Uniosun Journal of Engineering and Environmental Sciences (UJEES), Vol. 8 No. 2, Sept., 2026
DOI: 10.64980/ujees.v8i2.024 **Olaiya et al.**
Published: September 30, 2026

IMPROVEMENT OF MECHANICAL PROPERTIES OF ALUMINIUM ALLOYS WITH MANGANESE IV OXIDE AND CASTING PARAMETERS

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Abstract
Aluminium and its alloys are widely employed in engineering applications owing to their excellent corrosion resistance and high strength-to-weight ratio. The abundance of discarded aluminium components - particularly beverage cans and aircraft parts, makes recycling an attractive proposition, offering substantial economic and environmental benefits. This study investigates the use of manganese (iv) dioxide (MnO_2) as a reinforcing additive to enhance the mechanical properties of recycled aluminium alloy, thereby broadening its range of engineering applications. Varying quantities of MnO_2 were introduced into molten recycled aluminium alloy, which was then poured at different temperatures and cooled by different methods. Test pieces were machined from the resulting ingots and subjected to hardness, tensile, and impact strength tests. The experimental design (DOE) was developed using Taguchi methods in Minitab 2020 statistical software, and the effects of varying MnO_2 content and casting parameters were evaluated against the measured responses. Regression equations were generated for each response to enable pre-determination of the exact quantity of MnO_2 and casting parameters required for a desired optimum mechanical property. The highest hardness of 141.1 HV was achieved with aluminium alloy reinforced with 4.8% MnO_2 and cooled in air; the highest ultimate tensile strength (UTS) of 154.59 MPa was obtained with 12.6% MnO_2 and air cooling; and the highest impact strength of 14.94 J was recorded with 2.4% MnO_2 and sand cooling. It was concluded that reinforcing aluminium alloy with an appropriate percentage of MnO_2 and selecting the right cooling medium enhances various mechanical properties for improved engineering applications.

Keywords
Aluminium alloy, MnO_2, pouring temperature, cooling medium, hardness, UTS, impact strength

1. INTRODUCTION

Aluminium is the second most abundant metallic element on earth and has grown to be a formidable competitor in engineering applications since the end of the 19th century, when its production became economically viable (Ungureanu et al., 2007) [1]. Owing to its unique properties—excellent corrosion resistance, low density, and a potentially high strength-to-weight ratio—aluminium and its alloys have proved highly useful across a wide range of engineering applications. With the increasing use of metals driven by their mechanical properties, foundry activity has expanded accordingly, and aluminium has become the most recycled metal in the world, since far less energy is required to produce it through recycling than from its ore (Navaneeth et al., 2019) [2]. Indeed, recycling aluminium reduces energy consumption by approximately 95% compared with extraction from ore (Blomberg and Solderholm, 2009) [3]. Aluminium alloys are suitable for diverse applications in view of their unique properties prominent among which is corrosion resistance, high reflectivity, adequate strength, low density, nontoxic and comparatively low cost (Dilmec, *et al.*, 2013) [4]; (Gurubell, 2010) [5]; (Daramola *et al*., 2015) [6].

To further enhance the usefulness of this material, the present research aims to determine the effects of manganese (iv) oxide (MnO_2) and other input variables on selected mechanical properties of aluminium alloy, namely hardness, tensile strength, and impact strength. The composition arising from varying quantities of the MnO_2 additive, pouring temperature, and cooling medium after solidification of the molten metal, and further cooling of the cast ingots in various cooling media are then investigated. Minitab 2020 software, via a partial factorial Taguchi design, was used for the experimental design.

In casting processes, the quality of a casting is premised on various process parameters, ranging from pouring temperature and cooling medium to the type and quantity of additives. The mechanical properties of a material are paramount in the design of machine components, as they constitute the most important characteristics when the material is subjected to service applications (Olaiya *et al*., 2019) [7]. The mechanical properties of any material depict its response when loaded. Such properties may or may not depend on the microstructure of the material, but rather on the other properties that make up its composition. When materials are selected for engineering applications, consideration of their properties is of utmost importance. For this reason, aluminium is usually alloyed with one or more elements to alter or improve some of its properties (Adeoti *et al.,* 2015) [8]. Subramaniam *et al.,* (2018) [9] reported gradual increase in hardness when Aluminium 7075 was reinforced with particles of Boron carbide (B_4C) and particles of coconut shell fly ash by star casting. Decrease in composite elongation was however observed. Aluminium alloys are being adopted for a wide range of products, including aircraft parts, automobile components, and shipbuilding applications, where super plasticity is required on account of their high strength-to-weight ratio compared with other metals (Li *et al.,* 2023) [10]. (Nabhan *et al.,* 2025) [11] investigated the mechanical and corrosion behaviour of SiC reinforced aluminium. Tremendous improvement in toughness and fracture resistance was observed while tensile strength, hardness and durability of the composite were the trend of decline. Several studies have employed additive manufacturing (AM) to fabricate and improve the properties of aluminium parts (Zhang *et al.,* 2020) [12]. In a study, it was reported that an aluminium alloy specimen quenched in shea nut oil at 530 °C gave the highest impact strength, while the least impact strength was recorded for the water-quenched specimen at 400 °C; microstructural analysis showed that the water-quenched specimen at 530°C possessed a finer microstructure and maximum heat extraction property compared with that quenched in shea nut oil. That study consequently demonstrated that quenching Aluminium 6061 alloy in various quenching media after heating enhances its mechanical properties. (Abubakr *et al.,* 2009) [13]. In studies of age hardening and annealing heat treatment on the mechanical properties and microstructural analysis of Al 7075 alloy—properties including tensile strength, impact strength, and hardness—annealed specimens showed an increase in impact strength (Daljeet *et al*., 2012) [14].Considerable attention is currently focused on metal matrices reinforced with high-modulus ceramic reinforcement because of their superior properties compared with most conventional materials (Wodarczyk-Fligier *et al.*, 2007 [15].; Dobrzaski *et al*., 2006 [16].; Torres *et al*., 2002) [17]. In designing cast automotive parts, it is important to have intimate knowledge of how the alloy solidifies at different cross sections of the cast part and how this influences its mechanical properties, as this knowledge enables the designer to ensure that the casting achieves the desired properties for its intended application (Li *et al.,* 2004) [18].; (Shabestari 2004) [19]. (Alaneme *et al*. 2013) [20]. studied the mechanical and corrosion properties of a hybrid aluminium composite reinforced with SiC obtained from bamboo, finding that tensile strength, hardness, and durability of the composite decreased with increasing weight fraction of bamboo leaf powder, whereas significant improvement was recorded in toughness and fracture resistance. The corrosion resistance of the hybrid composite also improved significantly in a basic medium compared with an acidic medium. Several studies of cast aluminium alloys have established that high-purity hypoeutectic alloys exhibit three main solidification reactions during solidification, beginning with the formation of aluminium dendrites (liquidus), followed by the development of two main eutectic phases (Mackay *et al*., 2000 [21]; Ciceres *et al.,* 1999 [22].; Boileau *et al.,* 1997) [23]. Treatment of moulding sand with additive during casting enhances hardness in aluminium alloy. Starch powder additive shows a more significant effect on hardness of aluminium alloy in comparison with other additives (Ademilua *et al.,* 2013) [24]. Substantial information is available that the quality of every cast component can be achieved through grain refinement, which entails increasing the rate of heat extraction (rapid cooling), adding grain-refining agents (chemical grain refinement), and vibrating the melt (Deshpande, 2006) [25]. A high rate of solidification occurs when the heat extraction rate exceeds the latent heat of solidification, resulting in refined grains and enhancement of the material's strength and other mechanical properties (Dobrzanski *et al.,* 2006) [25]; (Muwei, 2021) [26], In an investigation, it was revealed that improvement of work-hardening characteristics of aluminium, corrosion resistance, weldability and extreme high strength is provided by Magnesium. Combination of silicon with magnesium results in formation of hardening phase Mg2Si which results in Aluminium strengthening. Muwei (2021) [27]. (Davis *et al.,* 1999) [28], (Krishna *et al*., 2013) [29]. Durowoju and Babatunde (2014) [30] researched the effect of MnO_2 on the features and formation of pores in recycled Al-332 alloy, revealing that with the addition of a small quantity of MnO_2, shrinkage pores were eliminated and gaseous pores were reduced in shape and size; it was also found that the smaller the percentage of pores, the higher the tensile strength. Aluminium recycling offers significant environmental

and economic benefits. With a mind-set of cost and energy savings, many producers now target the use of recycled materials (Durowoju and Babatunde, 2014) [30] in other to manufacture of premium-quality castings for structurally safe machine components such as automotive parts, there's need to minimize or eliminate porosity and inclusions to negate their harmful influence on mechanical properties (Davidson and Regener, 2000) [31]. Particulate-reinforced metal matrix composites (PMMCs) are currently used as structural components in aerospace, automotive, and industrial applications (Ademilua *et al*., 2013) [24].; (Prasad and Ramachandra, 2013) [32].; (Vanan and Paul, 2014) [33]. PMMCs combine the ductility and toughness of the metal matrix with the high strength and stiffness of the ceramic reinforcement (SiC, Al_2O_3) to achieve better properties (Vanan and Paul, 2014) [33]. Daramola *et al*. (2015) [6] investigated the mechanical and corrosion properties of Al 6063 alloy with a coconut shell composite, finding that hardness and tensile strength increased proportionately with the percentage weight of coconut shell, with a corresponding decrease in corrosion resistance. A similar finding was made by Agunsoye *et al.,* 2014) [34]. who revealed that the mechanical and wear properties of recycled waste aluminium can be enhanced by reinforcement with coconut shell.

However, from the literatures reviewed so far, the role of casting parameters, suitable and quantities of additives suitable for enhancing the mechanical properties are not available. Consequent upon this identified gap, this study becomes necessary. From the findings of (Olaiya *et al.,* 2024) where black powder from discarded battery (containing 23.25% MnO_2) was used as an additive, it was established that MnO_2 (the predominant constituent of the black powder) additive has the capability of improving the mechanical properties of Aluminium alloys but the effects of other casting parameters – pouring temperature, actual quantity of MnO_2 and cooling medium was not available. Hence the need for a broader investigation to uncover the important effects and the listed investigated variables. This research is a follow-up to (Olaiya *et al.,* 2024) [7]. Consequently, the ongoing study shall examine the effects of the various quantities of manganese iv oxide, MnO_2, pouring temperature, and cooling medium on each of the responses – hardness, tensile strength and impact strength. The availability of such information will be useful to metallurgical industries in producing aluminium alloys of desired mechanical properties for various engineering applications.

2. MATERIALS AND METHOD

The materials used in this research work and the methodology adopted for the analysis of the findings are enumerated as follows:

2.1 Materials

The materials used in this research are:

Discarded Aluminum cans: The composition of which was achieved using Atomic Absorption Spectrometer (AAS) and is as shown on Table 1.

Black powder chemical containing 53.14% of Manganese iv oxide, MnO_2. The composition that was achieved with the use of X-ray fluorescence (XRF) machine is shown in Table 2.

Table 1: **Composition of Aluminum alloy ingot**

Elemental constituent	Al	Si	Fe	Cu	Mn	Mg	Zn	P	Ni
Composition (wt %)	94.022	0.825	0.332	1.055	0.770	0.005	2.014	0.021	0.053
Elemental constituent	Ti	S	Cr	Sn	Mo				
Composition (wt %)	0.912	0.016	0.825	0.002	0.006				

Table 2: Composition of MnO_2 Additive.

Constituent	MgO	Al_2O_3	SiO	P_2O_5	SO_3	TiO_2	Fe_2O_3	ZnO	Ta_2O_5	MnO
Composition (wt %)	0.780	0.360	2.372	0.020	N.D.	0.180	14.180	0.009	0.060	53.140
Constituent	PbO	ThO_2	L.O. I.							
Composition (wt %)	5.400	N.D.	25.900							

ND indicates "Not Detected".

L.O.I. indicates "Loss on ignition".

2.2 Methods

The methodology for the conduct of the design of experiment in this work was Taguchi with the use of 3 levels and 3 factors as distributed in Table 3.

2.2.1 Design of experiment

In this study, design of experiment via Taguchi partial factorial has been used. The factors taken into consideration are quantity of additive (MnO_2), pouring temperature and cooling medium. The input factors (variables) and their levels are presented in Table 3.

Table 3: Factors and their level

Factors	Unit	Level 1	Level 2	Level 3
Qty of additive (MnO_2)	grams	40	120	240
Pouring temp	^oC	600	630	650
Cooling medium	-	Water	Air	Sand

Using partial factorial Taguchi experimental design, experimental layout of L9 orthogonal arrays was generated using Minitab 2020 statistical software and presented in Table 4.

Table 4: Experimental layout of L9 (3^2) orthogonal arrays.

Experimental runs	Qty. of MnO_2 (grams)	Pouring temp (^oC)	Cooling medium
1	40	600	Water
2.	40	630	Air
3.	40	650	Sand
4.	120	600	Air
5.	120	630	Sand
6.	120	650	Water
7.	240	600	Sand
8.	240	630	Water
9.	240	650	Air

2.2.2 Experimental Procedure

60 Kg of aluminum cans collected were properly cleaned, melted, de-slag and cast into ingots. Casting operations were carried out using a crucible furnace for melting with suitable metal moulds for casting in the foundry shop. The foundry activities are shown in plates I and II



Plate I: Crucible Furnace



Plate II: Pouring and Casting activities



Plate III: Cast Ingots

5kg from the initial 60 Kg of the cast aluminum ingots was then re-melted and cast into cylindrical rods without treating the molten metal with any additives. This was used as a control sample, labelled as A. The

cast cylindrical rods are shown in plate IV. The same procedure was repeated to obtain cast cylindrical rods from cast ingots B1 to B9.



Plate IV: Cast cylindrical rods

Table 5: Control sample

Sample	Composition	Cooling medium
A	5kg of Aluminum alloy scraps only poured at 630^0C	Air

The second step involves re-melting of 5kg each only (with additive) from the 60 Kg previously cast aluminum ingots. The cast cylindrical rods from which test pieces were produced for the three mechanical properties investigated are shown in plate II.
The new cast material for this study is now the material achieved after re-melting and treatment of the aluminium ingot with the Chemical powder containing 53.14% MnO_2. The composition of the experimental materials and casting variables for the control sample A and B-series samples are shown in Table 6.

Table 6: Details of Experimental Materials and Casting variables

Symbol	**Composition**	**Pouring temperature**	**Cooling medium**
A (Control sample)	5kg of Aluminium alloy only	600^0C	Air
B1	5kg of Aluminium alloy with 24g (0.0048%) of MnO_2	600^0C	Water
B2	5kg of Aluminium alloy with 24g (0.0048%) of MnO_2	630^0C	Air
B3	5kg of Aluminium alloy with 24g (0.0048%) of MnO_2	650^0C	Sand
B4	5kg of Aluminium alloy with 72g (0.0144%) of MnO_2	600^0C	Air
B5	5kg of Aluminium alloy with 72g (0.0144%) of MnO_2	630^0C	Sand
B6	5kg of Aluminium alloy with 72 g (0.0144%) of MnO_2	650^0C	Water
B7	5kg of Aluminium alloy with 144g (0.01288%) of MnO_2	600^0C	Sand
B8	5kg of Aluminium alloy with 144g (0.0288%) of MnO_2	630^0C	Water
B9	5kg of Aluminium alloy with 144g (0.0288%) of MnO_2	650^0C	Air

Details of cooling
After solidification, different samples of the cast metal were cooled to ambient temperature in three different media which include water, air and sand.

2.2.3 XRD

Sample castings A1and B1 to B9 were subjected to X-ray Diffraction (XRD) analysis via The Rigaku Miniflex XRD, manufactured by Japanese X-ray scientific, analytical and industrial instrumentation manufacturers.

2.2.4 Testing of mechanical properties

Following the procedure of ASTM E8M-91 standards (1992), test pieces were produced for hardness, tensile and impact tests as shown in figures 1, 2 and 3 respectively. The dimensions of specimens are shown. Plates V, VI and VII show the machined samples of the test pieces as prepared for Hardness, tensile and impact strength tests. Experiments were then conducted on all the samples.

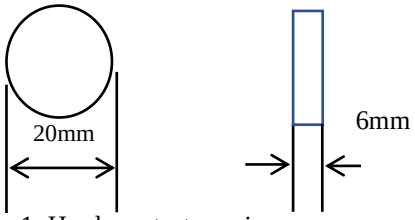


Figure 1: Hardness test specimen

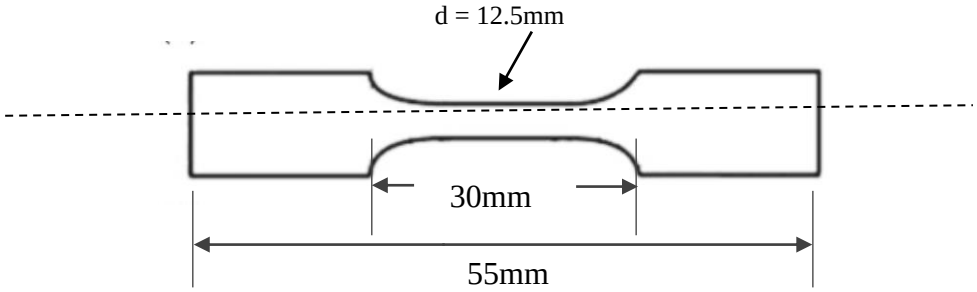


Figure 2: Tensile test specimen

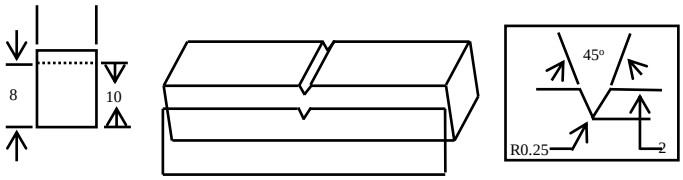


Figure 3: Impact test specimen



Plate V: Machined sample for hardness test



Plate VI: Machined sample for tensile test



Plate VII: Machined sample for Impact test

3. RESULTS AND DISCUSSION

The results obtained after the conduct of the experiments and the analysis are shown in as presented below.

3.1 Experimental Results
3.1.1 Mechanical properties

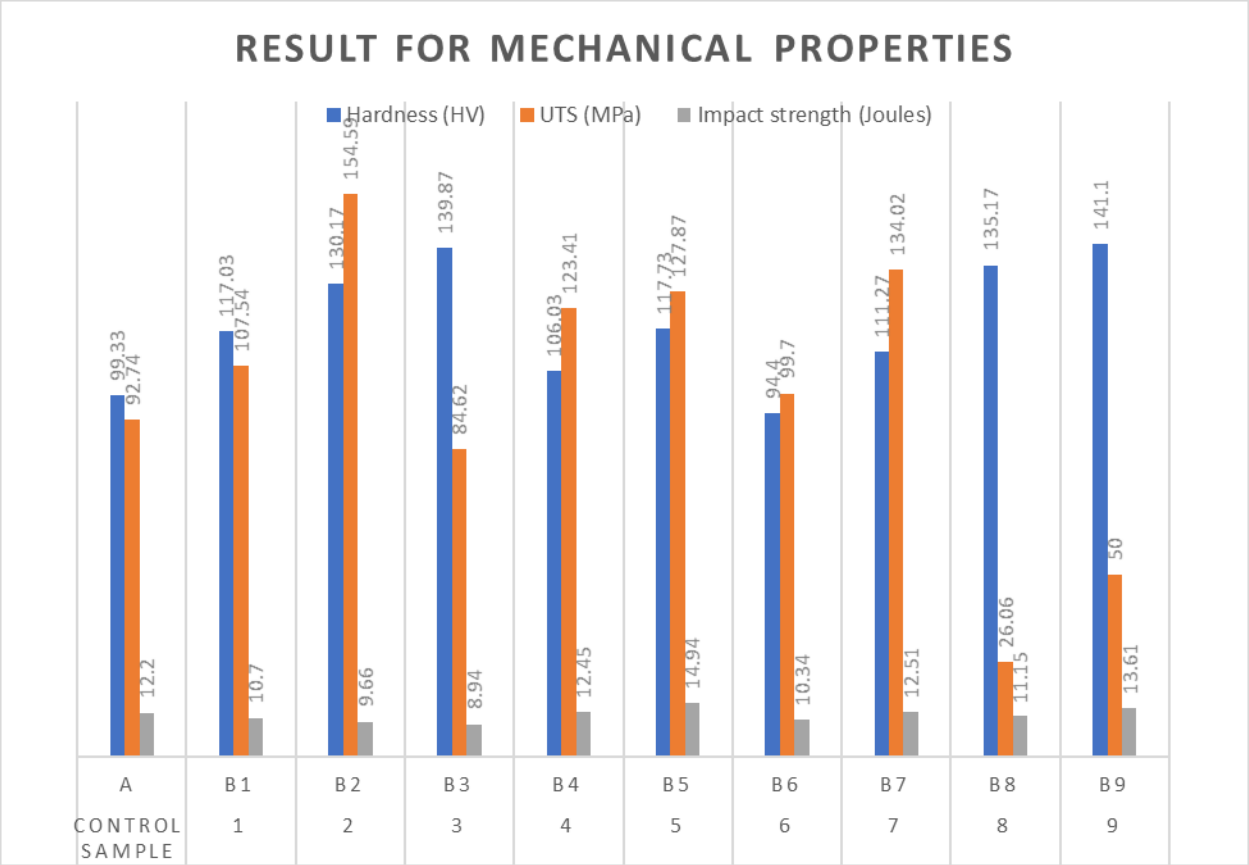


Figure 4: Results of Mechanical Properties

3.1.1 XRD micrographs

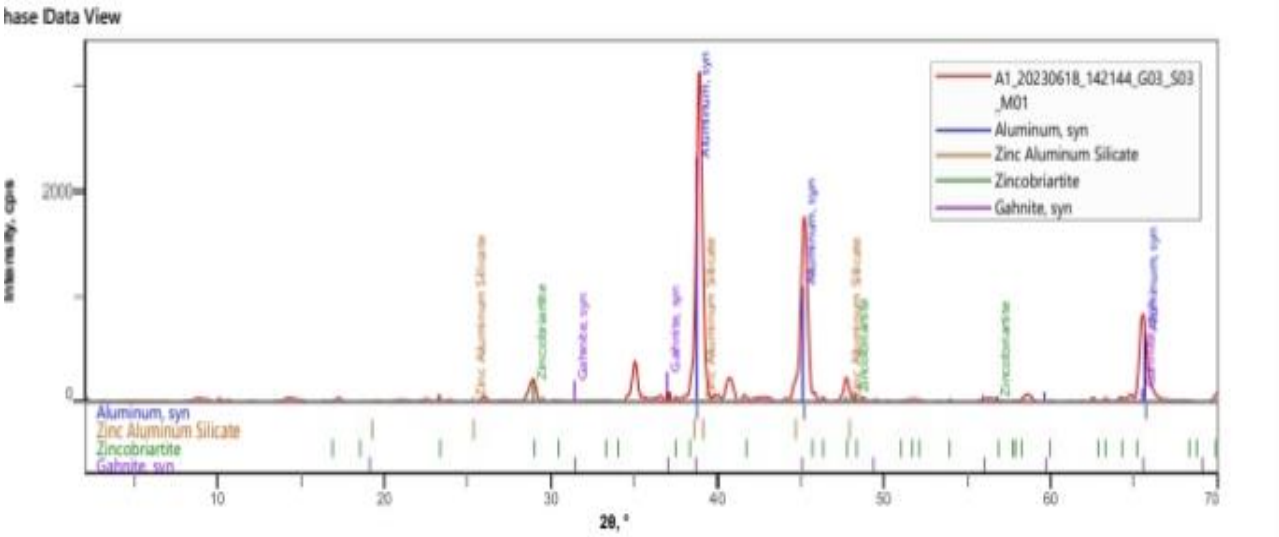


Figure 5: XRD graph of control sample A1.

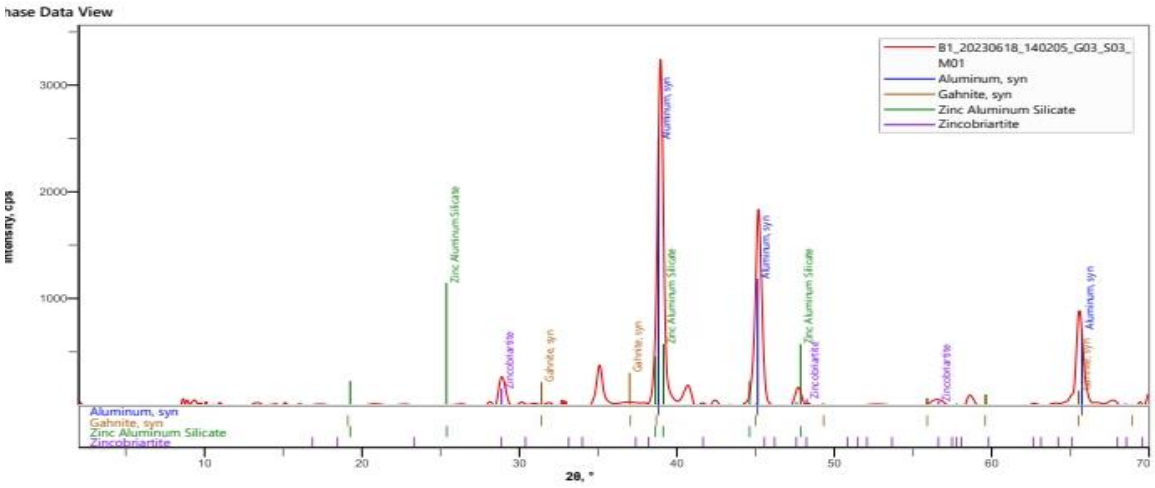


Figure 6: XRD graph of sample B1

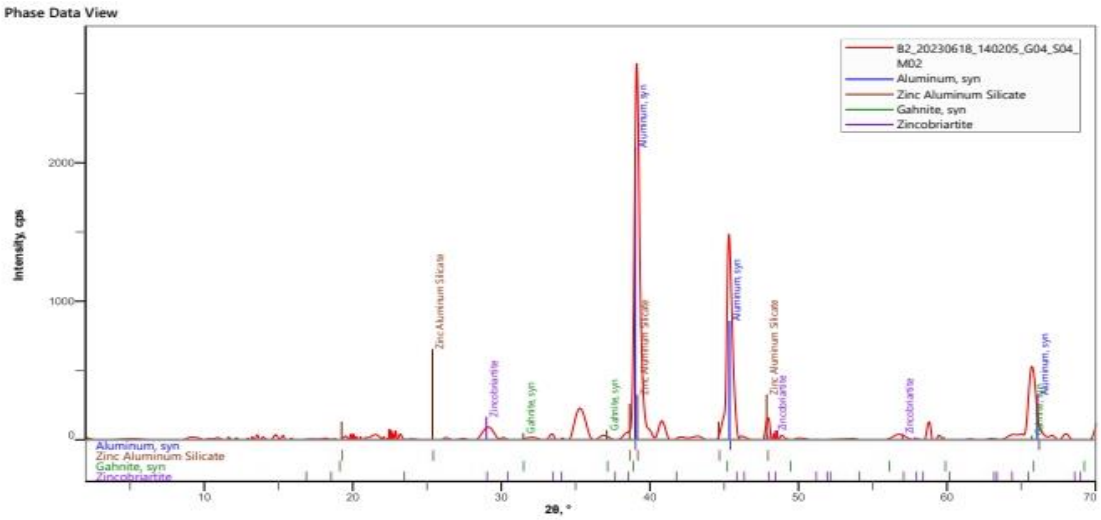


Figure 7: XRD graph of sample B2

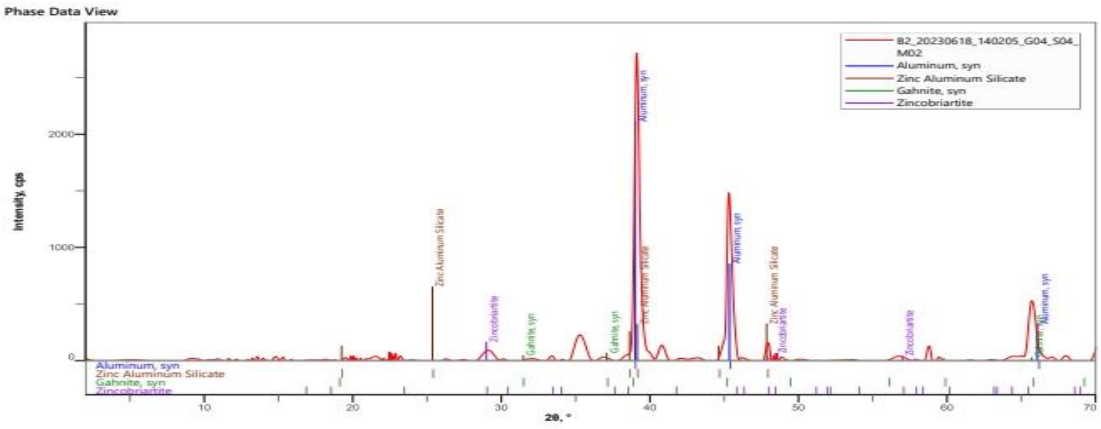


Figure 8: XRD graph of sample B3

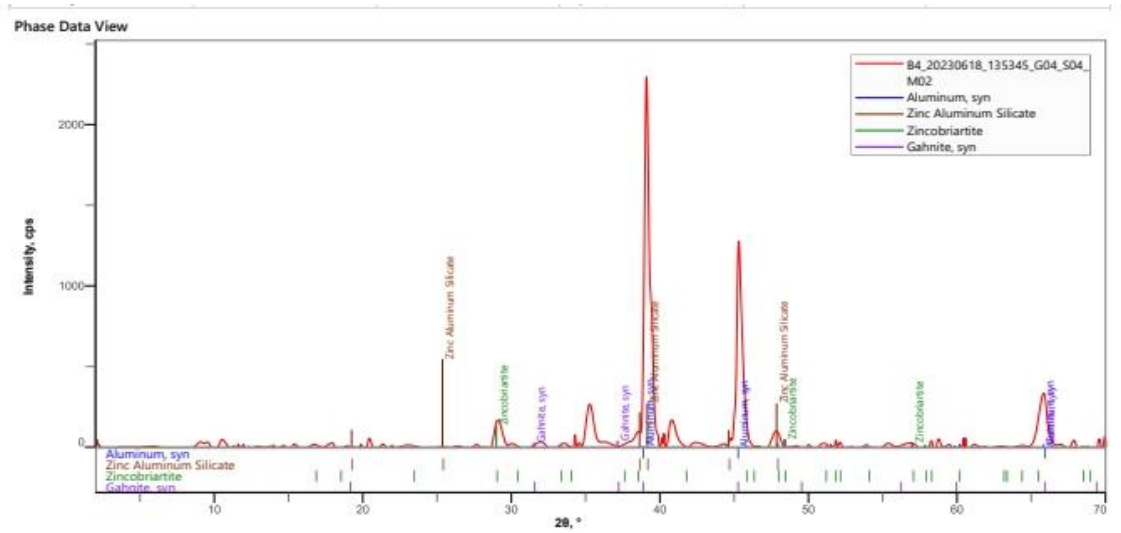


Figure 9: XRD graph of sample B4

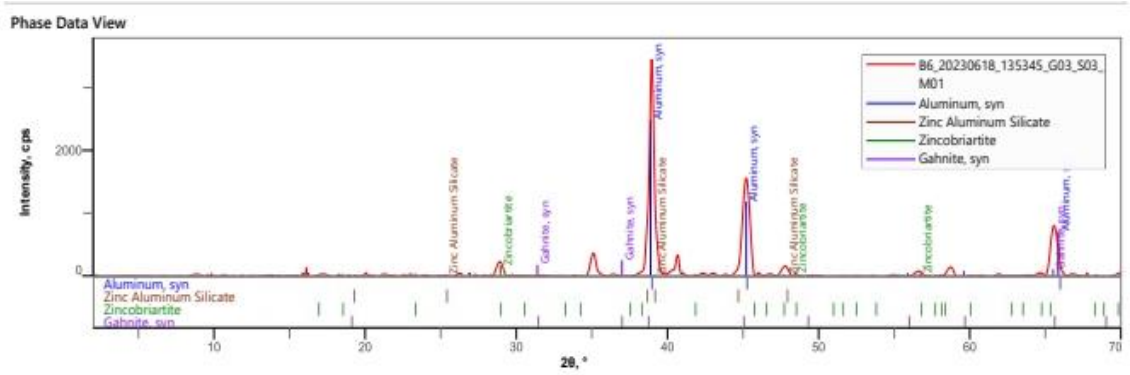


Figure 10: XRD graph of sample B5

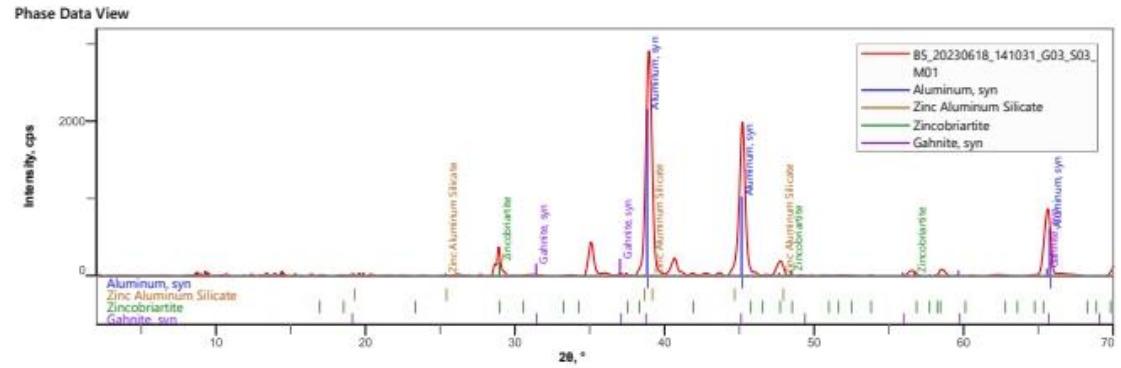


Figure 11: XRD graph of sample B6

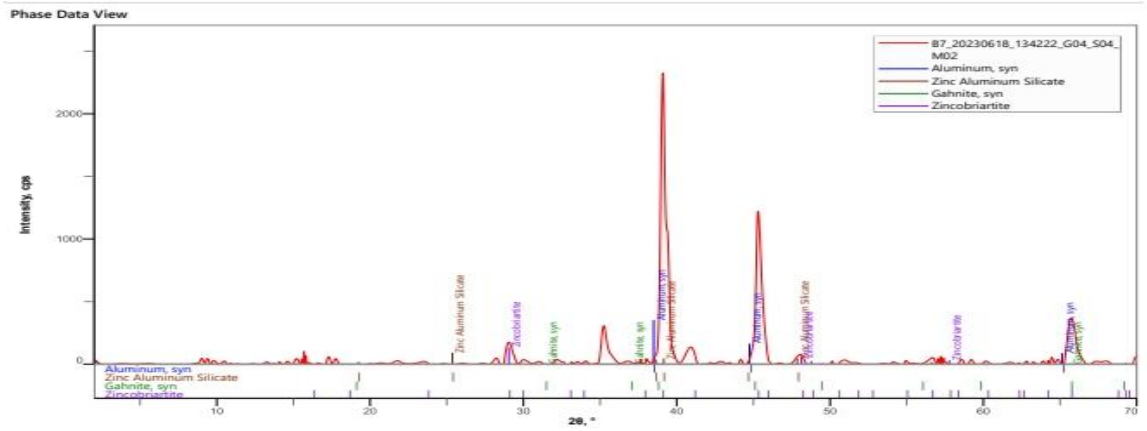


Figure 12: XRD graph of sample B7

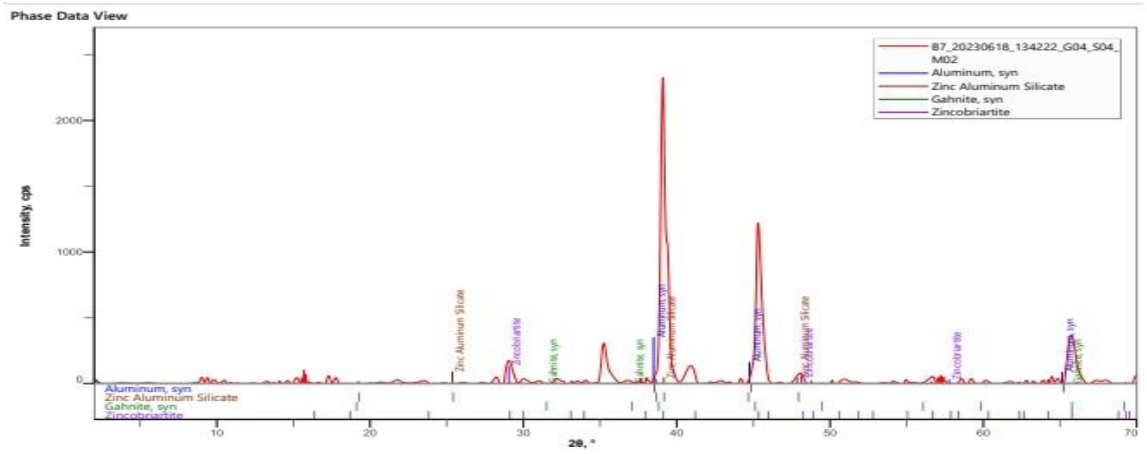


Figure 13: XRD graph of sample B8

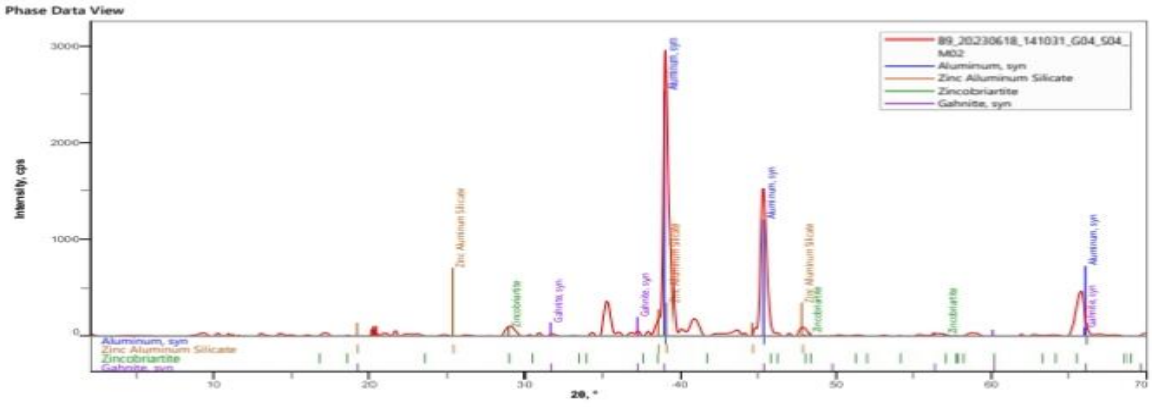


Figure 14: XRD graph of sample B9

3.2 Analysis of Experimental Results

3.2.1 Mechanical properties

The results in Figure 4 with refences to Table 6, show variations in the responses as the quantity of MnO_2, pouring temperature and cooling medium changes. Highest hardness value of 141.1 HV was obtained for sample B9 while sample B6 yields the lowest value of 94.40 HV. Sample B2 gives the highest UTS value of 154.59 MPa while the lowest value of 26.06 MPa was obtained for sample B8. Sample B5 gives the highest impact strength of 14.94Jouls while the least value of 8.94 Joules was obtained for sample B3. The results obtained for the investigated mechanical properties are shown in Figure 4 and presented in Table 7. The highest values obtained for each response are asterisked in Table 7.

Table 7: Results of tested Mechanical properties.

Sample	Hardness (HV)	Tensile Strength (MPa)	Impact Strength (Jouls)
A (Control)	99.33	92.74	10.7
B1	117.03	107.5	10.7
sB2	130.17	154.59*	9.66
B3	139.87	84.62	8.94
B4	106.03	123.41	12.45
B5	117.73	127.87	14.94*
B6	94.74	99.7	10.34
B7	111.27	134.02	12.51
B8	135.17	26.06	11.15
B9	141.1*	50.00	13.61

3.2.2 XRD analysis

It can be seen from the XRD diffractograms (Figure 5) of the unreinforced A that the major diffraction peaks occurred at diffracting angles (2θ) of 38.9^0 and 45.13^0 with inter-planar distances of 2.31 Å and 2.01 Å and relative X-Ray diffracting intensities of 2199 and 1343. As a result of chemical reactions formed between aluminum and other major elements in the recycled Al cans during melting and solidification, the intermetallic bond formed around Al.

In the XRD of the composites produced (Figures 6 to 11), reactions leading to the formation of intermetallic compounds like Aluminum, Zinc Aluminum Silicate, Ghanite, Zincobriatite are seen consistently forming bonds with the Al matrix. These intermetallic compounds enhanced the mechanical properties of the composites as revealed in the mechanical test results when compared with the control sample. However, for the nine composite samples, there is a shift in the diffracting angles due to reactions of reinforcements with the Al alloy matrix as well as the varying process variables used. As a result, major and common diffraction peaks occurred at diffracting angles (2θ) of about 28.9^0, 35.1^0, 39.0^0, 45.2^0, 47.6^0 and 65.7^0 with inter-planar distances of about 3.08 Å, 2.55 Å, 2.31 Å, 2.00 Å, 1.91 Å and 1.42 Å respectively. The intensities of the intermetallic compounds formed at each of the diffracting angles increases as weight fraction of MnO_2 increases.

3.2.3 Analysis of variance ANOVA

Analysis of variance (ANOVA) is a statistical tool used in detecting differences between experimental group means (Sawyer, 2017) [35]. ANOVA was performed as presented in Tables 8 to 10 for various responses at confidence level of 95%. From Table 9, It can be observed that quantity of MnO_4 has the highest effect of 55.44% on hardness value, pouring temperature has 26.16% effect while cooling rate has the lowest effect of 12.77%. From Table 8, quantity of MnO_4has the highest effect of 39.98% on UTS, pouring temperature has 29.62% effect and cooling rate has the least effect of 26.68%. As shown on Table 9, quantity of MnO_4 has the highest effect of 59.58% on Impact Strength, pouring temperature has the least effect of 29.62% while cooling rate has effect of 21.19%.

Table 8: ANOVA Table for Hardness

Factor	DOF	SS	MS	F	P
Qty of MnO_2 (grams)	2	1162	581.000	10.700	55.438
Pouring temp(^{0}C)	2	557.7	278.850	5.135	26.608
Cooling medium	2	267.7	133.850	2.465	12.772
Error	2	108.6	54.300		5.181
Total	8	2096	262.000		100.000

Table 9: ANOVA Table for UTS

Factor	DOF	SS	MS	F	P
MnO_2 (grams)	2	5483	2741.500	10.709	39.975
Pouring temp (^{0}C)	2	4062	2031.000	7.934	29.615
Cooling medium	2	3659	1829.500	7.146	26.677
Error	2	512	256.000		3.733
Total	8	13716	1714.500		100.000

Table 10: ANOVA Table for Impact Strength

Factor	DOF	SS	MS	F	P
Qty of MnO_2 (grams)	2	17.68	8.990	17.222	59.576
Pouring temp(^{0}C)	2	4.762	2.381	4.561	15.779
Cooling medium	2	6.394	3.197	6.125	21.186
Error	2	1.044	0.522		3.459
Total	8	30.18	3.773		100.000

3.2.4 Main effects plot

The essence of the main effects plots in this study is to determine the optimum value for each of the input variables in the casting process to achieve various optimum responses which include hardness, tensile strength and impact strength. Figures 15 to17 show the main effects plots of signal to noise (S/N) ratio used in determining the optimal value for each of the input variables in casting process taking cognizance of profound variables.

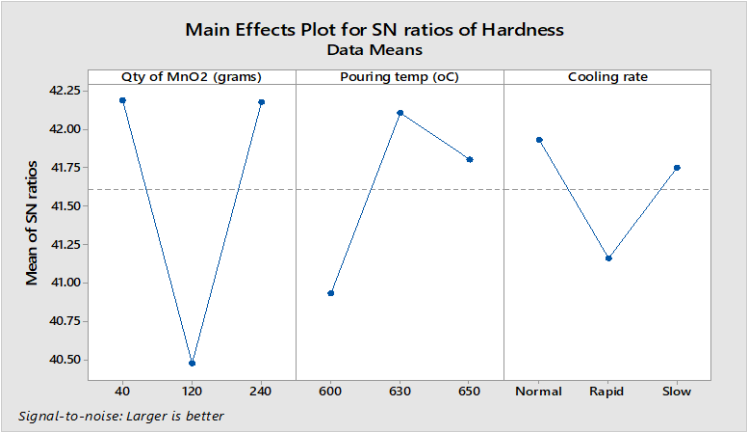


Figure 15: Main Effects Plots for S/N ratio of hardness

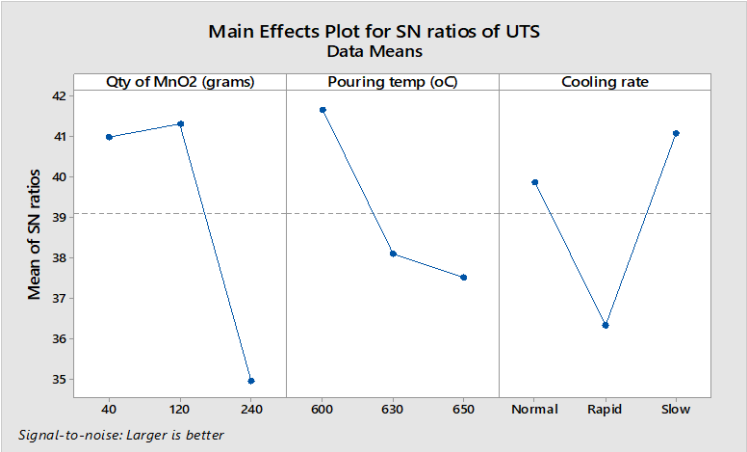


Figure 16: Main Effects Plots for S/N ratio of UTS

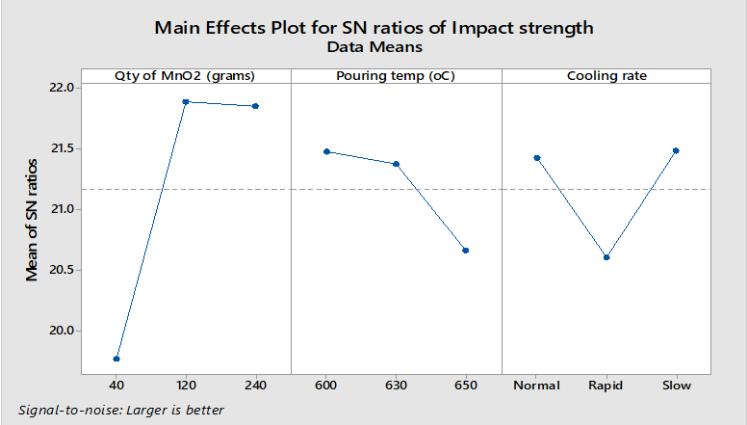


Figure 17: Main Effects Plots for S/N ratio of Impact Strength

3.2.5 Contour plots

With 3 interacting variables and 3 conflicting responses, contour plots enable us to determine the interacting effects between pouring temperature and quantity of additive at different cooling media for each of the responses. It shows the non-linear optimum region for each response (hardness, tensile strength and impact strength) and make it possible for us to perform multi-objective optimization using overlaid contours to find a compromise condition that satisfies all the investigated mechanical properties simultaneously. The contour plots generated are as presented in Figures 18 to 23.

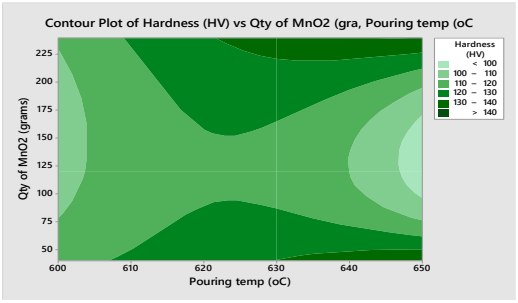


Figure 18: Contour Plot of **Hardness** vs Qty of MnO_2, Pouring temperature.

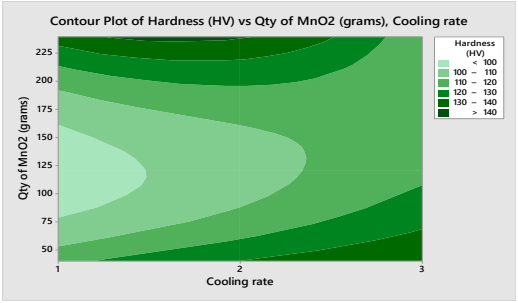


Figure 19: Contour Plot of **Hardness** vs Qty of MnO_2, Cooling medium.

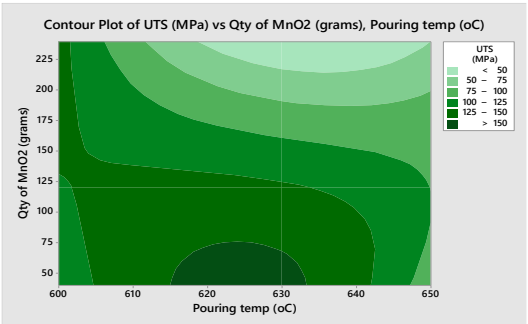


Figure 20: Contour Plot of **UTS** vs Qty of MnO_2, Pouring temperature.

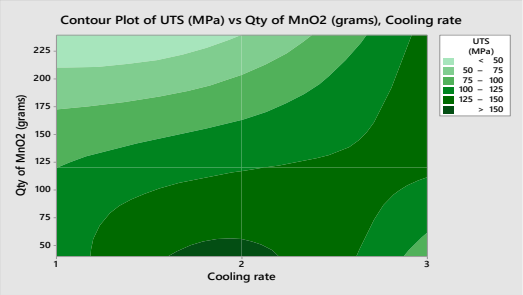


Figure 21: Contour Plot of **UTS** vs Qty of MnO_2, Cooling medium.

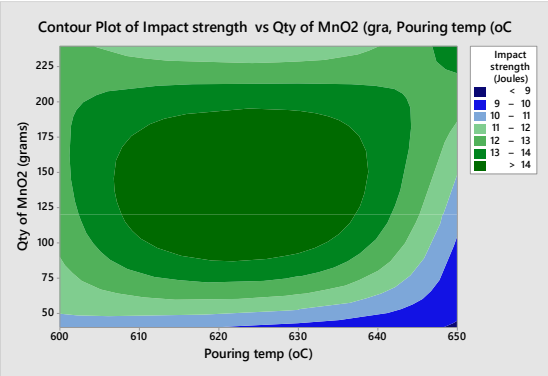


Figure 22: Contour Plot of **Impact strength** vs Qty of MnO_2, Pouring temperature.

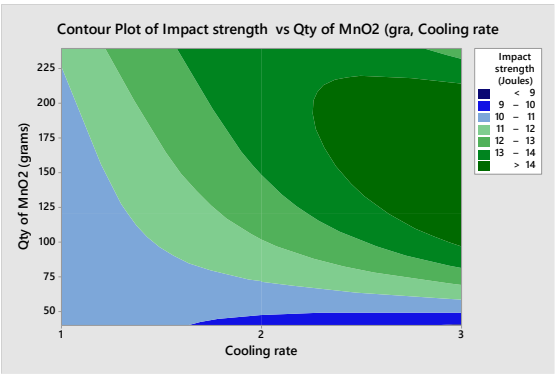


Figure 23: Contour Plot of **Impact strength** vs Qty of MnO_2, Cooling medium.

3.3.6 Regression equations

To predict the values of experimental responses – hardness, UTS and Impact strength, for various values of input parameters which include quantity of manganese oxide, pouring temperature and cooling medium, regression equations were generated as presented in equations 1 to 3.

Hardness (HV) = -5143-1.45QM+16.9PT+.002399QM*QM-.0134PT*PT+.00125QM*PT…… (1)

R-sq = 74.43% and R-sq (Adj) = 61.80%

UTS (MPa) = -4773+5.35QM+15.4PT-0.00205QM*QM-0.0122PT*PT-.00799QM*PT…… (2)

R-sq = 64.04% and R-sq (Adj) = 54.10%

IS (Joules) = -338-.106QM+1.16PT-0.000182QM*QM-0.00097PT*PT+0.000271QM*PT…… (3)

R-sq = 61.70% and R-sq (Adj) = 50.103%

4. CONCLUSION

Effects of reinforcement of Aluminium with varying quantities of MnO_2 and other casting parameters-pouring temperature and cooling medium on mechanical properties (hardness, UTS and Impact strength) of Aluminium alloy has been thoroughly investigated. It has been found that with MnO_2 reinforcement, the investigated mechanical properties – hardness, UTS and Impact Strength of Aluminium alloy improve significantly. This study corroborates the findings of (Durowoju and Babatunde, 2014) [30] and Olaiya *et al*., (2024) [7] on effects of MnO_2 on the mechanical properties of Aluminium alloy. The study also reveal the novelty idea of combining varying casting variables and % of MnO_2 reinforcement to achieve significant improvement in mechanical properties of Aluminium alloy for various engineering applications.

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