Investigation of Al-7075/Al_2O_3/SiC by swirl casting and WEDM

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Abstract. The research, engineering, military, automotive, sports, and telecommunications industries are just a few of the many that make heavy use of aluminium metal matrix composites. The unique synergistic qualities of these composites, such as reduced weight density, improved performance, and thermal conductivity, make them highly desired. Because of its reputation for small but noticeable structural improvements, Al-7075 aluminium has seen extensive use in the aerospace industry. This research followed international criteria for evaluating specimens in terms of positional stiffness, deformation, impact resistance, and wear. It used the stir casting process to add SiC/Al_2O_3 to Al-7075 in percentages ranging from 2% to 8%. Hybrid Al-HMCs are the product of an aluminium metal matrix composite that was able to include 8% SiC/Al_2O_3via the stirring process. Because it combined aluminium oxide with silicon carbide, this Al-HMC showed improved mechanical qualities and stiffness. Aluminium metal composites with increasing amounts of Al_2O_3/ SiC showed reduced fatigue and frictional strengths. The effect on hardness remained small even when the MMC's SiC/Al_2O_3 proportions grew significantly. To further investigate the Wire Electrical Discharge Machining (WEDM) process, researchers used the L9 Arrays Design of Experiments (DOE) technique to incorporate new process variables. Our objective was to enhance the rate of material removal from Al-7075/SiC/Al_2O_3 while simultaneously improving the marginal surface roughness. Finding the best WEDM process parameters, including the ideal percentages of SiC/Al_2O_3, to achieve the desired surface roughness while minimising material removal rate was the goal of this investigation. To produce Al-7075/SiC/Al_2O_3 composite materials with varying additive percentages in a production environment, this study will determine the best and most accurate WEDM process variables to use.

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1 Introduction

1.1 Metal Matrix Composite

Exploring the world of Metal Matrix Composite (MMC) elements entails combining and acquiring distinct components such as minerals and ceramics. Adding ceramics and minerals to a manufactured metallic compositional framework with active material reinforcements greatly increases the total value of the element, making it more robust and enlightened. The chosen materials combine to create useful and effective combinations with their own unique properties, such as increased efficiency, the inherent stiffness of some ceramics, and aluminum's deformability under compression during heat variations. In terms of Young's modulus (70 GPa vs. 400 GPa), heat conductivity (2416.4 x 10^6/°C), and yield strength (35 Mpa vs. 600 Mpa), for example, silicon carbide and aluminium vary significantly. The T6 conditioned A6061/SiC/17p composite demonstrates how additives may enhance the properties of an aluminium matrix metal composite, leading to enhanced properties including a yield strength of 510 Mpa and a Young's modulus of 96.6 GPa [1]. A well-structured arrangement of a similar volume, incorporating real synthesis while taking particular accommodation situations into account, can further improve these features. Wire Electrical Discharge Machining (WEDM) is a one-of-a-kind machining technique that excels in metalworking on synthetic materials, even when faced with complex geometries. Using WEDM procedures, scientists have come a long way in classifying various Metal Matrix composite materials[2]. Wet electrical discharge machining (WEDM) typically employs cutting components made of wire-like copper or brass, with sizes varying from 1mm to 2.5mm. The use of piezoelectric liquid helps create sparks in the workpiece material and the tool itself since there is very little contact between the wire tool and the workpiece surface. Fasteners, mechanical dies, tooling, and measurements are just a few examples of the many industrial products that benefit from this technique[3,4]. The cutting capabilities, insulating liquid, and workpiece are three of the many operating factors that affect WEDM. Engineers and researchers face a challenging problem when they must pick operation factors such as form, waviness, and material removal rate (MMR) correctly. Cutting performance is quite sensitive to these factors, and even little adjustments may have a big effect[5]. Incorporating hybrid metal matrix composite materials into the EDM process has allowed for the achievement of substances and properties that are otherwise quite variable, but it has also sometimes produced a large exterior domain between several hegemonies[6]. To improve strength or density allowances, scientists have created nanocomposites with different properties and transition times, which include hard component combinations. An economical way to produce these nanocomposites is by mixing stir casting with nanoparticle additions[7]. There is a high need for manufacturing processes that include innovative three-dimensional ingredient layouts and strong material metalworking, particularly when automation plays a role in industrialization. The decrease of handling time and expense while maintaining a balance between large productive output and component dependability is a primary objective. Therefore, in order to achieve more surface polish and quality, it is important to enhance overall manufacturing distinctness for particular component metal matrix composites[8].

1.2 Aluminum Stand Metal Matrix Composite

The development of Aluminium Metal Matrix Composites (AMMCS) has traditionally relied on aluminium matrix materials, most notably Aluminium Metal Matrix Material (AMMM). Their low starting prices and wide variety of desirable properties are the main reasons for this. The desirable properties of aluminum-based metal matrix composites

(AMMCs) include improved thermal conductivity (as compared to pure metals), better temperature resistance, decreased thermal expansion, and higher specific stiffness and tensile strength. Among the many functional uses for AMMCs are electronics heating elements, aeronautical manufacturing, astrophysical structures with layered absorbers, combustion engines, engine impeller cooling fins, and automotive components. Aluminium alloys such as 7075, 6061, A357, A359, 2618, and 2214 make up the bulk of the media's manufacturing components. Table 1 details the spectrophotometric evaluations of Al 7075 for the present production material. Using hardened aluminium alloy-metal matrix composites, particularly Al-7075 alloys, this study intends to investigate the possibility of improving appearance and reducing costs. Adding metal reinforcements to an aluminium matrix and then heating it extensively is the process for making composite materials. Hybrid composites are best manufactured by stir casting, an old technique with a reputation for adaptability, and this process demands very high heat. Use the design in Fig. 1 when stir-casting with whirling poles is required. This design relies on steel propellers mainly because of the material's superior heating consistency [9,10].

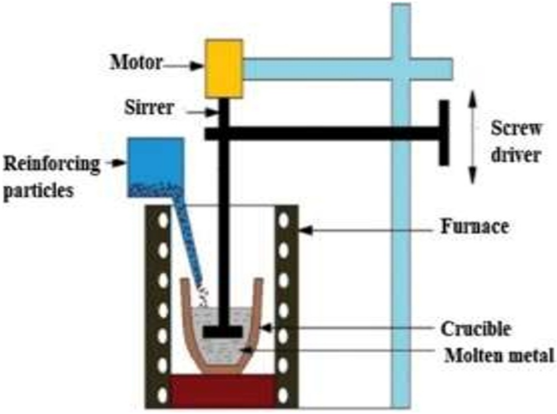


Fig. 1. Stir casting-Set-UP

Table.1. AL-7075 Composition

basics	Cr	Cu	Fe	Ma	Mg	Si	Zn	Ti	Al
Content	0.8	1.35	0.3	2.21	0.08	0.4	5.67	0.06	Balance

1.3 Stir Casting Technique

By mechanically forcing already-existing solid metals into liquids, Swirl Casting creates composite materials with a dispersible phase consisting of tiny fibres and ceramic components. Metal matrix composites (MMCs) are a component of the liquid composite material that undergoes a transformation in this process. Swirl Casting stands out in its latter stages and is famous for its metal synthesis capabilities. There is a volume-limited active retractable phase in the process (usually around 30%, sometimes less, depending on needs). There is an option for a quasi-standard continuous phase transmission configuration. The next step is to add tiny compressed fibres to the mixture. The structural component stands out due to the noticeable separation of parts with a mismatch in intensities. As seen in Figure 1, the swirl casting method makes use of a mechanical stirring device. The low cost, ease of learning, and straightforwardness of this method have made it famous.

2 Experimentation

When it comes to the fabrication of sample materials, the present investigation makes use of the swirl casting approach. Specifically, composite materials made of Al 7075 are used, which include reinforcing components such as silicon carbide and structures of aluminium oxide with a mesh size of 200. It is possible to generate Metal Matrix Composites (MMCs) through stir casting with a saline solution during the manufacturing process of the castings. This method creates an electric sparking gap between the cutting wire and the components, which is analogous to the utilisation of brass filament with a diameter of 0.025 centimetres in Wire Electric Discharge Machine (WEDM), as shown in Figure 2.

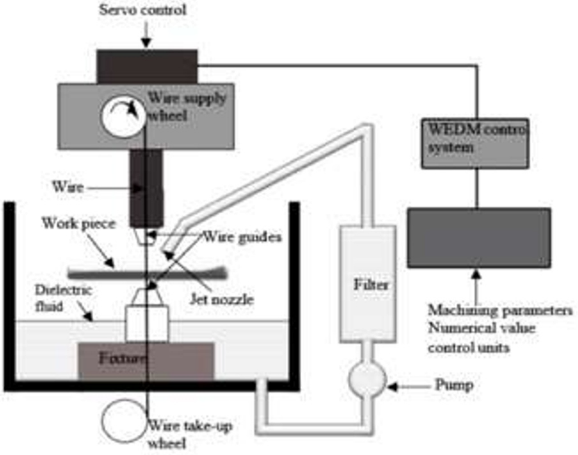


Fig.2. Set-Up of WEDM

Within List II, a variety of operational factors that were explored in the research study are outlined. This investigation makes use of experimentation that is created via the Design of Experiments (DOE) methodology, and it utilises an indirect pattern with L9. We chose to focus on four aspects: the pulse-off time, the voltage, the length of the pulse-on, and the feed rate. Utilising abrasive sandpaper of varying grades allowed for the enhancement of the surface area of the components of the cut specimen. A mirrored polishing process was performed on all of the trial goods utilising wheel-polished equipment. Additionally, an aluminium dispersion was applied over plush material. Both a visual microscope and a scanning electron microscope (SEM) were used in the process of generating morphologies. The technique developed by Keller was used in order to dissolve specimen parts that had composite components. After the initial gathering of microscopic images, the physical toughness of the sample components was evaluated using Vickers hardness measurement. This was accomplished by applying a weight of fifty grammes to the apex of each output specimen. An instrument manufactured by Mitutoyo called the surface morphology ruggedness instrument was used in order to assess the overall surface morphology and surface finish of the porous structures that were machined by EDM [11,12].

Table .2 Input Process Parameters on WEDM

Stages	**Input Process Parameters**			
	TON (Pulse On Time)	**TOFF (Pulse Off Time)**	**V (Voltage GAP)**	**F (Feed Rate of Wire)**
1	6	10	45	5
2	8	8	65	7
3	10	6	85	9

3 Results And Discussions

3.1. Hardness Test

An increase in the hardness of ALMMC composites has been achieved by the use of the stir casting technique. This resulted in an increase in hardness of between two and four percent for Al2O3 and SiC with a weight percentage of between four and six percent, and an increase of between six and eight percent for those with a weight percentage that was higher than that range. There is a correlation between an increase in the weight % of reinforcing material, such as (Al2O3&SiC), and a more substantial improvement in rigidity. A representation of the distribution of overall stiffness is shown in Figure 3.a. This representation is for varied weight percentages of the extra material that was chosen. In general, the findings of this study demonstrate that swirl casting is an effective method for increasing the hardness of ALMMC. Furthermore, the study provides useful insights into the ways in which the weight percentages of reinforcement influence the composite's hardness.

Table.3. Average Mechanical Test Results

Specimen	Hardness (VHN)	Tensile Strength (Mpa)	Impact Strength (J)	Wear rate
1-(Al-7075,2% Al_2O_3& SiC)	181	195	2.9	412
2-(Al-7075,4% Al_2O_3& SiC)	186	224	4.3	402
3-(Al-7075,6% Al2O3& SiC)	194	312	5.5	310
4-(Al-7075,8% Al2O3& SiC)	198	342	9.7	286

3.2. Impact test

Figure 3.c illustrates how the weight percentages of selected chemicals, such as Al2O3 and SiC, have an effect on the toughness of the material that is a man-made composite. In order to enhance the robustness of this specimen inside the ALMMC compound material, the researchers decided to include Al2O3 and SiC with a weight percentage of 8 percent as reinforcement. This resulted in an increased collision potency.

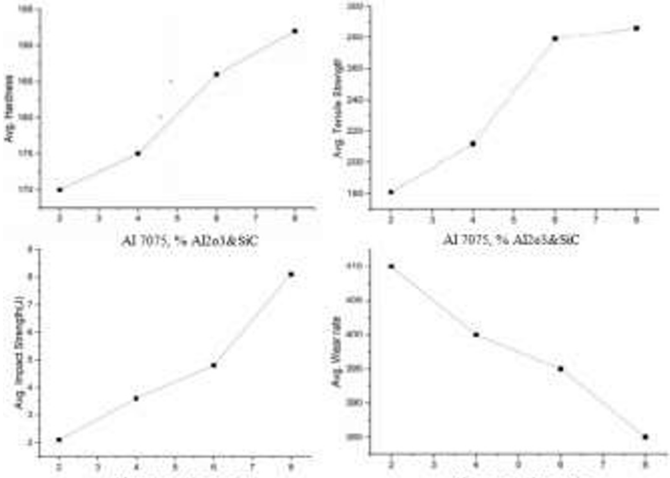


Fig. 3. (a) Hardness vs. Al2O3&SiC wt% (b) Tensile strength vs. Al2O3&SiC wt% (c) Impact strength vs. Al2O3&SiC wt% (d). Wear vs. weight percentage Al2O3&SiCYield strength - Al7075/Fe_3O_4/PKSA 0 to 9 wt% composite.

Impact strength vs. Al2O3&SiC wt% (d). Wear vs. weight percentage Al2O3&SiC
Increasing the overall strength of the composite specimens is the goal of the Swirl Casting process, which involves the insertion of reinforcements into ALMMC. Examinations of fractures, as well as evaluations of impact and elongation, provide insight into the yielding qualities and fracture behaviour of the composite specimens. According to the findings of the study, the weight percentages of Al2O3 and SiC have an effect on the toughness of the composite specimens. In order to achieve the necessary level of toughness and overall mechanical characteristics of the casted composite material, the data reveal that it is essential to pick the weight percentages for reinforcements with great care. This work highlights the potential of employing Al2O3&SiC ash reinforcement and Swirl Casting to increase the toughness and mechanical characteristics of ALMMC composite materials. In summary, this study highlights the possibility of using these techniques.

3.3 Tensile Test

The objective of the study was to explore the influence of varying weight percentages of Al2O3&SiC ash reinforcement on the tensile strength of ALMMC, employing a Tensometer for conducting tensile tests. The results, as outlined in Table 3, revealed that the incorporation of Al2O3&SiC ash reinforcement in different weight percentages led to an augmentation in tensile values and the overall strength of the composite. Furthermore, the outcomes indicated that an increase in the weight percentage of Al2O3&SiC ash within the composition resulted in a corresponding enhancement in tensile strength, as depicted in Figure 3.b. This research underscores the positive impact of introducing Al2O3&SiC ash reinforcement on the tensile strength of ALMMC, which is crucial for improving the mechanical properties of the composite. It also underscores the significance of meticulously selecting the weight percentage of additives in achieving optimal outcomes for the mechanical properties of the composite.

3.4 Wear Test

This inquiry included the use of a pin-on-disc test setup for the purpose of carrying out wear testing on certain specimens. when shown in Figure 3.d, the results demonstrate that there is a decrease in the percentage of wear rate when the weight % of Al2O3 and SiC additives in Al-7075 rises. On the other hand, one noticed a more significant reduction in the rate of wear when the material had smaller weight percentages of additives, such as Al2O3 and SiC reinforcement. The incorporation of graphite into weight percentages is a contributor to the self-lubricating feature, which further reduces the rate of wear. The findings of this research highlight how important it is to carefully choose the weight % of reinforcements in order to get the highest possible level of wear resistance in the composite material. The findings suggest that the addition of higher weight % additives into Al-7075, such as Al2O3 and SiC reinforcement, may result in lower wear rates. This makes Al-7075 a potential alternative for applications that need exceptional wear resistance.In this investigation, wear tests were conducted on specific specimens using a pin-on-disc-test configuration. The study results, depicted in Figure 3.d, reveal a decrease in the wear rate percentage as the weight percentage of Al2O3&SiC additives in Al-7075 increases. Conversely, a more substantial reduction in the wear rate was observed with lower weight percentages of additives like Al2O3&SiC reinforcement within the material. The self-lubricating property of graphite, included in weight percentages, contributes to the decrease in the wear rate. The research underscores the critical aspect of thoughtfully selecting the weight percentage of reinforcements to achieve optimal wear resistance in the composite material. The findings suggest that incorporating advanced influence percentage additives like Al2O3&SiC reinforcement into Al-7075 can result in diminished wear rates, positioning it as a promising option for applications demanding superior wear resistance.

3.5. The Influence of processing variables on machining process performance

The data that is shown in Table 4 provides an overview of the numerous factors that were used in the outcomes of the inquiry, with a particular emphasis on the rate of material removal and the surface roughness. This research focuses the regulation of four essential process parameters in precision machining: Voltage-Gap, TON, TOFF, and feed rate (wire). Because of the potential influence they have on the functioning of the machine as well as the quality of the end output, these factors play an extremely important role. This research highlights the considerable effect that these factors have on the MRR and Ra values of the machined material by identifying particular ranges for each parameter for each parameter based on the outcomes of the experiments. To get the required results in precision machining, it is thus vital to have a solid grasp of these factors and to optimise them. The results of this study may be used to guide the compilation of data for standards and suggested practices in precision machining, which will contribute to an increase in both the efficiency and quality of the machining process [13,14].

Table 4 Material removal rate and Surface Roughness are also investigated as process factors.

E. No	**Input Process parameters**				**Output Responses MRR(mm3/min)**				**Surface Roughness(Ra)**			
	TON (Pulse On Time)	**TOFF (Pulse Off Time)**	**V (Voltage GAP)**	**F (Feed Rate of Wire)**	**1-Al 7075, 2% Al_2O_3&SiC**	**2-Al 7075, 4% Al_2O_3&SiC**	**3-Al 7075, 6% Al_2O_3&SiC**	**4-Al 7075, 8% Al_2O_3&SiC**	**1-Al 7075, 2% Al_2O_3&SiC**	**2-Al 7075, 4% Al_2O_3&SiC**	**3-Al 7075, 6% Al_2O_3&SiC**	**4-Al 7075, 8% Al_2O_3&SiC**
1	6	10	45	5	24.62	23.91	24.19	25.81	0.60	0.96	1.63	1.67
2	6	8	65	7	18.22	20.284	21.70	21.93	1.31	1.61	1.72	1.81
3	6	6	85	9	16.18	20.42	17.61	17.91	1.40	1.64	1.45	1.45
4	8	10	65	9	19.22	22.41	21.27	21.81	1.60	1.38	1.64	1.82
5	8	8	85	5	18.48	16.21	14.51	14.90	1.14	1.28	1.55	1.63
6	8	6	45	7	33.14	28.27	21.22	21.60	1.24	1.72	1.72	1.87
7	10	10	85	7	18.44	21.05	15.22	15.27	1.45	1.64	1.86	1.91
8	10	8	45	5	29.56	28.14	22.31	22.65	0.93	1.50	1.17	1.37
9	10	6	65	9	19.12	21.49	21.16	21.58	1.03	1.13	1.31	1.61

3.6 Material removal rate (MRR)

For Al-7075 compound matrices, the Material Removal Rate (MRR) is heavily influenced by the gap voltage and wire feed rate. The compound's material removal rate may be increased by increasing the gap voltage and wire feed rate, as shown in Table 4. There was no discernible effect of pulse-off time (TOFF) on the total material removal rate (MRR). Table 4 displays the findings of the investigation and an evaluation of the surface roughness of machined Al-7075 Metal Matrix Composites (MMCs). Surface roughness was shown to decrease when the total weight % of Al2O3&SiC in MMCs increased. The reason for this decrease in surface imperfections is that the reinforcement particles have filled up the spaces between the aluminium matrix. This research concludes that the Material Removal Rate (MRR) and surface roughness may be reduced by increasing the amount of Al2O3&SiC additives added to Al-7075 MMCs. It is critical to find the ideal reinforcing weight % in order to get the best Material Removal Rate and surface quality. During Wire Electrical Discharge Machining (WEDM), the MRR of Al-7075 MMCs is affected by crucial input factors such as Pulse-On Time (TONNE), gap voltage, and wire feed rate[15,16].

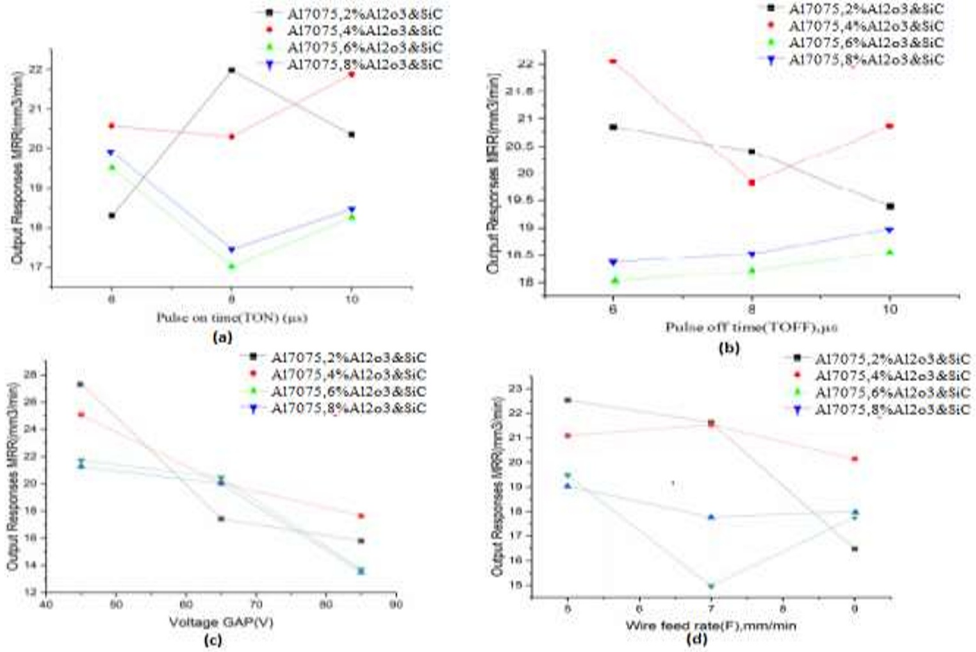


Fig. 4. Material Removal Rate Response Graphs

3.7 Surface roughness (RA)

The investigation on Al-7075 with Al2O3&SiC also looked at the material's surface roughness, and Figures 5a-d show the findings. In the figures, we can see the average surface roughness for different weights of additive particles inside Al-7075, showing results for Al2O3&SiC at 2%, 4%, 6%, and 8%. It was found that the total Ra (surface roughness) was 1.31µm. The values of 1.21µm, 1.28µm, 1.32µm, and 1.42µm for the cumulative surface roughness rose when the proportion of Al2O3&SiC increased from 2% to 4%, 6%, and 8% weight inside Al-7075, respectively. Incorporating harder particles into MMCs explains why adding more additives, measured in weight % of reinforcements, causes the surface roughness to rise.

Wire Electrical Discharge Machining (WEDM) had its surface details reduced by increasing the Pulse-On Time (TONNE), according to the study. The decrease in surface roughness was thought to be caused by sparks that occurred between the wire and specimen. There was an inverse relationship between surface roughness and pulse-off time (TOFF). Increasing the Pulse-On Time (TONNE) led to more expulsions ON-OFF (pulse), which in turn caused the specimen material to take on a more reflecting and uneven shape, leading to a rougher surface. Overall, the results indicate that the surface roughness of the compound materials is greatly affected by the amount of additives, specifically the weight percentage of Al2O3&SiC in the Al-7075 compound material, as well as the Pulse-On Time (TONNE) and Pulse-Off Time (TOFF) in the WEDM process[17].

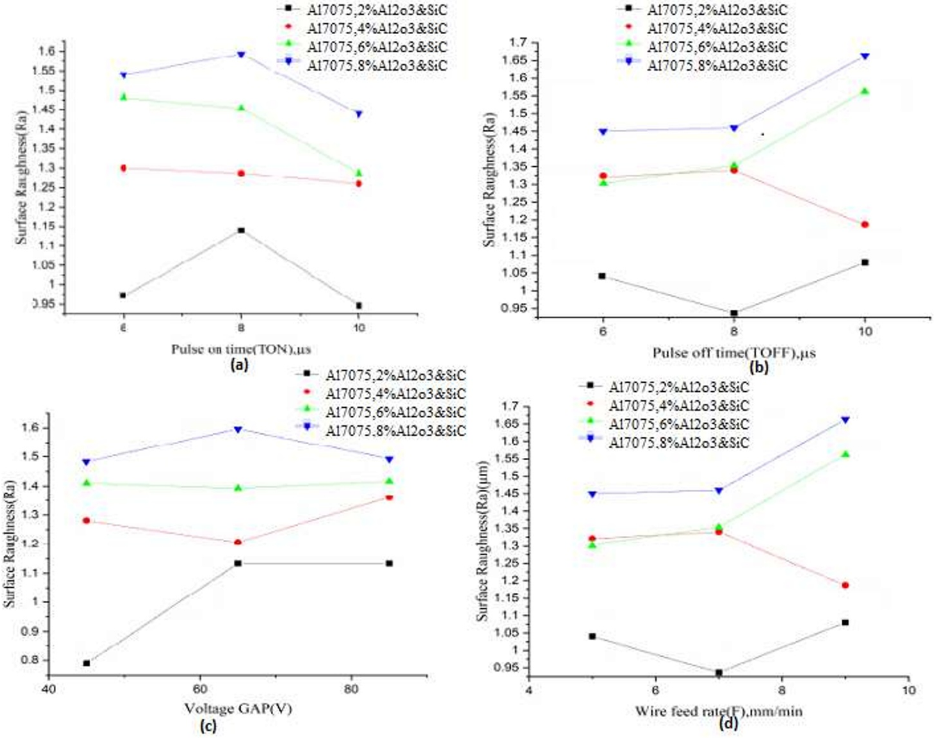


Fig. 5. Surface Roughness Response Graphs

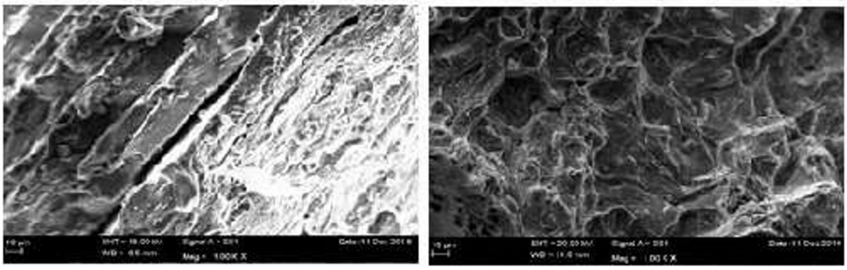
3.8 Microstructure and SEM

In Figure 6-(a-d), we can see how the scanning electron microscopy (SEM) observations of the additive distribution (Al2O3&SiC) correlate with their properties. With the additives (Al2O3&SiC) evenly distributed throughout the specimens of the test samples, SEM comparisons are possible with ease. This tensile test piece is subjected to a high-intensity electron beam that is raster-scanned in order to study the microscopic structure of the specimen near the breaking point.

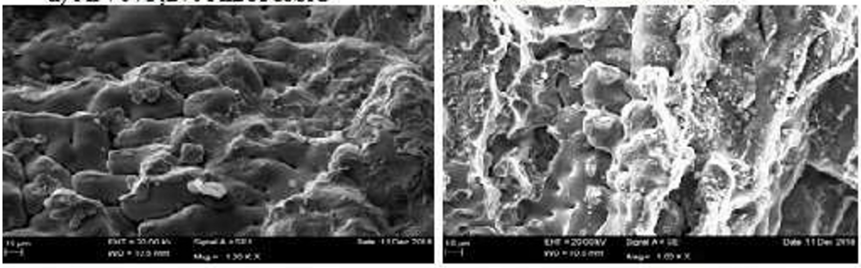
Figure 6-b shows schematic a, b, and c microstructures seen under a 300X optical microscope, demonstrating excellent distribution. The fraction of additive particles grows in relation to the weight % of Al2O3&SiC in the compound matrix, whereas the fraction of secondary particle space decreases. There are cases when the Al-7075 compound matrix's additional additives (Al2O3&SiC) take on a negative sign.

In Figure 6-a, scanning electron microscopy (SEM) and optical microscopy reveal the (Al2O3&SiC) matrix's microstructure and the distribution of its reinforcing subdivisions. These methods make it possible to look at the amount of reinforcing particles and the inter-particle space, which are important aspects in deciding the material's strength and longevity.

Understanding the relationship between the microstructure and qualities of materials is crucial, as the research concludes. Researchers may use modern imaging methods to understand how materials behave under different situations. This knowledge then leads to the creation of materials that are more resilient and long-lasting, which has many potential uses.

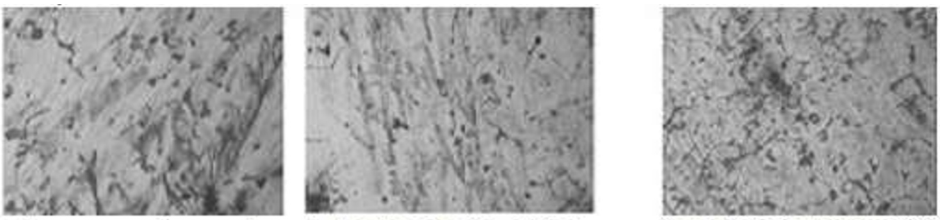


a) Al 7075,2% Al2o3&SiC b) Al 7075,4% Al2o3&SiC



c) Al 7075,6%Al2o3&SiC d) Al 7075,8%Al2o3&SiC

Fig. 6.a SEM



a)Al 7075,4% Al2o3&SiC b) Al 7075,6%Al2o3&SiC c)Al 7075,8%Al2o3&SiC

Fig. 6. b Microstructure

4 Conclusions drawn from the present work:

Wire-cut-electric-discharge-machining (WEDM) was used to evaluate the material removal rate (MRR) and surface roughness (RA) of Al-7075/Al2O3&SiC composites with weight percentages of 2%, 4%, 6%, and 8% that were produced using the liquid-state technique. Reducing the material removal rate and increasing the surface roughness, respectively, are the results of incremental additions of Al2O3&SiC by weight % inside Al-7075 composites. It seems that increasing the weight % of Al2O3&SiC makes machining Al-7075 more difficult, but the surface quality is smoother. In brief, these are the main points:

- A metal matrix composite of Al-7075/Al2O3&SiC is effectively produced using an inexpensive and extensively used stir casting process.
- Composite materials made of Al-7075 with Al2O3 and SiC have a much greater toughness than pure Al-7075.
- Al-7075 has evenly distributed Al2O3&SiC particles, according to scanning electron microscopy (SEM) microstructure study.
- Crucial process parameters for the MRR test employing wire feed are the pulse-off time (TONNE) and the voltage gap provided inside the wire and specimen of the Al-composite. The former is a minimum requirement.
- Reinforced Al-7075 with Al2O3 and SiC shows a steady decline in the percentage of Al compound matrix material removal rate (MRR).
- While increasing the ratio of additives inside the Al compound metal matrix (MMCs) can increase surface roughness when reinforcing Al-7075, it has no effect on the material removal rate, and WEDM can machine even the most difficult composites.

References

1. B. F. Abu-Sharkh and H. Hamid, "Degradation study of date palm fibre/polypropylene composites in natural and artificial weathering: mechanical and thermal analysis," *Polymer Degradation and Stability,* vol. 85, pp. 967-973, 2004. (Reference to a journal)
2. I. M. Daniel and O. Ishai, *Engineering mechanics of composite materials*. New York: Oxford University Press, Inc., 1994. (Reference to a book)
3. A. Dufresne, "8 - Cellulose-Based Composites and Nanocomposites," in *Handbook of Biopolymers and Biodegradable Plastics*, ed Boston: William Andrew Publishing, 2013, pp. 153-169. (Reference to a chapter in an edited book)
4. Introduction to Composite Materials, F.C. Campbell, Structural Composite Materialsttp://machinedesign.com/article/metal-matrix-composites-1115, Nov- 15, 2010 .
5. Pradeep K. Rohatgi (1993) Metal-matrix Composites, Defence Science Journal, Vol 43(4) , pp 323-349.
6. N.G. Patil, P.K. Brahmankar, D.G. Thakur, On the effects of wire electrode and ceramic volume fraction in wire electrical discharge machining of ceramic particulate reinforced aluminum matrix composites. Proceedings CIRP 42, 286–291 (2016).
7. J. Zhao, J.C. Jie, C. Fei, C. Hang, T. Li, Z. Cao, Effect of immersion Ni plating on interface microstructure and mechanical properties of Al/Cu bimetal. Trans. Nonferrous Met. Soc. China 24, 1659–1665 (2014).
8. H.K. Garg, K. Verma, A. Manna, R. Kumar, *Hybrid Metal Matrix Composites and a further improvement in their machinability*—a review. Int. J. Latest Res. Sci. Technol. 1(1), 36–44 (2012)
9. K.B. Vijay, S. Dharminder, S. Puneet, Research work on *composite epoxy matrix and Ep polyester-reinforced material*. Int. J. Eng. Res. Technol. 2(1), 1–20 (2013)
10. B.S. Yigezu, P.K. Jha, M.M. Mahapatra, The key attributes of synthesizing ceramic particulate reinforced Al-based matrix composites through stir casting process: a review. Mater. Manuf. Processes 28(9), 969–979 (2013)

11. Y.C. Shin, C. Dandekar, in Mechanics and modeling of Chip Formation in Machining of MMC, ed. by J.P. Davim, Machining of Metal Matrix Composites (Springer-Verlag London Limited, 2012) https://doi.org/10.1007/978-0-85729-938-3-1
12. B.C. Kandpala, J. Kumar, H. Singh, Machining of aluminum metal matrix composites with electrical discharge machining—a review. Mater. Today Proc. 2, 1665–1671 (2015)
13. A. Kumar, D.K. Bagal, K.P. Maity, Numerical modeling of wire electrical discharge machining of super alloy Inconel 718. Proc. Eng. 97, 1512–1523 (2014)
14. S. Prashanth, R.B. Veeresha, S.M. Shashidhara, U.S. Mallikarjun, A.G. Shiva siddaramaiah, A study on machining characteristics of Al6061-SiC metal matrix composite through wire—cut electro discharge machining. Mater. Today Proc. 4(10), 10779–10785 (2017)
15. Y. Pachaury, P. Tandon, An overview of electric discharge machining of ceramics and ceramic-based composites. J. Manuf. Process. 25, 369–390 (2017)
16. S. Mohanty, B.C. Routara, A review on machining of metal matrix composites using nano-particle mixed dielectric in electro- discharge machining. Int. J. Automot. Mech. Eng. 13(2), 3518–3539 (2016)
17. G. Talla, D.K. Sahoo, S. Gangopadhyay, C.K. Biswas, Modeling and multi-objective optimization of powder mixed electric dis- charge machining process of aluminum/alumina metal matrix composite. Eng. Sci. Technol. Int. J. 18, 369–373 (2015)
18. P. Sivaprakasam, P. Hariharan, S. Gowri, Optimization of micro- WEDM process of aluminum matrix composite (A413-B4C): a response surface approach. Mater. Manuf. Process. 28, 1340–1347 (2013)
19. P. Shandilya, P.K. Jain, N.K. Jain, Prediction of surface rough- ness during wire electrical discharge machining of SiCp/6061 Al metal matrix composite. Int. J. Ind. Syst. Eng. 12(3), 301–315 (2012)
20. H. Singh, H. Kumar, Review on wire electrical discharge machining (WEDM) of aluminum matrix composites. Int. J. Mech. Product. Eng., ISSN: 2320-2092 3(10) (2015).
21. Michael Oluwatosin Bodunrin, Kenneth Kanayo, Alaneme Lesley Heath Chown(2015), Aluminium matrix hybrid composites: a review of reinforcement philosophies; mechanical, corrosion and tribological characteristics, Journal of materials research and technology, vol 4(4) Dec 2015, pp 434-445.
22. H. Warren, Hunt, Darrell R. Herling (2004), Text book, Aluminium Metal Matrix Composites, Advanced Materials and rocesseshttp://www.science.org.au/nova/059/059.
23. Yoshiro.Iwai, Hidetomo.Yonede, and Tomomi.Honda, (1995), “Sliding wear behaviour of SiC whisker reinforced aluminum composite”, wear 181-183, pp.594-602.
24. Rupa Dasgupta (2010) The Stretch, Limit and Path Forward for Particle Rein-forced Metal Matrix Composites of 7075 Al-Alloys. Scientific research Engineering, vol 2, pp 237-256
25. Zeynep TAŞLIÇUKUR, Gözde S. ALTUĞ, Şeyda POLAT (2012) “Characterization of microstructure and fracture behavior of GG20 and GG25 cast iron materials used in valves” metal vol 5 pp 23-25
26. Sidney H.Avner. (1986); Introduction to physical metallurgy, McGraw-Hill.]

27. N. Mahathaninwonga, T. Plookphola, J. Wannasina, S. Wisutmethangoonb(2012) T6 heat reatment of rheocasting 7075 Al alloy ,Materials Science and Engineering Volume 532, Pages 91–99]
28. S.M. Bayazida, , , H. Farhangia, H. Asgharzadehb, L. Radanc, A. Ghahramania, A. Mirhajib Effect of cyclic solution treatment on microstructure and mechanical properties of friction stir welded 7075 Al alloy , Materials Science and Engineering, Volume 649, Pages 293–300
29. Siavash gholami, esmaeil emadoddin, mohammad tajally, ehsan borhani(2015) Friction stir processing of 7075 Al alloy and subsequent aging treatment , Transactions of Nonferrous Metals Society of China, Volume 25(9) Pages 2847–2855
30. Jin-feng l, zhuo-wei peng, chao-xing li, zhi-qiang jia, wenjing chen zi-qiao zheng (2008) Mechanical properties, corrosion behaviors and microstructures of 7075 aluminium alloy with various aging treatments ,Transactions of Non-ferrous Metals Society of China, Volume 18(4), Pages 755–762