

A multi-faceted investigative approach to ram speed, extrusion temperature and die exit width effects on mechanical properties of extruded Al 6063 alloy

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ABSTRACT

This research focused on the die exit width, ram speed and temperature effects on extruded Al 6063 alloy mechanical properties. It is a multiple approach that involves numerical, experimental and simulation methods in optimizing the extrusion process. The Q-Form was used in extruded sample flow stress and strain distribution analysis. The result revealed die exit width as the parameter with the most significant influence on Al 6063 alloy tensile strength and hardness, followed by extrusion temperature and then ram speed. The die width increase from 6mm to 8mm yields 73.5 % and 75.8 % tensile strength and hardness increase. The optimized process parameters predicted by the model are a speed of 16.2567 mm/s, a temperature of 526.334 °C, and a die exit diameter of 7.1862 mm, which yields a tensile strength of 151.031 MPa and a hardness of 183.644 HB, respectively. Based on Qform findings, the sample extruded using these optimal parameters yielded uniform metal flow products with low stress concentration. The research enables deep knowledge into the extrusion parameters and mechanical properties relationship, leading to aluminum alloy hot extrusion process optimization. This research has contributed to the more effective and efficient extrusion process development that can be applied in many aluminum extrusion industries. The product quality can be improved through optimized process parameters, thereby reducing the cost of production and boosting the extrusion process's overall efficiency.

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1. Introduction

One of the multifaceted manufacturing methods that entails the complex interaction of many process parameters, the die design, and the material mechanical properties is extrusion, which leads to setbacks in materials properties quality, energy usage, product quality and process optimisation (Mehul et al., 2025). Adequate selection of the extrusion process parameters, such as die exit width, ram speed, and temperature, plays a crucial role in the determination of aluminium alloy behaviour because these parameters substantially impact the tensile strength, hardness, microstructure, deformation behaviour, and flow stress of the material (Mehul et al., 2025). The relevance of these process parameters towards achieving an enhanced materials and product quality, and energy consumption reduction has been emphasised by many recent studies (Sindre et al., 2024). For example, Xiangrong (2024) used a Taguchi method for extrusion process optimisation that involves thinning rate, temperature, and speed for product quality enhancements and energy consumption reduction (Xiangrong, 2024). This study aims at further investigation of the material behaviour and process parameters of complicated connections by building upon the past research to ensure effective and efficient extrusion process development.

Another important parameter that significantly influences the extrusion process is billet temperature and die geometry. Extrusion procedure is normally conducted at a temperature higher than the recrystallisation temperature of the material under consideration, but at a lower temperature than its melting point (Azeez et al., 2021). Therefore, the aluminium extrusion

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temperature ranges from 350°C to 550 °C based on the specific aluminium alloy (Xiangrong, 2024). The die exit width that is responsible for the extruded product shape also plays a crucial role in mechanical properties. It is also an aspect of extrusion tools design that requires careful consideration (Azeez et al., 2021a). Qiong et al. (2020) worked on an extrusion prediction deformation model with residual stress on an aeronautical plate of Al 6063 alloy material using various extrusion parameters. Their research emphasised the extrusion parameter optimisation in obtaining the required properties and quality product. Also, the relevance of material response to process parameters interactions in extrusion process optimisation was revealed by the researchers.

Tensile strength, elongation, hardness, and yield strength substantially determine the product quality and extrusion process. Many Aluminium alloys show different levels of these properties (Atish & Inamdar, 2016). Some of these are Al 7075 and Al 2024 grades that exhibit high hardness and tensile strength, while the likes of Al 6063 and Al 6061 show average yield strength with high elongation (Atish and Inamdar, 2016). The billet homogenization treatment and structure of the casting also impact the extrusion process (Dyi-Cheng et al., 2024). The details of the relationship between extrusion input and output parameters are important in extrusion process optimisations and enable the right selection of the specific aluminium alloy (Francy et al., 2024). This research is novel based on the detailed investigative technique to study the material behaviour and process parameter interaction, which resulted in the development of optimised aluminium alloy process parameters

The mechanical behaviour prediction and optimisation of the extrusion process requires effective numerical modelling and simulation tools. Qform software, for example, can be used for the extrusion process simulation, and design expert software can be used to determine the effects of various process parameters on material properties predictions (Azeez et al., 2021b). Through the combination of numerical and experimental findings, the researcher can be able to derive a significant solution to complicated material behaviour and process parameters interaction, consequently resulting in process effectiveness and enhanced product quality. Furthermore, the efficient simulation tools and numerical models' development enable the facilitation of extrusion process optimisation and material behaviour predictions.

The extrusion process optimization is important in obtaining the desired properties and product quality. Through the detailed knowledge of extrusion temperature, dies exit width and extrusion speed, and their interactions, manufacturers will be able to optimise these parameters for energy consumption management, enhanced mechanical and product quality (Ming et al., 2025). There is also a need for exploration of the complex interaction that exists between material behaviour and process parameters in the development of a more effective and efficient aluminium alloy extrusion process (Sindre et al., 2025). This will aid the optimised extrusion process development and can substantially impact many industrial advancements. Such industries include construction, aerospace and automotive, which majorly depend on aluminium alloy of high quality.

2. Materials and Methods

2.1 Al 6063 and its characterisation

The procured Al 6063 alloy grade from Tower Aluminium Extrusion company located at 9 Oba Akran, Ikeja, Lagos, Nigeria, was selected for this study due to its wide application in the extrusion process and its excellent corrosion resistance, strength, hardness, and extrudability among other qualities. Table 1 presents the physicochemical makeup of this alloy. Each of the original materials was in cylindrical cross-section form of 20mm diameter, 700 mm long, presented in **Fig. 1a**, before it was machined to billet size 15mm in diameter, 55mm long each, as presented in **Fig. 1b** for experiments using a lathe machine (model no: C6132A/750). The original hardness and tensile strength of the as-received Al 6063 alloy were respectively assessed using a Brinell hardness testing machine (model no: TFKB-3000) and a universal testing machine (model no: BSUTE-100). **Table 2** presents the hardness and tensile strength values of the as-received Al6063, which were discovered to be aligned with the literature-reported value (Zina & Mohammed, 2024).

Table 1

Physicochemical composition of Al6063

Chemical properties	
Components	Percentage composition
Aluminium	98.35
Iron	0.28
Titanium	0.08
Copper	0.1
Chromium	0.10
Zinc	0.09
Magnesium	0.52
Manganese	0.08
Silicon	0.35
Others	0.05
Physical properties	
properties	Values
Elastic Modulus (GPa)	69.4
Density (g/cm ³)	2.69
Melting point (°C)	620



Fig. 1. Aluminium sample (a) rod (b) machined billet

Table 2. Mechanical properties of Al 6063

Properties	Value
Tensile strength (MPa)	113
Hardness (HB)	128

2.2 Experimental design

Response Surface Methodology (RSM) with Central Composite Design (CCD) was used in investigating extrusion process parameters' impacts on the hardness and tensile strength of Al 6063 alloy. RSM is a statistical method employed in developing mathematical models and for process parameter optimization (Krzysztof & Marcin, 2014). The Ram speed (S) of range 15-25mm/s, temperature (T) of range 400-550 °C, and die exit width (W) of range 6-8mm were considered as the input parameters. Design Expert software was used to design the 6 axial, 6 centre, and 8 factorial points to make a total of 20 experimental runs on CCD. **Table 3** and **Table 4** present the details of the experimental design matrix.

Table 3. Design parameters of the experiments

Parameters	Code	-1	0	+1	-α	+α
Temp. (°C)	T	400	475	550	348.87	601.13
Speed (mm/s)	S	15	20	25	11.59	28.41
Die exit width (mm)	W	6	7	8	5.32	8.68

Table 4. Design matrix of the experiments

Experiments run	Coded value			Original value		
	T	S	W	Temp (°C)	Speed (mm/s)	Die exit width (mm)
1	-1	-1	-1	400	15	6
2	+1	-1	-1	550	15	6
3	-1	+1	-1	400	25	6
4	+1	+1	-1	550	25	6
5	-1	-1	+1	400	15	8
6	+1	-1	+1	550	15	8
7	-1	+1	+1	400	25	8
8	+1	+1	+1	550	25	8
9	-α	0	0	348.87	20	7
10	+α	0	0	601.13	20	7
11	0	-α	0	475	11.59	7
12	0	+α	0	475	28.41	7
13	0	0	-α	475	20	5.32
14	0	0	+α	475	20	8.68
15	0	0	0	475	20	7
16	0	0	0	475	20	7
17	0	0	0	475	20	7
18	0	0	0	475	20	7
19	0	0	0	475	20	7
20	0	0	0	475	20	7

To avoid the unidirectional bias in the experimental prediction, alpha (α) = 1.68179 was used in generating the experimental design to ensure 6 centre points and a rotatable design. This design enables input parameters interactions and quadratic effects predictions, allowing accurate hardness and tensile strength mathematical model development. The experiments were methodically designed to cover individual parameters' effects and their output interactions. The experimental runs 1-8 are factorial points, while 9-14 and 15-20 are respectively axial and centre points. The structure of this design is to enable reliable

and robust model development so that the extrusion process parameters optimization can yield the desired hardness and tensile strength results. Eq. (1) presents the general representative mathematical model for response prediction (Azeez et al., 2021b).

$$\hat{Y} = \alpha_0 + \epsilon + \sum_{m=1}^l \alpha_m x_m + \sum_{m=1}^l \alpha_{mn} x_m x_n + \sum_{m=1}^l \alpha_{mm} x_m^2 + \epsilon \tag{1}$$

\hat{Y} = responses, ϵ = random error, ; α_0 = total mean, α_{mm} = input parameter quadratic effect, α_m = input parameter linear effects

Through the models and their coefficient analysis, significant factors and interactions influencing the output parameters can be identified. Models and input parameters' significance will be assessed using Analysis of Variance (ANOVA). The model's goodness of fit was evaluated using the determination coefficient (R^2) and adjusted R^2 . The variation percentage based on the model response was indicated by R^2 , while the model predictors were accounted for by adjusted R^2 . The insight into the ram speed, die exit width, and extrusion temperature effects on the hardness and tensile strength of Al 6063 alloy was provided by the results. The model efficiency and precision in response prediction were assessed through the coefficient of performance, and this provided enough details of the model capacity in the interpretation of experimental data.

2.3 Experimental procedure

A hydraulic press of 1000 kN capacity was used in conducting the extrusion process. Other tools and equipment used are a ram, a die holder and an electric furnace for billet heating. The sample material is Al 6063 alloy, which was machined into a billet size 15mm in diameter, 55mm long. **Table 1** and **Table 2** have already presented the physicochemical and mechanical properties of the billets. Using a resistance heated furnace with an integration of temperature control within ± 4 °C, the billets were heated to a desired different temperature of 400-500 °C based on the experimental runs. The 3 locally fabricated dies (**Fig. 2**) of constant entry width of 15mm, but variable die exit widths of 6 mm, 7 mm, and 8mm, were used in carrying out the process. High pressures and temperature resistance are the die design considerations, and it was preheated to 200 °C using an electric coil before extrusion. Thermocouple was used in monitoring die temperatures, and a temperature-controlled system was used to control it.

The experiment was set up by attaching the die and its holder to the hydraulic press as presented in **Fig. 3**. The speeds were varied and controlled on the hydraulic press following the experimental design matrix. The process is not completed until the billet is finally extruded from the die, and the extruded product is obtained for hardness and tensile testing.



Fig. 2. Dies showing region of entry and exit



Fig. 3. Experimental set-up

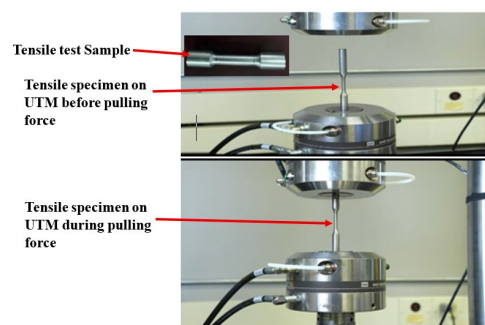


Fig. 4. Tensile test experimental setup

2.4 Tensile strength testing

A universal testing machine was used in evaluating the extruded products' tensile strength following ASTM E8 guidelines (ASTM, 2025). A CNC machine was used in preparing the extruded products to a suitable size. The extruded samples were machined to a 5.8 mm diameter with a 23.5 mm gauge length. The tensile test was conducted at $0,001 \text{ S}^{-1}$ strain rate, and the peak load before breakage of the material was noted. The maximum load attained during the test was used as the basis for tensile strength calculation in MPa. The UTM (model no: BSUTE-100) of 100 kN capacity was used in this test, and it was properly calibrated based on manufacturer recommendations. The UTM used has a data acquisition system for load -data displacement recordings. The hydraulic system was used to grip the specimen at room temperature, and the pulling force was applied. The tensile test experimental setup is presented in **Fig. 4**.

2.5 Hardness testing

A Brinell hardness testing machine was employed in the hardness evaluation of the extruded product following ASTM E10 guidelines (ASTM, 2025). The extruded sample billets were machined to a suitable size for the hardness test, after which they were ground and polished to a smooth flat surface for the test. A 3mm ball indenter diameter with 250 kgf applied load was used in the hardness evaluation. Indenter diameter was used as the basis for hardness calculation in HB. The hardness tester calibration was done based on manufacturer recommendations. The is a measuring microscope that was attached to the tester for accurate indentation diameter measurement. The sample was positioned on a firm anvil at room temperature. The hardness testing experimental setup is presented in **Fig. 5**.

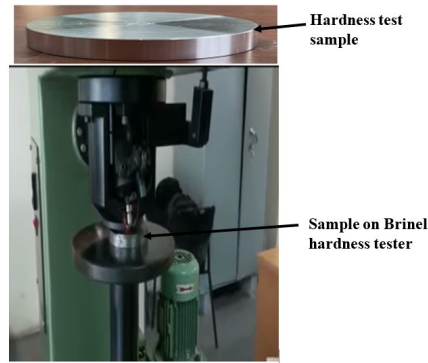


Fig. 5. Hardness testing experimental setup

The hardness and tensile test results were utilised in assessing the die exit width, extrusion temperature, and ram speed on Al 6063 alloy mechanical properties. RSM was used in experimental data analysis, while the extruded product hardness and tensile strength of prediction were achieved through the developed models.

2.6 Numerical simulation

Qform software (version: 10.1.7) was used for the extrusion process numerical simulation. This is a unique simulation tool dedicated to metal forming process simulation only (Marek et al., 2025). The design of the simulation setup conformed to experimental settings. The ram speed, die exit width and extrusion temperature as boundary conditions were set following the experimental design matrix. Aluminium extrusion flow stress behaviour during extrusion was obtained using Qform software. It also enables the developed RSM mathematical model validation. This will ensure that the predicted optimal responses are reliable and accurate. Through the combination of experimental and statistical analysis with simulation, detailed results of the extrusion process will be obtained, leading to optimised process parameters with an enhanced product quality.

3. Results and Discussions

Table 5 presents the tensile strength and hardness response to the interaction between the speed, die exit width and temperature as processing parameters in the Al6063 extrusion process. Through a detailed results analysis, it was discovered that 25 mm/s speed, 550 °C temperature, and 8 mm die exit width, which occurred at experiment 8, produced the highest hardness of 225 HB. This shows a substantial 75.8% increase in hardness compared to 135 HB, which is the lowest extruded sample hardness value that was obtained at 15 mm/s speed, 400 °C temperature, and 6 mm die exit width, under experiment 1. The total of 20 experiments has an average hardness value of 181.8 HB and 8.77HB standard deviation. The findings also revealed the tensile strength range from 120 MPa to 196 MPa, while the highest value was obtained at 25mm/s speed, 8mm die exit width and 550 °C, which at experiment 8. This translates to a huge 73.5% increase relative to the 120 MPa lowest extruded sample tensile strength value obtained at 6mm die exit width, 15mm/s speed, and 400 °C temperature at experiment 1.

Table 5. Output responses to input variables

Experiments run	Input variables			Output variables	
	Temp (°C)	Speed (mm/s)	Die exit width (mm)	Hardness (HB)	Tensile strength (MPa)
As- received				128	113
1	400	15	6	135	120
2	550	15	6	140	126
3	400	25	6	144	132
4	550	25	6	198	164
5	400	15	8	205	170
6	550	15	8	216	180
7	400	25	8	210	174
8	550	25	8	225	196
9	348.87	20	7	174	138
10	601.13	20	7	186	159
11	475	11.59	7	177	143
12	475	28.41	7	183	152
13	475	20	5.32	137	123
14	475	20	8.68	223	187
15	475	20	7	180	146
16	475	20	7	180	147
17	475	20	7	182	147
18	475	20	7	181	146
19	475	20	7	180	147
20	475	20	7	180	146

3.1 Model equations

A numerical model was developed to forecast the output parameters (tensile strength and hardness) based on the interactions between die exit width, temperature and speed in the extrusion of aluminium alloy. The forecast model for tensile strength and hardness is presented in Eq. (2) and Eq. (3), respectively.

$$TS = 146.27 + 7.71A + 6.23B+20.92C+4.75AB - 0.75AC-3.75BC+2.22A^2+1.87B^2 + 4.52C^2 \tag{2}$$

$$H = 180.37 + 7.70A + 6.67B+28.09C+6.63AB-4.13AC-6.63BC+0.7A^2+0.7B^2 + 0.7C^2 \tag{3}$$

These developed models were used to predict the tensile strength and hardness for all 20 experimental runs. It was noticed that the deviations between the experimental (actual) and model (predicted) results for tensile strength and hardness are minimal, as presented in Fig. 6 (a and b)

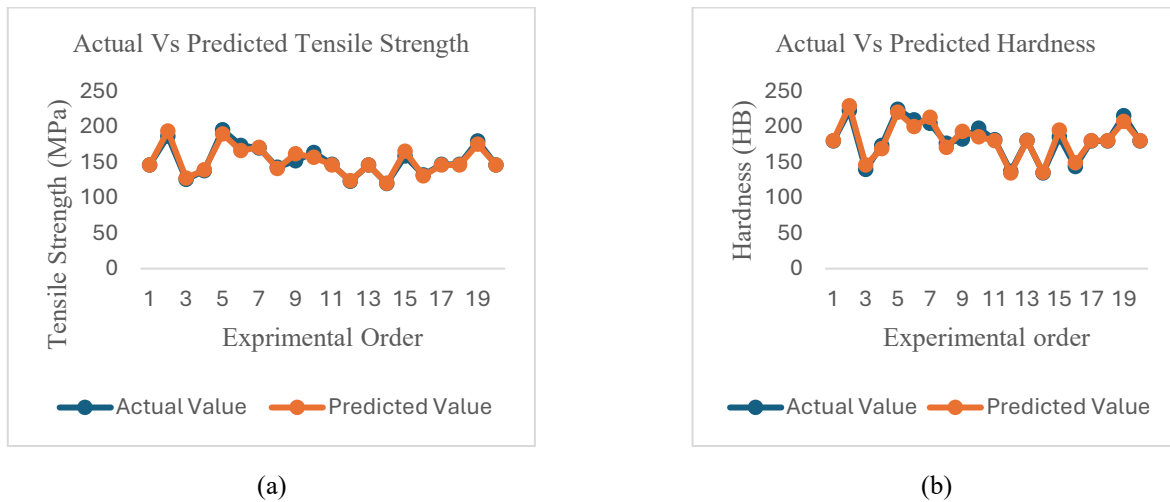


Fig. 6. Variation between actual and predicted value for (a) tensile strength (b) hardness

3.2 Input parameters' significance in the developed models.

It was discovered from the statistical analysis results that the parameter that exhibits the highest significance level in terms of tensile strength and hardness prediction is die exit width. The next to die exit diameter in terms of significance level is temperature, followed by speed. Based on the ANOVA results presented in Table 6, the die exit width has a hardness p-value and F-value of <0.0001 and 140.17, implying a high significance level. Likewise, temperature as an extrusion parameter shows a hardness p-value and F-value of 0.0088 and 10.54, implying a high level of significance. It was revealed from Table 5, when experiment 1 is compared with experiment 5, that tensile strength and hardness increased by 50MPa and 70HB for every 2mm die exit width. The 3D plots presented in Figures 7(a-c) and 8(a-c) revealed further confirmation of die exit width as the most significant factor in tensile strength and hardness forecast after the interactions between all the input parameters. In Table 7, the hardness and tensile strength model determination coefficient (R²) are 0.9597 and 0.9444, respectively, implying a highly accurate model in output response prediction. Also, the percentage differences between the adjusted and predicted R² for hardness and tensile strength in Table 7 are 7.72% and 5.60% respectively. Since the percentage differences are less than 20% in both cases, the model output prediction is accurate. The adequate precision that measures signal-to-noise ratio for tensile strength and hardness is 15.239 and 15.450, and since the values in both cases are greater than 4, the model is an excellent fit (Azeez et al., 2021b).

Table 6. Variance analysis for the hardness and tensile strength models

Source	Tensile Strength		Hardness	
	F Value	p- value	F Value	p-value
Model	24.07	< 0.0001	18.86	< 0.0001
A-T	22.05	0.0008	10.84	0.0088
B-S	14.41	0.0035	7.90	0.0184
C-W	162	< 0.0001	140.17	< 0.0001
AB	4.90	0.0512	0.1295	0.0296
AC	0.1222	0.7389	2.59	0.0513
BC	3.05	0.1111	4.57	0.0583
A ²	0.93	0.1945	0.0919	0.7680
B ²	1.37	0.2694	0.7680	0.7680
C ²	8.00	0.0179	0.7680	0.7680

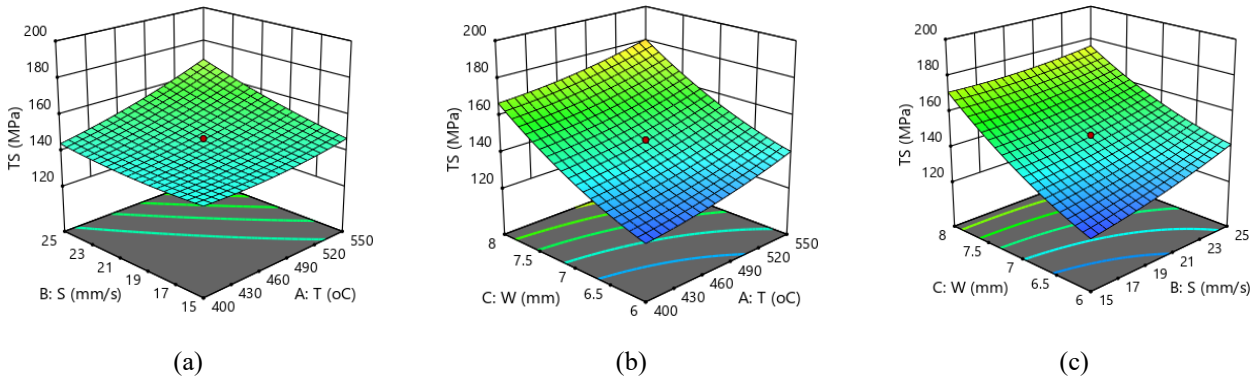


Fig. 7. Tensile strength response to (a) speed and temperature (b) die exit width and temperature (c) die exit width and speed.

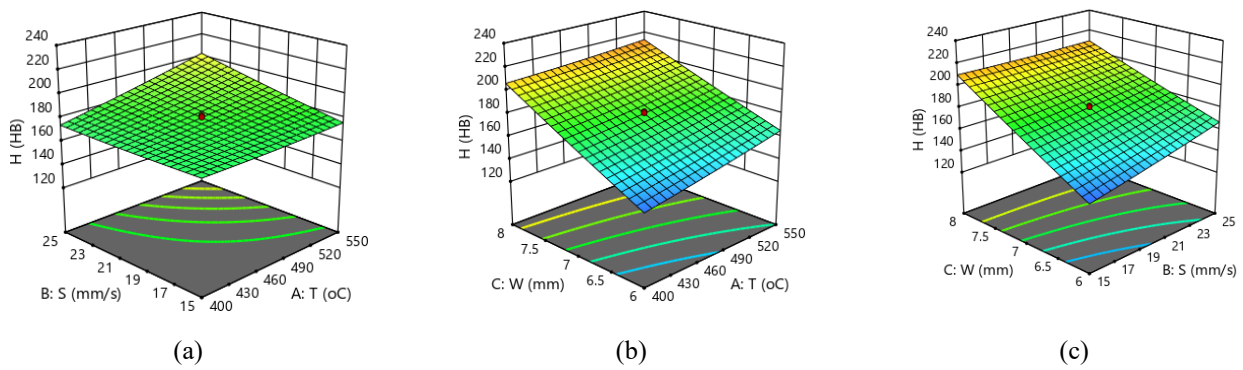


Fig. 8. Hardness response to (a) speed and temperature (b) die exit width and temperature (c) die exit width and speed.

Table 7. Determination coefficient results

Model summary	Tensile Strength	Hardness
Standard Deviation	8.77	9.84
R ²	0.9444	0.9597
Adjusted R ²	0.8943	0.8909
Predicted R ²	0.8603	0.8634
Adeq Precision	15.239	15.450

High-level significance of the die exit width, which its increase simultaneously enables increased hardness and strength, can be related to the possibility of high strain rate due to larger force from the extruder, which materials can be subjected to at a large die exit width. This increases the compression rate and therefore increases material hardness and tensile strength (Ali et al., 2025). However, some studies (Zina & Mohammed, 2024; Martins et al., 2024) suggested that a small die angle enables increased hardness and tensile strength due to high extrusion load, but the die exit width and temperature interaction in this research has revealed the impact of high temperature in complementing larger die exit width in hardness and tensile strength of aluminium improvement.

These research results align with previous findings that revealed the die exit width has a substantial effect on the extruded aluminium alloy mechanical properties. For instance, Zina and Mohammed (2024) discovered that the increase in exit width from 16 mm to 20mm led to 28% and 34% tensile strength and hardness increase respectively. Another finding by Atish and Inamdar (2016) revealed a substantial impact of smaller die exit width on enhancing the mechanical properties and microstructure of extruded aluminium alloy. These research findings enable validation of the research that revealed the speed and temperature significance extent on the extruded product mechanical properties (Hoang et al., 2025).

3.3 Process parameters optimisation

Optimisation ramp in **Fig. 9** presents the optimisation results that reveal the optimal process parameters value that give the required output. The optimal solutions were evaluated by the RSM desirability function. The results revealed 526.334 °C temperature, 16.2567 speed, and 7.18692mm die exit width as the optimal process parameters. These optimised values lead to enhanced material properties (tensile strength 151.013 MPa, and Hardness 183.644 HB). The high value of desirability 1.00 is an indication that the optimal solution is ideal and satisfies the targeted objectives (Alejandro et al., 2025).

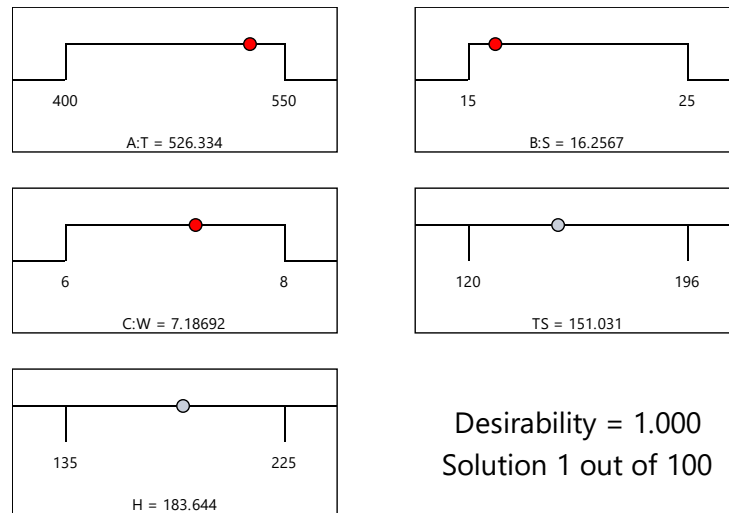


Fig. 9. Input parameters optimisation ramp

3.4 Confirmatory experiments validation

Confirmatory experiments were conducted to validate the developed model's accuracy. The experimental design in this case focused on conducting tests at the optimal level of the process parameters (526.334 °C temperature, 16.2567 speed, and 7.18692mm die exit width). Three experimental iterations were conducted to ensure consistency. From the experiment, the tensile strength has an average value of 148.780 MPa with 1.491% variation from the model-predicted values. The average hardness value of 185.117 HB with a variation percentage of 0.802 % was noticed. Since the variation percentages between the experimental and predicted values at optimal parameters are very small, the model is in good agreement with the experimental values (Azeez et al., 2021b). The percentage variation formula between the experimental values and the model prediction is presented in Eq. (4) (Marco et al., 2025). Confirmatory experiments and model forecast results, and their variation percentages, are presented in **Table 8**.

$$\%variation = \frac{|predicted-experimental|}{predicted} \times 100 \quad (4)$$

Table 8. Confirmatory experimental results with variation percentage

Trials	Tensile strength (MPa)		Hardness (HB)		% Variation	
	Experimental	Prediction	Experimental	Prediction	Tensile strength	Hardness
1	148.211	151.031	185.116	183.644	1.867	0.802
2	149.024	151.031	185.243	183.644	1.329	0.871
3	149.103	151.031	184.991	183.644	1.277	0.733
Average	148.780	151.031	185.117	183.644	1.491	0.802

3.5 Simulation results

The flow stress distribution simulation of the unextruded sample is presented in **Fig. 10a**. The maximum and minimum flow stresses fall respectively between 89.85 MPa and 23.6 MPa. A uniform distribution and low flow stress were noticed because the billet had not undergone plastic deformation. **Fig. 10b** shows the flow stress distribution in the simulated process at optimal settings predicted by the numerical model (526.334 °C temperature, 16.2567mm/s speed, and 7.18692mm die exit width). The maximum and minimum flow stress levels in this case are, respectively, 109.4 MPa and 60.28 MPa, while the minimum flow stress level dominates the extruded billet. A little increase in flow stress level compared to the unextruded billet is due to the plastic deformation it has undergone during the extrusion process. **Fig. 10c** presents the flow stress simulation that presents the highest mechanical properties in the order 8 (550 °C, 25 mm/s, 8mm) of the experimental design matrix. It was found to have maximum and minimum flow stresses of 156.3 MPa and 117.5 MPa, respectively. The flow stress is higher compared to the simulated one under the optimal setting. Higher stress level is noticed to be concentrated at the angular die region. Over-pressing may be responsible for this because any values of parameters used after the optimal settings do not add value to the product (Azeez et al., 2021a). It is either that the product remains the same or other defect surfaces (Zina & Mohammed, 2024; Zi-Ning et al., 2025). **Fig. 10d** revealed the simulated product flow stress at the parameter settings (400 °C, 15mm/s, 6mm) that produced the least mechanical properties in the experimental design matrix presented in Table 5. In this case, the maximum and minimum flow stress of 183.3 MPa and 110.8 MPa was obtained. A high flow stress level was observed compared to other conditions. While the average flow stress distribution dominates the extruded sample. The flow stress induced in this case may be due to the huge force of extrusion required in extruding at a lower die exit width which increases the sample stress level. Flow stress measures deformation resistance, and materials with higher flow stress induced in it are prone to fatigue failure. Therefore, the simulation conducted under optimal parameter settings gave the lowest flow stress level apart from unextruded material. This implies that at this lower flow stress level, the material under consideration

will last longer than at higher flow stress levels. This result agrees with the numerical model that forecasts the best quality at the optimal setting (Azeez et al., 2021b).

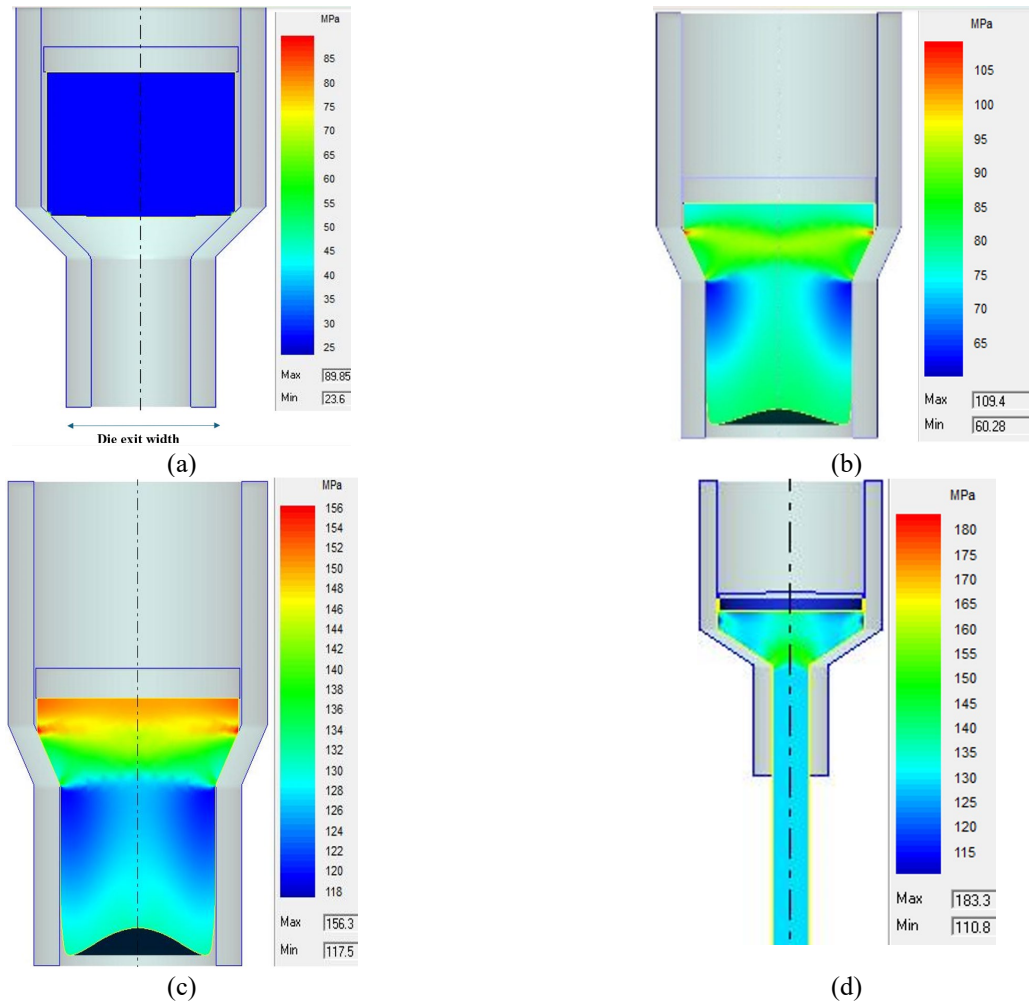


Fig. 10. Simulation results of aluminium (a) unextruded, (b) extruded at optimal settings, (c) extruded at 550 °C, 25 mm/s, 8mm, (d) extruded at 400 °C, 15 mm/s, 6mm.

4. Conclusion

In conclusion, the die exit width critical role in the Al 6063 alloy hot extrusion optimisation was demonstrated in this research. The substantial effect of die exit width on tensile strength and hardness highlights the precise control requirements of these parameters. Even though speed and temperature also impact the properties of materials, die exit width is the most significant factor. Specifically, an increase in die exit width from 6 mm to 8mm significantly yields 73.5 % and 75.8 % tensile strength and hardness increase, respectively. However, a smaller die exit width conversely reduces tensile strength and hardness but increases flow stress level. These results have enabled valuable hot extrusion optimization insight, making the desired mechanical properties of Al 6063 alloy achievement possible. Based on these findings, the process parameters controlled by various manufacturers in achieving better Al 6063 performance and quality products are a reality. The future research can focus on targeting the die exit width greater than 8mm for improved tensile strength and hardness.

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