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Influence of process parameters on microhardness and porosity of Al 2024 microwave cast

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ABSTRACT

A new approach to metal casting has been developed that uses microwave radiation at 2.45 GHz to melt and heat the metal. At microwave powers of 600, 800, and 1000 W, AA2024 is employed as a charge material. Three susceptor materials WC and Silicon Carbide—are used in the process, and the solidification takes place in two stages, one in a closed cavity and the other in an open one. It was discovered that tightly cast samples 15 and 9 had smaller equiaxed grains and micro indentation hardness testing. Intermetallic phases of Al_2Mg_3 and $MgZn_2$ were detected in these cast samples, however, cast specimen 18 includes intermetallic stages of Al_2Mg_3, Magnesium Zinc, and Al_2Mg_3. This study discovered that the solidification atmosphere, microwave power, and susceptors affect grains and intermetallic precipitates. In this study, the micro indentation hardness (HV)of cast sample 18 is about 166 HV, larger than the other casts. The hardness, porosity, and XRD characterization of the generated casts is examined. Rapid solidification and increasing microwave power affect the composition, distribution and size of eutectic stages, leading to a rise in micro indentation hardness.

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1. Introduction

Casting aluminum alloy components for industrial and commercial usage is the most common and vital method of production [1,2]. This process allows for greater flexibility in terms of size, shape, and complexity of parts; nevertheless, regulating stages micro-segregation, casting defects, and grain size are certain difficulties that need to be addressed for improved cast characteristics [3–6]. Environmental degradation is caused by using conventional metal melting technologies, which emit many fumes, toxic gases, and smoke [7]. Conventional casting technologies have additional drawbacks, including high production costs, porosity, material loss, and safety concerns [8,9]. Non-conventional technologies such as microwave energy processing and innovative techniques for melting metal were developed to address these problems [10]. Processing metals in the microwave uses less energy and is more economical [11].

It's impossible to compare the heat generation in microwave processing to that of a traditional casting technique. To put it another way, in microwave-processed castings, core-to-surface heat generation and transfer occur, whereas in conventional castings, the opposite occurs [12,13]. 2005 microwave energy was first used for metal smelting applications at 2.45 GHz. For example, in microwave welding and microwave sintering, it has been reported that microwave radiation is utilized to melt metallic base and powder materials on-site [14,15]. The molecular heating possible with microwave energy decreases the typical temperature gradient when using conventional heating methods. Authors [16] found that the room-temperature mechanical qualities of AA 2024 are superior to those of other aluminum alloys, such as hardness, toughness, and strength. As a result, armor plates, military vehicles, railroad transport systems, road transporters, and other appli-

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cations are required. Micro-segregation of Magnesium/Zinc phases has also been postulated as a reason for the poor castability of Al-2024. It was explained [17 18] that during solidification, the growth of molten metal/alloy is dendritic in nature. The skeleton of the solid phase is formed during solidification when grains contact with each other.

According to authors [19,20], microwave-metallic material interaction produced treated components with a fine, nearly equiaxed grain structure. To put it another way, mechanical characteristics were improved compared to a traditional method. The mechanical properties of AA2024 alloy were studied by authors [21,22] by varying the process conditions. Using a vertical continuous casting method, the billets were cast at varied metal temperatures and at varying speeds. The greater the casting speed, the greater the billet's hardness and tensile strength and the lower its elongation value. According to researchers [23,24], the mechanical characteristics of AA2024 may be influenced by the casting mould. AA2024 cast casts had an important effect on hardness, tensile and impact strength of mould material. The naturally bonded sand mould is to responsible for the alloy's greater hardness (33.7HB) comparing to metallic and cement moulds. Mold materials, as well as their thermal and chemical qualities, influence surface finish. At high temperatures, it investigated the feasibility of melted and casting metallic powders using hybrid microwave heating.

Another application of microwave energy was the creation of Ni-based powder castings strengthened with silicon carbide (SiC). The resulting microstructure had a virtually equiaxed grain development because of the homogeneous distribution of reinforcement. In microwave-processed castings, a greater microhardness was achieved due to the production of hard phases and homogeneous dispersion of SiC particles. Microwave irradiation was used by researchers [25] to characterize the metallurgical and mechanical properties of AA 1050 in its raw and processed forms. 89.9 MPa with a 12.93% elongation was the average for cast aluminum, which has a dense and tiny grain structure. Microwave stir casting was used by authors [26] to produce Al-5% Silicon carbide MMC. XRD measurements showed that the cast metal matrix composite contained various phases of aluminum and SiC. Microstructural investigation revealed the presence of Silicon carbide near the grain limitations and a consistent grain structure. Authors [27,28] studied the charge heating, melting mechanisms, and the alloy's main heating stages during irradiation using time–temperature characteristics. Microwave heating creates an oxide layer that works as a microwave antenna. During the irradiation process, the graphite mold was preheated, which reduced the temperature difference between the liquid metal and the mold wall during solidification. An ambient microwave energy of 2.45 GHz and 1000 W cast the sample in-situ inside the microwave. The in-situ cast samples had a UTS of 148.46 MPa and a maximum micro indentation hardness of 132HV, with the grain boundaries having the highest mean micro indentation hardness. The yield strength was described to be at 80 MPa, while the grain size ranged from 29 to 80 μm, according to the author. The susceptor and mold influence exposure, melting time, mould heating, and cast qualities. Additional research was done by analyzing the physics of the procedure in terms of contact time and mold sand and characterizing the effect of preheating and mold material. The cast formed in an alumina mold with a SiC susceptor has a micro indentation hardness of 146HV and a tensile strength of 138 MPa.

Additionally, the microstructure and tensile characteristics of the AA2024 were studied in both in-situ and ex-situ microwave casts. This study found that an in-situ technique may achieve finer grains and denser casts. Because of the higher nucleation sites and faster cooling rates, the in-situ casts had smaller grain sizes on average than the ex-situ casts. It has been proposed by researchers [29] that sand mold compound casting be used to combine A356 alloy with magnesium. Microhardness in Al356/Mg is largely due to the presence of three phases:Mg_2Al_3, $Mg_{17}Al_{12}$ and $Mg_{17}Al_{12} + \delta.Mg_2Al_3$. At 650.30°C and 399.96 mm of Hg vacuum pressure, the greatest microhardness value (326.86 HV) was reached. Scientists [30,31] investigated the resistance to corrosion of AA2024 alloy castings by increasing the alloy's Ag and Fe content, respectively. At a lower Fe %age, increased Ag and Zn content increased hardness and strength. According to EDX, a variety of intermetallic phases rich in Silicon, Fe, Magnesium, and Ag that increase the resistance to wear and corrosion are formed. To solve the fundamental issue of conventional casting, microwave casting is the best option. This study also includes a section on porosity analysis. As compared to conventional casting procedures, in-situ microwave casting has a porosity of < 2%. Cast characteristics have therefore been enhanced, and exceptional micro-indentation hardness has been attained.

2. Experimentation

At 2.45 GHz, Samsung's MC35J8085PT multimode household microwave applicator was utilized to manufacture situ microwave casts of AA2024. Categorization of possible reasons is made possible, allowing the search for root causes to proceed. The temperature of charge is observed using an IR pyrometer with an integrated laser guide (limits 300–1850 °C, minimum count: 1C) during in-situ casting. Using a susceptor such as silicon carbide, wood, or stone charcoal in the microwave casting setup helps maintain the temperature in the cavern and reduce heat loss. The Susceptor allows for the precise heating of a specific area where bulk charge processing is to be carried out. Three microwave powers of 1000 W, 800 W, 600 W are utilized to cast the moulds. To remove the entire bulk of metal before casting, acetone is utilized. Mold and base are two components of the in-situ microwave casting apparatus, each of which is constructed from a different material. Table 1 shows the material's microwave absorption properties (ε and penetration/skin depth) when utilised for in-situ microwave casting. The depth to which a substance or skin can be penetrated by a microwave ($1/\varepsilon^{th}$) serves as a guide to the microwave's loss of surface energy. Electrical energy can be converted into heat by calculating its dielectric loss factor (ε). Microwave absorbers with higher dielectric loss factors and reflectors with small surface depths are preferable in terms of performance. Materials with microwave absorption characteristics can be used to fast heat the load and improve the performance of the mold components during in-situ component development. During microwave absorption, the temperature of the mold material can be adjusted by varying the input power in the application cavity. Mold-to-molten-metal temperature gradients during automatic casting can be decreased by this technique, which also reduces the thermal gradient's impact on the material's particle size. The mould assembly was put in the applicator cavity to produce the required aluminum alloy castings. Molds with good microwave absorption characteristics were made from graphite.

The thermal conduction of the provided susceptors utilized in this research is lower than stone charcoal (SC) and Wood (WC),

Table 1
Absorption of microwaves by various materials at room temperature.

Fundamentals	Materials	Penetration (mm)	Dielectric Loss Factor (Fm^{-1})
Base	Al_2O_3	12,568	0.008
Mold	Gr	0.22	11.4
Charge	Al	0.0018	Negligible

indicating that the conduction heating of Silicon Carbide(SiC) will be stronger throughout the radiation process. Temperature measurements are important to understand the microwave heating features of susceptor resources by irradiating them in an applicator's cavity. Fig. 1 depicts the temperature–time properties of Silicon Carbide, SC and wood charcoal.

In comparison to SC and WC, SiC heats up to 350 °C, 88% faster and 92% faster, respectively. When compared to SC, SiC's temperature is 83% higher in 200 s and 91% greater in 220 s. Since SiC has a substantially higher heating rate than CC, it is obvious that this is the case here. Therefore, it is logical to suppose that SiC transfers more heat to the charge material and heats it up faster than SC or WC during the in-situ microwave casting method. Microwave absorption begins as a result of conduction when the temperature of the base exceeds the critical temperature (Tc).

The commercially available aluminum alloy AA2024 was used as charging material throughout the experimentation and in-situ castings were made utilizing three different microwave powers: 600 W, 800 W, and 1000 W, respectively.

There was no external shielding gas during the experiments, which were conducted in a standard laboratory setting. 150 g of charge were used in the experiment. They are inserted in the graphite poured basin with dimensions of 10 mm by 4 mm, which has been preheated to AA 6063 alloy. Over high-refractive alumina bricks, the rotational glass table was placed in order to keep the complete heat generated in the hollow from being lost. A graphite sheet was then used to cover the mould setup, ensuring that no contaminants from the surrounding environment could enter the mould cavity. Heat transfer rates on charging in microwave radiation can be increased by using SiC, wood, and stone charcoal as susceptors for hybrid heating. The pouring basin and hollow heat up quickly because of their excellent microwave absorption properties. Because of this, it is initially heated to the critical temperature by conduction from the pouring basin to the mould cavity. The term "conventional heating" refers to this method of heating the charge material (CH). The critical temperature of charge material can be raised using susceptors. Sprues allow the self-pouring of charge materials into mould cavities, referred to as microwave hybrid heating (MHH). At this point, all irradiation has been halted. The mould cavity must be solidified at both the closed and open cavities. An equivalent amount of HNO_3+HCL+CH_3COOH solution is utilised for etching purposes, and the microstructure is entirely exposed. A graphite mould is used to piece together and fill with the metal that has been supplied. In order to protect the mold and provide a chamber for it, an insulating layer of hysil is used. Afterward, the entire contraption is placed in the microwave and

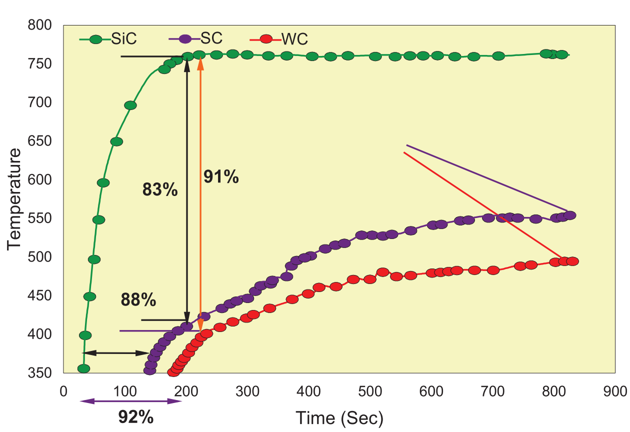

Fig. 1. Characteristic curves of SiC, SC and WC with respect to time and temperature.

let to melt down to nothing. SiC has a lot greater melting point than SC or WC when it comes to metals that have been received. SiC is a better melting material than SC and WC due to its longer melting time (approximately 800 s) and highest heat transmission rate to charge (810 s). Table 2 displays the chemical components of the AA2024 alloy as received.

2.1. Process parameters

The experimental procedure's initial inputs are the process parameters that may have an impact on the ultimate result. The experimentation is dependent on a number of process factors, and these parameters themselves are subject to change. The plot in Fig. 2 shows how the process conditions impact the in-situ microwave casting procedure.

A one-factor-at-a-time experimentation method is used to determine the range of several process parameters. Taguchi's L18 OA have been chosen to explore the impact of three elements on the micro indentation hardness of AA2024 castings created through microwave casting technique, namely the solidifying environment, microwave power outcome and susceptor material. Microwaves can easily be absorbed by a susceptor in a heat transfer process at room temperature, which transfers energy to the target material. Authors used SiC, stone, and wood charcoal as susceptors because of their high loss and ease of microwave absorption at room temperature. Listed in Table 3 are the process parameters and their values that have been selected for the experiment.

3. Methodology

3.1. Taguchi approach

The Taguchi methodology, which is applied in this work, improved the process constraints for in-situ microwave molding of the AA 2024.Quality engineers use the Taguchi method as a reference and a guide while creating new products and developing new processes. Engineers and managers who have studied Taguchi's concept better know the value of a product's design excellence.

Experiment with an Orthogonal Array A number of orthogonal arrays (OAs) of conventional dimensions have been proposed by Taguchi for use in industry. Taguchi offered two-, three-, and four-level OAs, depending on the amount of parameters of interest also their corresponding stages. Mixture arrays like L-18 have also been proposed for the experimentation of factors with varying levels. For each trial, a signal-to-noise ratio is calculated using Equation (1).

$$\mathbf{S/N} = -10 \times \log\left[\frac{1}{n}\sum\left(\frac{1}{y^2}\right)\right] \quad (1)$$

4. Results and discussion

Taguchi's L-18 OA was used for a randomized series of 18 tests. The micro-indentation hardness of three casts was assessed for each trial, as shown in Table 4. Minitab 18 calculates the SNR and raw data mean responses for each variable at all levels, shown in Tables 5 and 6, respectively. S/N graphs and the raw data indicate that the in-situ microwave casting process's best levels are the third microwave power, the third susceptor level, and the second solidification environment level (open cavity). These levels all result in the highest hardness values.

The solidification environment changes from a closed to an open cavity as microwave power increases, increasing the micro-

Table 2
Chemical arrangement of AA2024.

Elements	Silicon	Iron	Copper	Manganese	Magnesium	Zinc	Chromium	Aluminium
Wt%	0.5	0.5	4.4	0.6	1.5	0.25	0.1	Bal

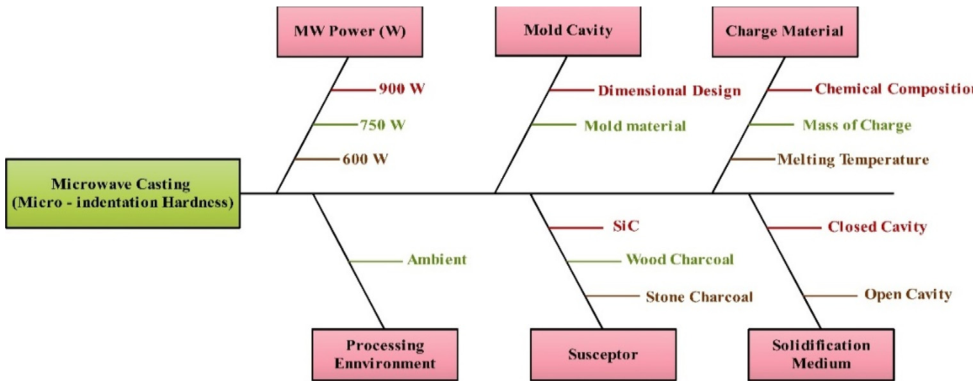

Fig. 2. Cause and effect diagram by Ishikawa.

Table 3
Processing factors and its Levels.

Factors	Levels	Assortment
Microwave power	1	600 W, 800 W, 1000 W
Solidification environment	2	Opencavity(OC) and closed cavity(CC)
Susceptor	3	SC, WC, SiC

indentation hardness in the process. Microwave power increases produce a rise in temperature because of an increase in heat generation within the cavity. The cast's grains recrystallize due to increased temperature and open solidifying. Increasing grain-to-grain bonding pressures lead to an increase in hardness. An increase in micro-indentation hardness up to 1000 W microwave power is accomplished by increasing cooling rates, which results in more refined grains and dispersion of intermetallic precipitates in grains and on grain borders. Controlling the casts' micro-indentation hardness is a function of the cooling process. According to our findings, quick cooling in an open cavity significantly improves the generated casts' micro-indentation hardness. The micro-indentation hardness increases when the susceptor material is changed from stone charcoal to SiC because of the change in the solidification environment. The susceptor material's thermal conductivity significantly influences microwave casting's hardness. Due to the greater conduction heating that occurs when SiC is irradiated, it has a higher thermal conductivity than stone and wood charcoal. The hardness of SiC is also increased by its ability to absorb microwave radiation.

Table 4
Experimental trials on hardness.

Experimental Run	A – Solidification Environment	B- Microwave Power (W)	C – Susceptor	Trial 1	Trial 2	Trial 3	Micro indentation Hardness Mean value	S/N ratio (db)
1	CC	600	Stone charcoal	120	119	119	119	41.5109
2	CC	600	Wood	122	127	128	125	42.8684
3	CC	600	SiC	131	129	127	12	43.1442
4	CC	800	Stone charcoal	116	123	121	120	41.5836
5	CC	800	Wood	128	127	126	127	43.0074
6	CC	800	SiC	125	137	128	130	43.2789
7	CC	1000	Stone charcoal	131	127	126	128	43.1442
8	CC	1000	Wood	124	132	134	130	43.2789
9	CC	1000	SiC	156	152	148	152	43.6369
10	OC	600	Stone charcoal	117	122	121	120	43.5836
11	OC	600	Wood	139	134	141	138	44.7976
12	OC	600	SiC	143	149	146	146	44.2871
13	OC	800	Stone charcoal	139	144	143	142	44.0458
14	OC	800	Wood	152	145	147	148	43.6371
15	OC	800	SiC	152	157	156	155	44.8066
16	OC	1000	Stone charcoal	139	145	136	140	43.9226
17	OC	1000	Wood	147	142	143	144	44.1672
18	OC	1000	SiC	170	165	163	166	45.4022
Average Mean								43.6595

Table 5
S/N Ratio response.

Levels	A	B	C
1	43.21	43.30	43.23
2	44.35	43.68	43.61
3	–	44.09	44.31
Delta	1.23	0.91	1.15
Rank	1	3	2

Table 6
Means response.

Levels	A	B	C
1	131.7	131.3	129.3
2	145.6	137.9	136.1
3	–	144.6	147.3
Delta	19.9	15.3	17.9
Rank	1	3	2

Table 7
Micro-Hardness ANOVA Results (S/N ratios).

Source	DoF	Adj SS	Adj MS	F-Value	P-Value	% Contribution
A	1	1132.3	1132.3	33.96	0.000	36.99%
B	2	614.5	302.8	8.88	0.005	18.21%
C	2	981.8	494.6	15.56	0.002	32.64
Error	12	409.0	35.0			12.156%
Total	17	3136.6				

To determine how process variables affect micro-indentation hardness, an ANOVA was used. Table 7 shows the ANOVA results for micro-indentation hardness in terms of SNR. The ANOVA is often completed at a 95% confidence level or a 5% significance level in most engineering contexts. A 5% significance threshold was also used for the current study's analysis. The micro-indentation hardness of AA2024 casts produced by in-situ microwave casting is significantly impacted by all three of the selected process parameters since the p-values for each of the three microwave casting process parameters were less than 0.05.

Acetone was used to clean and dry all specimens; some examples were engraved, and others were cleaned and hot-dried. A solution of the Keller's etchant was used to etch the specimens, which were left in the solution for 30 s. Kroll's reagent was employed for electropolishing, resulting in a high polishing level. To investigate the cast specimens' microstructures, an optical microscope was used.. At room temperature, XRD is utilised to research the stages in the cast formed. XRD used a scanning rate of 1 min^{-1} and a scanning range of 5–90 to accomplish the scanning. The Vickers micro indentation hardness testing machine was used to measure the in-situ casts' hardness at room temperature.

4.1. Elemental analysis

Listed in Table 8 is a list of all of the elements and phases that can be found in the in-situ castings generated at various rules and susceptors in the solidification environment.

4.2. XRD analysis

As can be seen in Fig. 3(a), the X-ray diffraction pattern for sample no. 18 from the microwave cast of AA2024 made with 1000 W microwave power, Silicon Carbide as a susceptor, and solidification in an open chamber can be shown. At 39.02C, 46.78C, 63.98C and 79.44C there are four notable intensity peaks 2θ. The 39.02C peak is the most prominent. Al-2Mg is the chemical with the corresponding 2-theta value. This was due to the fact that the experiment was conducted in a non-vacuum environment with open cavities.

As shown in Fig. 3(b) (sample number 15), this second microwave cast was formed using 800 W power, Silicon Carbide as a susceptor, and solidification finished in an open cavity with the required parametric values of AA2024. A two-θ analysis shows four notable peaks in the data: 30, 60, 61, 95, and 120. The 2-θ value that corresponds to α-Al is 45.72. As a result of small A and B taking place in an OC, there are no aluminum oxides or aluminum-magnesium compounds at this peak.

Shown illustrates solid Aluminum results, and $MgZn_2$ provokes in-situ castings. The $MgZn_2$ phase is one of the XRD peaks identifying the matching α-Al crystal plane. All three samples saw a shift in the peak's location toward the lower angular locations when stress was released from the grains. The in-situ casts' increased hardness is due to AA2024 Mg and Si compound content. Except two additional cast samples, It shows the biggest peak in peak intensity. The micro-indentation hardness of sample 18 was significantly higher than that of samples 15 and 9.

5. Conclusions

In-situ, microwave casting was utilized to measure the micro indentation hardness of AA2024 castings, and several process parameters were examined. Taguchi's approach is used to optimize the parameters of the microwave hybrid heating process. Experiment results include: The ideal process parameters for in-situ microwave casting of AA2024 produced a hardness of 166 HV using Silicon Carbide as a susceptor, microwave power (1000 W), and an open cavity solidifying environment. The following are the appropriate process parameters for achieving the best micro-hardness in AA2024 castings by adopting in-situ microwave casting: An open cavity, 1000 W microwave power, and solidifying in SiC as a susceptor material were discovered. Mold preheating minimizes the temperature difference between molten metal and mold wall, resulting in low porosity (2%). Regarding microstructural characteristics and micro indentation hardness, Silicon Carbide as a susceptor material solidifying in an open cavity surpasses SC or WC as susceptors solidifying in closed cavities when manufactured with 800 or 600 W microwave power.

CRediT authorship contribution statement

S. Mayakannan: . **M. Muthuraj:** . **Egzon Ademi:** Investigation, Methodology. **Selva Ganesh Kumar:** . **B. Bhanu Prasad:** . **S.K.H. Ahammad:** .

Data availability

No data was used for the research described in the article.

Table 8
In-situ microwave casts revealed the elemental compositions of distinct stages.

In - situ casts			Fundamentals (wt%)						Possible phase
A	B	C	Aluminium	Magnesium	Manganese	Zinc	Silicon	Copper	
OC	1000 W	SiC	91.34	6.73	2.23	1.77	–	1.45	Al_2Mg_3,, Al_2Mg, $MgZn_2$
OC	800 W	SiC	84.78	6.08	2.32	2.87	1.95	1.54	Al_2Mg_3, $MgZn_2$, Mg_2Si
CC	1000 W	SiC	76.85	4.12	2.13	2.36	1.67	1.38	Mg_2Si, $MgZn_2$, Al_2Mg

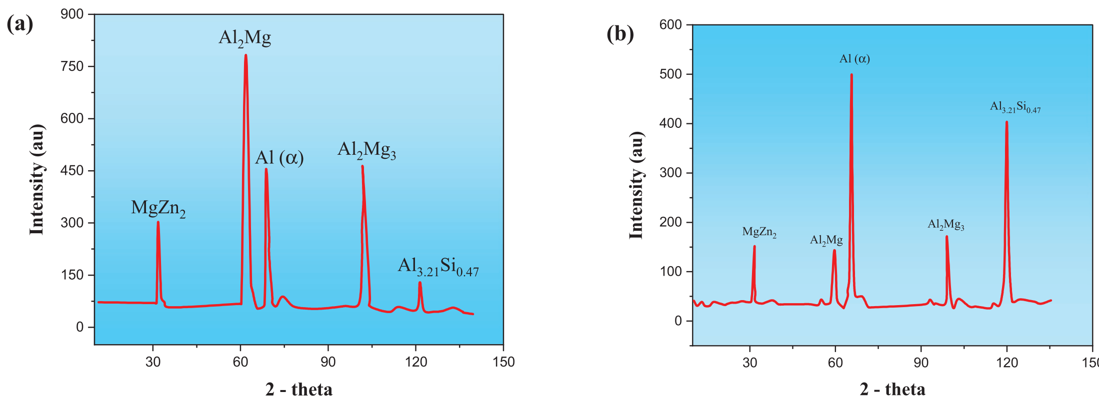

Fig. 3. XRD pattern of (a) sample 18, (b) sample 15.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] R.R. Mishra, A.K. Sharma, Structure-property correlation in Al–Zn–Mg alloy cast developed through in-situ microwave casting, Mater. Sci. Eng. A 688 (2017) 532–544, https://doi.org/10.1016/j.msea.2017.02.021.

[2] R.R. Mishra, A.K. Sharma, On mechanism of in-situ microwave casting of aluminium alloy 7039 and cast microstructure, Mater. Des. 112 (2016) 97–106, https://doi.org/10.1016/j.matdes.2016.09.041.

[3] X. Xi, B. Chen, C. Tan, X. Song, Z. Dong, Influence of micron and nano SiCp on microstructure evolution and mechanical properties of laser metal deposition AlSi10Mg alloy, J. Mater. Process. Technol. 306 (2022), https://doi.org/10.1016/j.jmatprotec.2022.117609.

[4] M.A. Taha, M.F. Zawrah, H.M. Abomostafa, Fabrication of Al/Al_2O_3/SiC/graphene hybrid nanocomposites from Al-dross by powder metallurgy: sinterability, mechanical and electrical properties, Ceram. Int. 48 (14) (2022) 20923–20932, https://doi.org/10.1016/j.ceramint.2022.04.084.

[5] P. Saini, P.K. Singh, Studies on microstructural characteristics and mechanical properties of hybrid Al-4032 AMC reinforced with SiC and granite marble powder, Proc. Inst. Mech. Eng. Part C J. Mech. Eng. Sci. 236 (11) (2022) 6192–6203, https://doi.org/10.1177/09544062211065342.

[6] V. Kumar, P. Kumari, Fabrication and characterization of Cu/SiC-based axially functionally graded beam, Adv. Eng. Mater. 24 (5) (2022), https://doi.org/10.1002/adem.202101239.

[7] L.U. Gezici, E. Özer, I. Sarpkaya, U. Çavdar, The effect of SiC content on microstructural and tribological properties of sintered B4C and SiC reinforced Al-Cu-Mg-Si matrix hybrid composites, Mater. Test. 64 (4) (2022) 502–512, https://doi.org/10.1515/mt-2021-2103.

[8] P. Saini, P.K. Singh, Fabrication and characterization of SiC-reinforced Al-4032 metal matrix composites, Eng. Res. Express 4 (1) (2022) pp, https://doi.org/10.1088/2631-8695/ac4831.

[9] S. Gupta, A.K. Sharma, Microstructure and microhardness of Mg/SiC metal matrix composites developed by microwave sintering, J. Inst. Eng. Ser. C 103 (1) (2022) 63–68, https://doi.org/10.1007/s40032-020-00636-w.

[10] J. Menghani, Y. Chaudhary, S. Pandya, Effect of reinforcement on microstructure and mechanical properties of aluminium hybrid composites, Mater. Today Proc. (2022), https://doi.org/10.1016/j.matpr.2022.04.986.

[11] V.A. Voronov, Y.E. Lebedeva, A.S. Chainikova, D.M. Tkalenko, A.A. Shavnev, Effect of silicon carbide whiskers on the physicomechanical properties of ZrB_2/SiC ceramic composite materials, Inorg. Mater. 58 (1) (2022) 104–110, https://doi.org/10.1134/S0020168522010137.

[12] A. Sharma, D.B. Karunakar, Comparative evaluation of microstructural and mechanical properties of microwave and spark plasma sintered ZrB_2-SiC-TiC composites, J. Mater. Eng. Perform. 31 (1) (2022) 576–589, https://doi.org/10.1007/s11665-021-06204-2.

[13] M.F. Zawrah, W.M. El-Meligy, H.H.A. Saudi, S. Ramadan, M.A. Taha, Mechanical and electrical properties of nano al-matrix composites reinforced with sic and prepared by powder metallurgy, Biointerface Res. Appl. Chem. 12 (2) (2022) 2068–2083, https://doi.org/10.33263/BRIAC122.20682083.

[14] A. Seshappa, B. Anjaneya Prasad, Characterization and investigation of mechanical properties of aluminium hybrid nano-composites: novel approach of utilizing silicon carbide and waste particles to reduce cost of material, Silicon 13 (12) (2021) 4355–4369, https://doi.org/10.1007/s12633-020-00748-z.

[15] G. Singh, N. Sharma, S. Goyal, R.C. Sharma, Comparative measurements of physical and mechanical properties of AA6082 based composites reinforced with B4C and SiC particulates produced via stir casting, Met. Mater. Int. 27 (11) (2021) 4333–4345, https://doi.org/10.1007/s12540-020-00666-0.

[16] S. Bhaskar, M. Kumar, A. Patnaik, Effect of Si_3N_4 ceramic particulates on mechanical, thermal, thermo-mechanical and sliding wear performance of AA2024 alloy composites, Silicon 14 (1) (2022) 239–262, https://doi.org/10.1007/s12633-020-00810-w.

[17] J. Pal, D. Gupta, T.P. Singh, Processing and characterization of SS316 based metal matrix composite casting through microwave hybrid heating, Proc. Inst. Mech. Eng. Part C J. Mech. Eng. Sci. (2022), https://doi.org/10.1177/09544062221104443.

[18] V. Gangwar, H. Singh, S. Kumar, Influence of process parameter on microstructure, residual stress, microhardness and porosity of AA-6063 microwave cast, Int. J. Met. 16 (2) (2022) 826–841, https://doi.org/10.1007/s40962-021-00638-z.

[19] R.R. Mishra, A.K. Sharma, Effect of susceptor and mold material on microstructure of in-situ microwave casts of Al-Zn-Mg alloy, Mater. Des. 131 (2017) 428–440, https://doi.org/10.1016/j.matdes.2017.06.038.

[20] S.Y. Ong, A. Walker, Using Kotter's 8 steps of change to tackle over-fasting of children attending day surgery, Paediatr. Anaesth. (2022), https://doi.org/10.1111/pan.14499.

[21] N.R. Gowda, N. Madaan, R.K. Singh, Bottlenecks and reflections from turnkey installation of MRI in a tertiary care Greenfield project: A case study, BMJ Lead. (2022), https://doi.org/10.1136/leader-2021-000563.

[22] Š. Markulik et al., Analysis of fault conditions in the production of prestressed concrete sleepers, Appl. Sci. 12 (2) (2022) pp, https://doi.org/10.3390/app12020928.

[23] E. Kardas, The analysis of qualitative parameters of anodised coating of finishing strips, in: METAL 2018 - 27th International Conference on Metallurgy and Materials, Conference Proceedings, 2018, pp. 2002–2007, [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85059412547&partnerID=40&md5=722a5d27b8569123e275c3022047fa87.

[24] M.A. Pekok, R. Setchi, M. Ryan, Q. Han, D. Gu, Effect of process parameters on the microstructure and mechanical properties of AA2024 fabricated using selective laser melting, Int. J. Adv. Manuf. Technol. 112 (1–2) (2021) 175–192, https://doi.org/10.1007/s00170-020-06346-y.

[25] C. Cao, W. Li, K. Yang, C. Li, G. Ji, Influence of substrate hardness and thermal characteristics on microstructure and mechanical properties of cold sprayed

TC4 titanium alloy coatings, Cailiao Daobao/Mater. Rev. 33 (1) (2019) 277–282, https://doi.org/10.11896/cldb.201902014.

[26] C.-X. Gu, Y.-Z. Liu, and H.-F. Jia, Effects of temperature and holding time on properties and microstructures of semi-solid powder rolling AA2024 strip, Fenmo Yejin Cailiao Kexue yu Gongcheng/Mater. Sci. Eng. Powder Metall. 20 (3) (2015) 368–374, [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84937549985&partnerID=40&md5=b864d70475f2b91903346ae2c69fd809.

[27] H. Aydin, Quality and properties of the friction stir welded AA2024-T4 aluminium alloy at different welding conditions, Mater. Test. 52 (9) (2010) 640–650, https://doi.org/10.3139/120.110172.

[28] M. Ponte, E. Lertora, C. Gambaro, Mechanical and structural characterization of friction stir welded 5754 H32 and 2024 T3 aluminium alloys, Metall. Ital. 99(9) (2007) 13–19, [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-39449085862&partnerID=40&md5=44c867cbbb6a37085a8a3d5f0af3d5ff.

[29] B.J. Connolly, Q. Meng, A.L. Moran, R.L. McCaw, Mechanical and precorroded fatigue properties of coated aluminium aircraft skin system as function of various thermal spray processes, Corros. Eng. Sci. Technol. 39 (2) (2004) 137–142, https://doi.org/10.1179/147842204225016958.

[30] A.K. Yadav, A.K. Bagha, S. Bahl, R.C. Sharma, Experimental modal analysis for measuring the structural damping capacity of microwave cast SS202 material, in: Lecture Notes in Mechanical Engineering, 2022, pp. 733–740, https://doi.org/10.1007/978-981-19-0244-4_69.

[31] S.S. Gajmal, D.N. Raut, An investigation on wear behaviour of ASTM B23 tin-based Babbitt alloy developed through microwave-assisted casting, Int. J. Met. (2022), https://doi.org/10.1007/s40962-021-00721-5.