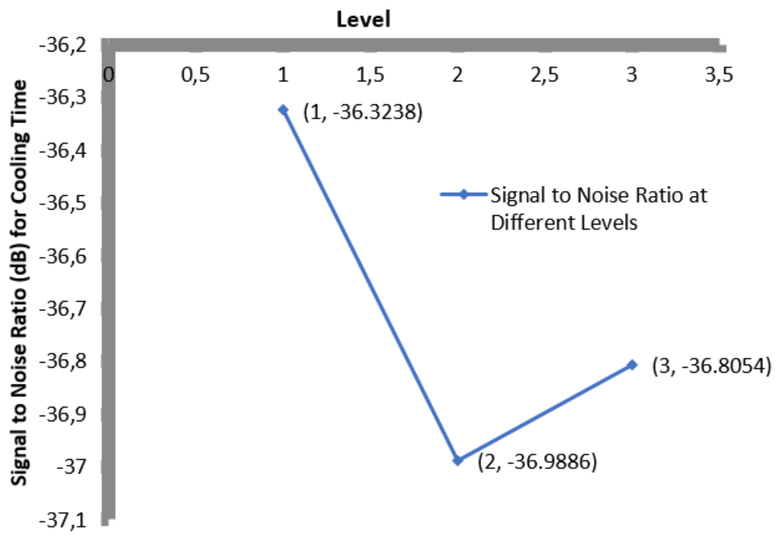

Figure 5. Signal to noise ratio (dB) for cooling time.

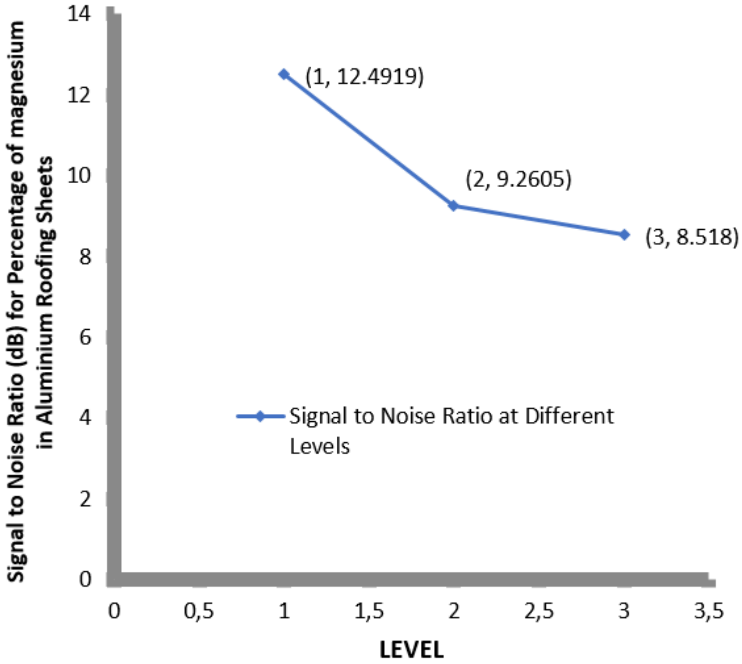

Figure 6. Signal to noise ratio (dB) for percentage of magnesium in aluminium roofing sheets

Table 10. Optimum values of factors of developed aluminium roofing sheets

Parameter	Optimum Value
Manufacturing Temperature	1250°C
Manufacturing Pressure	65 GPa
Cooling Time	95 seconds
Percentage of magnesium in Aluminium Roofing Sheets	0.5%

Kok (2004) looked at the mechanical properties of vortex-produced composites of 2024 aluminum alloy reinforced with Al_2O_3 particles. The appropriate melting temperatures, mold preheating temperatures, mixing speeds, particle addition rates, mixing times, and contact pressure for the production process are 700 °C for casting, 550 °C for mold preheating, 900 rpm for mixing speed, and 5 g/min for particle addition speed. The contact pressure is 6 MPa, and the mixing time is 105 seconds. The manufacturing temperature measured is consistent with the findings of this inquiry. To optimize the process parameters of medium-carbon steel joints joined by MIG welding, Altan (2010) applied the Taguchi technique. The results showed that the highest and the lowest Brinell hardness were 72 kgf and 64.2 kgf, respectively, and they were created by grooves with a 90° angle, 120 A current, and 30 V voltage. The maximal hardness of 65 kgf and the ideal hardness value of 72 kgf discovered in this study are consistent. Altan (2010) undertake a numerical analysis of the fatigue behavior of unpatched and patched aluminum and composite plates. They looked at the fatigue behavior of composite patched and unpatched Al 5083 aluminum plates using mathematics. The toughness results obtained in their study serves as a basis for the hardness obtained in this study.

Table 11. Confirmation experiment

Serial Number	Process Parameters				Hardness (Kgf)
	Manufacturing Temperature (°C)	Manufacturing Pressure (MPa)	Cooling Time (second)	Percentage of Magnesium in Aluminium Roofing Sheets (%)	
1	1250	65	95	0.5	64.9
2	1250	65	95	0.5	65.1
3	1250	65	95	0.5	65.2
4	1250	65	95	0.5	64.8
5	1250	65	95	0.5	65.0
	Mean Hardness (Kgf)				65.0

4. Conclusion

The best combinations of manufacturing conditions for the hardness of aluminium roofing sheets were found using the Taguchi method. According to the results, the maximum hardness was produced at manufacturing temperature of 1250 °C, manufacturing pressure of 65 GPa, 95 seconds of cooling time, and 0.5% of Magnesium. The most important aspect was discovered to be percentage of magnesium, which was followed by manufacturing pressure and manufacturing temperature. The least effective component was determined to be cooling time. This study is intended to help researchers and manufacturers of aluminium develop high-quality, defect-free aluminium roofing sheets, which would ultimately boost productivity in the aluminium industries.

Author Contributions

The percentage of the author(s) contributions is presented below. All authors reviewed and approved the final version of the manuscript.

	D.D.O.	A.E.
C	60	40
D	60	40
S	50	50
DCP	50	50
DAI	60	40
L	50	50
W	50	50
CR	60	40
SR	60	40
PM	50	50
FA	50	50

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans. The authors confirm that the ethical policies of the journal, as noted on the journal's author guidelines page, have been adhered to. The experimental procedures were approved by the Mechanical Engineering Department of Benson Idahosa University and Igbinedion University, Edo State, Nigeria.

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