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Super Ni 718 Machinability Investigation on Electrical Discharge Machining Using Hybrid Al 7(075+178) Electrode Under Abrasive Assisted Dielectric

Colonel Anuj Bindra[1,*], S. Gajanana[2], Devesh Kumar[3]

Abstract

As aluminum alloy is the lightest metal and has the best mechanical qualities among metal, it has proven to be a perfect choice for strututal industry, particularly in the aerospace sector.7xxx alloys from the Al alloy family are widely used in aviation constructions due to their outstanding processing, welding efficiency, great specific strength & stiffness, and high toughness. The two aluminum alloys that are most frequently used in airplane structures are Al7075 and Al7178 because they both have favorable mechanical properties like low density, high strength, ductility, toughness, and fatigue resistance. In the present work, a hybrid blend of Al 7(075+178) metal matrix, with an optimum composition, is prepared using Die casting technique. The prepared hybrid blend has been used as a tool in EDM to process Super Ni 718, a Nickel based super alloy, that has been employed as work material. In contemporary industrial environment, mostly Copper and brass electrodes are used as tool in the EDM for machining hard materials. However, to reduce the tooling cost, Al 7(075+178) metal matrix hybrid has been incorporated as alternative tool in this work. DoE Taguchi OAs are used for optimum experimental trails to develop regression model for material removal rate (MRR). By combining the unique properties of Super Ni 718 and the hybrid aluminum electrode, this research work seeks to optimize material removal processes while minimizing the ecological impact and thus, contributing towards a greener and more sustainable future in the sector of metal machining. The purpose of development of the blend of hybrid Metal Matrix AA with the help of different reinforcements will certainly lead to huge amount of applications in different sectors like Aviation, Automobile, Defence, Military and other Engineering sectors.

Keywords: AL (7075+7178), Taguchi-DoE, Hybrid Aluminum Alloy, Die Casting, Abrasive assisted EDM, Inconel 718.

INTRODUCTION

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Aerospace structures use 80% of aluminium by weight. As per available data, aluminium is always the first choice for many commercially available aircrafts. As it carries more weight and offers high corrosion resistance, that ensures the safety of the aircraft and its passengers [1]. For more than 80 years, different aluminium alloys proved to be an ideal material for structural aircraft materials. Aluminium alloys have lightweight and excellent mechanical properties among all metals and are widely used in engineering structures, especially in the aerospace industry [2].

Aluminium alloys are widely used in the fabrication of structural components for aircrafts due to their combination of high Strength, Stress–Corrosion–Cracking resistance and toughness [3]. They consists of different elements with different chemical compositions, where the Al is the dominant component with different alloying elements namely, Cu, Mn, Si, Mg, Mg+Si, Zn, Li and so on. These alloying elements in the composition of Al alloys determine their characteristics as well as inherent properties [4]. Engineering components are subjected to different types of loading throughout their service life but fatigue loading is the worst of all. In fatigue, materials fail below their yield point. 7xxx alloys are mostly used because they have the highest mechanical properties among all AL [5]. Al 7xxx alloys have high specific strength, high specific stiffness, high toughness, and outstanding processing and welding performance. The main components of these alloys are Zn, Mg, and Cu [6].

Among the numerous commonly used aluminium alloys, 7075 series Aluminium has the distinction of being the strongest grade aluminium alloy for a variety of industrial applications [7]. Being lightweight, easy-machinable, and adequate corrosion-resistant metal, it provides strength similar to steel alloys while also being a lightweight metal [8]. Among the Al alloy group, Al 7075 contains zinc as the main alloying element and is marked as the highest strength of Al alloy with approximately 570 MPa of tensile strength, that is much higher as comparable to others. It has high fatigue strength and has the distinction of being the strongest grade Al alloy for a variety of structural and aerospace applications [9, 10]. The 7075 Aluminium alloy is used for various components such as fuselage and wing due to its remarkable physical and mechanical properties such as high strength-to-weight ratio and excellent stress corrosion resistance for aircraft applications [11]. With the successful combination of perks of the inclusion of chromium, it has developed high stress-corrosion cracking resistance in sheet products [12].

As far as Al 7178 is concerned, with main alloying addition as zinc, it is formulated for forming wrought products. Post annealing, it offers excellent strength and is suitable for a number of different metalworking processes to include machining, welding, and heat treating [13, 14].

In EDM, being a non-traditional machining technique, due to electrical conductivity the workpiece substance gets melted and evaporated during the thermal machining process. Conventional machining techniques are difficult to employ to cut nickel-based superalloys due to their increased strength and stability in abrasive environments. For precision cutting, electric discharge machining is therefore suggested. Consequently, one benefit of employing EDM is its capacity to provide a precisely machined surface with tight tolerances. Furthermore, the material electrode has a significant impact on the efficiency of the EDM process due to its influence on surface roughness and the rate of metal removal.

In the present endeavor, a hybrid mix of AA 7075/7178 was created using the die casting technique to attain the optimal composition that yields high strength material for structural purposes. The experimental composition was constructed using the Taguchi L8 Orthogonal Array (OA) in Minitab software in order to determine the optimal possible cost-reduction alternative In addition, mechanical tests were performed on the acquired samples to determine their yield strength, hardness, ultimate tensile strength, and % elongation. Grain refinement and grain boundary network, two examples of microstructural behavior and morphology, were examined using scanning electron microscopy images at 100x and 500x magnification.

PROCESSES AND MATERIALS

Preparation of Materials

Metal casting is one of the best manufacturing processes in the industries for complex shapes, due to enhanced maching properties, cheaper and simpler processes. The popularity of Al in automobile & aerospace industries is due to their high strength-to-weight ratio, excellent casting characteristics, and very good mechanical properties such as wear resistance, hardness, compressive strength, ultimate tensile strength, high thermal conductivity & high Corrosion Resistance.

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In present scenario, industry aims at situation where the number of internal defective products in casting must be minimized to zero (Zero defect approach) and with enhanced mechanical properties. Gravity die casting process is one of the best continuous casting process for non-ferrous alloys such as aluminium alloys. It is mainly used for nonferrous materials with high fluidity and low fusion temperature such as zinc and its alloys, copper, Al, brass, magnesium, and tin-based alloys. Die casting technology has become the preferred advanced manufacturing technology among Al alloy components due to obvious reasons [15, 16]. Although the die casting process is somewhat complicated, the microstructure and mechanical properties of Al alloys are significantly influenced by the material composition and process variables, such as temperature, distance, flow rate, and mold [17, 18].

In the present work, melting of the Al alloys was carried out using Induction furnace. The samples were subjected to mechanical testing such as Hardness, Ultimate tensile strength, yield strength and microstructural morphology such as grain refinement which was analysed using scanning electron microscope images [19]. Two tool steel dies that had been hardened were used to produce a mould chamber, which was then filled with molten metal under intense pressure during the metal casting process. These dies function during the procedure similarly to an injection mold since they have been machined into form [20].

Preparation of Hybrid Alloy (Tool)

In this study, the blend of optimum composition has been prepared using the process of Die casting. Proposed composition of hybrid alloy has been shown below in Table 1.

Table 1. Composition of Alloy.

Component	Zn	Mg	Cu	Cr	Si	Fe	Mn	Ti	Al
Amount (wt.%)	5.1-7.3	2.1-3.1	1.2-2.4	0.18-0.29	0.4	0.5	0.3	0.2	87.32-88.12

An optimum composition of hybrid Al 7(075+175) alloy has been developed using the technique of varying the percentages of the four alloying elements i.e. Zn, Cu, Cr, Mg. For material preparation, both the lowest as well as highest percentages of these four parameters have been used, which has resulted in development of eight trails.

Die was prepared with cast iron metal for obtaining cylindrical shaped castings. Al 7(075 + 178) is melted in furnace between 7000°C to 7500°C and the molten alloy is poured into the die. Molten metal enters under gravity and cylindrical casts were taken out post its solidification. Each of the obtained trail has a diameter of 25 mm with length as 250 mm. The casted material undergoes machining using the technique of CNC turning for obtaining desired dimensions of 10 mm Dia and 120 mm length (with cylindrical in shape). Post this, it is prepared for its in-depth mechanical and metallurgical investigations. The tolerance and surface finish of prepared specimens are taken care of to a very much possible extent. The prepared blend of alloys has been used as an electrode to machine the selected workpiece using the process of EDM. Trails of casted specimens have been demonstrated below in Figure 1.

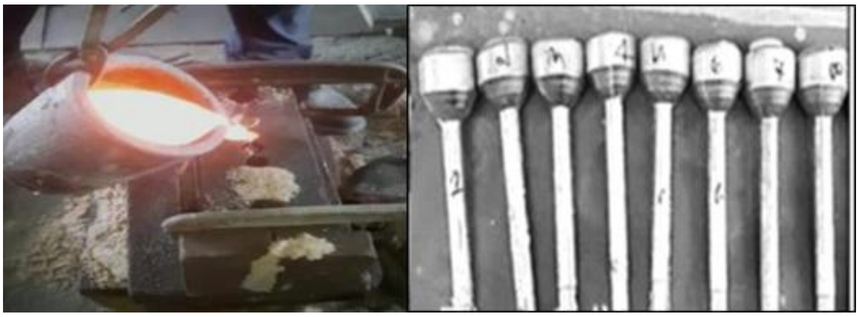

Figure 1. Casting of Specimen.

Preparation of Super Alloy (Work Piece)

A super alloy, commonly known as high-performance alloy, possesses comparatively much higher mechanical and thermal strength than individual metals. These properties make them eligible for the purpose where high strength to weight ratio of a material is expected. Usually categorized according to the main matrix element—nickel, cobalt, or iron—they contain a variety of alloying elements, such as titanium, chromium, and the refractory metals (Nb, Mo, W, and Ta). Super Ni 718 in particular, which is based on nickel, has gained popularity in a variety of applications due to its exceptional strength, great resistance to corrosion, outstanding weldability, and non-magnetic properties. It also maintains its high stability even under high pressures. Nevertheless, the alloy's increased strength makes it more difficult to cut using traditional methods. The experiment's foundational material is displayed in Figure 2.

Figure 2. Super Ni 718(Work material).

Material Characterisation

The term "microstructure" describes a material's small-scale surface structure that is created and examined under an optical microscope; typically, the magnification is greater than 25x. The microstructure of a material can have a big impact on its physical properties, like hardness, tensile strength, and corrosion resistance. In order to analyze the application of a material, these properties must be investigated. Numerous thermal methods can be used to improve the microstructure. Most of an alloy's microstructural characteristics lie on a few tens of millimeter scale. For analysis, ASTM E 562 has been used as the standard with Hydrofluoric acid (HF) as the etchant.

Observations &Comparitive Analysis

$CuAl_2$, $NiAl_3$, and Mg_2Si particles are arranged in an interdentric network in the microstructural pictures of Al 7(075+178).

Flakes containing $CuAl_2$, $NiAl_3$, and Mg_2Si dendritic patterns can be found in the microstructure of Al 7(075+178), indicating that the material has strong tensile strength and limited hardness.

In the microstructure of Al 7075(Fig.5), we find there is modularity surrounded by grain boundary network which leads to good tensile strength and hardness.

Experimental Procedures

Abrasive Assisted EDM

The machining processes that rely on thermal erosion by generating electrical sparks is called Electrical Discharge Machining (EDM). Its a thermal machining process that uses electrical energy to melt and evaporate the electrically conductive workpiece material [21]. It has several variants like, Wire Electrical Discharge Machining (W-EDM), Electrical Discharge Grinding (EDG), Micro Electrical Discharge Machining (μEDM), and hybrids like, Ultrasonic Assisted EDM, Vibration Assisted EDM, Laser Assisted EDM, Electrochemical Discharge Machining (ECDM), etc. Variants and hybrids of the EDM process are being developed to meet machining requirements of different workpiece material types, according to their machinability. Their machinability is determined by their properties like hardness, ductility, thermal and electrical conductivity, etc.

The characteristics of superalloys based on nickel, such as increased strength and resilience in harsh environments, make them difficult to cut with traditional methods. Consequently, due to its precise cutting, electric discharge machining (EDM) is recommended. The cutting proficiency of the Ni-based superalloys via conventional machining operations is very low due to abrasiveness in their microstructure and the higher value of strain hardening [22]. Non-conventional machining processes, i.e., electric discharge machining (EDM), laser beam machining, and plasma arc cutting, can machine the said superalloys [23]. But in all these variants, EDM is opted for the cutting operations of the super alloys due to the wider variety of machining potential. Thereof, the achievement of giving a high-quality machined surface with tight tolerances is the maximum benefit of the selection of EDM [24].

EDM is a spark erosion process that machines the superalloys and the composites with greater precision [25]. In the process of EDM, the electrode is immersed in the dielectric fluid, and the repetitive spark generated during the spark time melts and erodes the debris from the workpiece material by creating a voltage gap between the workpiece and the electrode [26].

Dielectric Medium

The machined profile generated after the EDM process is opposite to the electrode's periphery [27]. The cutting phenomenon in the EDM is carried out with the help of dielectric fluid, which functions like flushing debris, cooling of workpiece and electrode material, and discharge operation [28]. Various dielectrics can be used in EDM, i.e., mineral oils, gases, deionized water, and transformer oil, with or without adding additives. Usually, mineral oils (kerosene oil) are used for cutting purposes in EDM. These dielectrics have different chemical and physical properties, affecting the output parameters during the machining operation [29]. Kerosene oil gave a poor surface finish during the machining process due to low flash points, low volatility, and high flammability. Therefore, to eliminate the said drawbacks and uplift the output parameters like MRR, low down the SR, and obtain green machining, biodegradable dielectrics have been engaged in this study. Produced using a chemical process known as trans esterification, which entails combining vegetable or animal fats with an alcohol, usually methanol, in the presence of a catalyst, such as sodium hydroxide, biodiesel is a sustainable and renewable substitute for conventional diesel fuel. Primarily, there are four types of dielectric fluids commonly used for EDM experiments. There are Hydrocarbons & biodiesel dielectric oils, Water based additives, Gaseous based fluid and Powder mixed dielectric fluid. Our experiment is based on usage of environmental friendly naturally prepared hydro carbon dielectric oil like biodiesel oils–Jatropha based dielectric. We have prepared biodiesel using a mixture of 100 ml methanol, 10 grams of sodium hydroxide, and 2 litres of palm oil in a 2-litre capacity beaker with the assistance of a magnetic stirrer.

Our experiment is based on usage of following four variants of Dielectric mediums:-

- 75% bio diesel & 25% turpentine oil with abrasives (Tio_2)
- 25% bio diesel & 75% turpentine oil with abrasives (Tio_2)
- 75% bio diesel & 25% turpentine oil.
- 25% bio diesel & 75% turpentine oil.

Biodegradable oils can be used as the dielectric for the cutting procedure during EDM. But these biodegradable oils have some demerits like poor resistance to oxidation, less thermal stability, moisture availability. The flaws encountered by biodegradable oils can be eliminated by adding some additives like nano-powders in the dielectric medium [30]. Experimental investigations on the prepared blend have been carried out using the process of Abrasive assisted EDM. Thereof, powder-mixed EDM (PM-EDM) is the popular form of EDM in which enhanced output responses can be achieved, like increased MRR and improved surface finish [31].

For the PM-EDM, a large variety of nano-powders is employed for the machining operation during EDM, including SiC, aluminium, tungsten, graphite, copper, etc.

The specifications used in the EDM experiment are given in Figure 3.

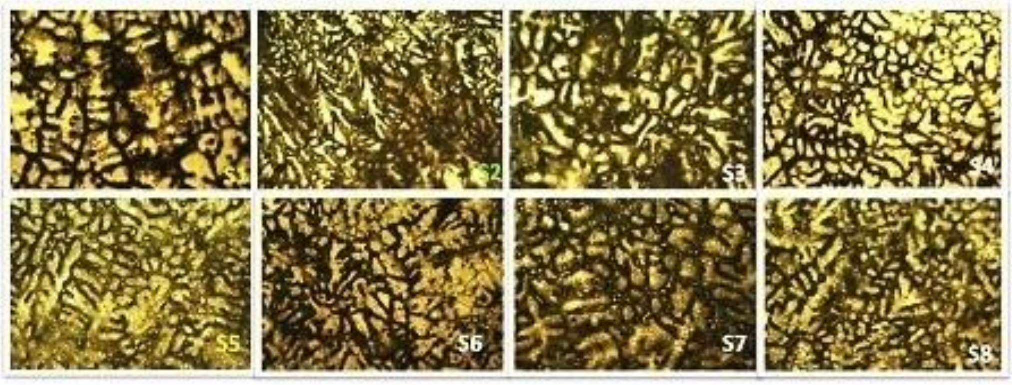

Figure 3. Microstrutural Analysis of Hybrid Al 7(075+178)(at 100x).

In this experiment, Tio2 has been used as abrasive in Dielectric medium. The tool's cryogenic treatment and the addition of nanopowder to the dielectric have significantly improved MRR, TWR, and surface quality, according to the results. The results are explained by the fact that the addition of TiO_2 changed the dielectric breakdown voltage. Many researchers have used biodegradable oils (sunflower oil, canola oil, coconut oil, etc.) as dielectric, and these oils have greater performance than conventional dielectric fluid. EDM machining performance for Ni-based superalloys with different dielectrics is unknown so far [32].

Taguchi DoE–Experimental Methodology

Dr. Genichi Taguchi developed a method for designing experiments to investigate the impact of different parameters on the performance characteristics of the process. In order to organize the process parameters and the levels at which they should be varied, Taguchi proposed an experimental design that used orthogonal arrays. This method allowed for the collection of necessary data to identify the factors that primarily affect product quality with a minimum amount of experimentation, saving time and resources. The understanding of how the variables work on affecting the properties of various materials and how they correlate and contribute to the desired output response will make it possible to determine the optimal conditions for preparing final outcome. This is difficult to achieve using conventional or individual optimization processes that cannot simultaneously analyse the complexity of each variable relationship to the optimization response. Furthermore, an ideal conventional optimization requires many experiments to accurately justify the targeted response, which is expensive, producing lots of uncontrolled-data, waste of time, and chemicals.

Therefore, to solve this problem, a strong optimization strategy like the Taguchi Design of Experiment (DoE) should be used. The Taguchi L8 orthogonal array (OA) design is a reliable and strong DoE for particle synthesis optimization [33–36]. An orthogonal array, signal-to-noise (SN) ratio, and analysis of variance (ANOVA) are three features making Taguchi DoE as a robust and powerful tool in designing an experiment [37]. The SN ratio and analysis of variance are practically used to determine the effect of each variable toward the response data, as reported by previous works [38–40]. Therefore, in the present work, applying a robust statistical Taguchi DoE method is a promising scientific way to

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achieve optimised results.

Moreover, the Taguchi method was used to determine the interaction of each factor, reduce the number of experiments, and for simplification [41–42]. The method is usually used to define a product in terms of the loss it provides, and in this case, the deviation of uncontrollable factors (noise factor) [43]. Furthermore, orthogonal arrays (OA) were used to provide complete information on all the factors affecting the characteristics of the research values obtained. The number of variables and the level of each variable determine which of the numerous OA standards are used in the Taguchi technique. It has been demonstrated that using OA can give comprehensive information on every component affecting the performance of the outcomes. When studying the combined effect of multiple factors on a response or output, factorial designs are frequently employed in research.

INVESTIGATIONS AND RESULTS

L8 Orthogonal Array

The process of choosing the quantity of trials and operating circumstances for them is known as experiment design, and it is necessary and sufficient to solve the problems that have been presented with the necessary accuracy. Given at Table 2 is the L8 orthogonal array, which has two levels and five factors.

Table 2. L8 orthogonal array.

Trail No	TON (μs)	TOFF (μs)	Voltage (V)	Current (A)	Die electric medium (Without Abrasives)
1	100	100	30	3	0.25
2	100	100	30	9	0.75
3	100	500	50	3	0.25
4	100	500	50	9	0.75
5	1000	100	50	3	0.75
6	1000	100	50	9	0.25
7	1000	500	30	3	0.75
8	1000	500	30	9	0.25

MRR and TWR Calculations

EDM was setup for input parameters. Both the tool and work piece were weighed before machining and values were recorded. The tool was then placed inside the tool holder and the work piece was placed on the machining table in such a way that it is immersed inside the dielectric fluid. The machining is then carried out for a period of ten minutes. The work piece is then weighed and the above steps are repeated for all the combinations of the input parameters that were after performing the design of experiments using Taguchi method in MINITAB software. The machined pieces have been shown in Figure 4.

Figure 4. Microstruture of Hybrid Al 7(075+178).

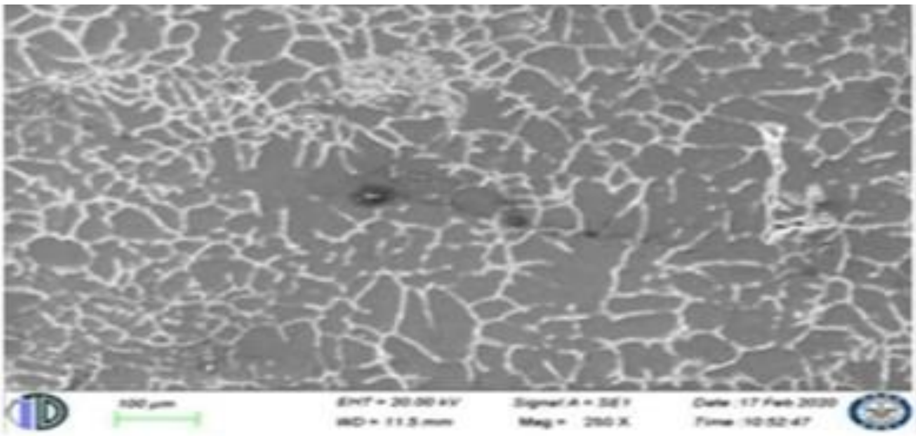

Figure 5. Microstruture of Al 7075.

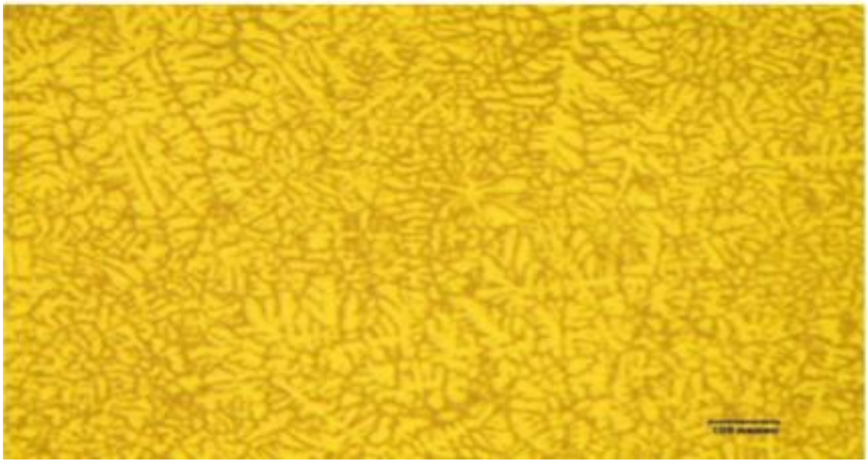

Figure 6. Microstruture of Al 7178.

Model	G-45i
Construction	Integrated type
Work table (mm)	450 × 270
Longitudinal movement (X) (mm)	290
Cross movement (Y) (mm)	220
Work tank dimensions (inside) mm	750 × 450 × 350
Max. work piece weight (Kg)	250
Max. work piece height (mm)	250
Quill travel (mm)	250
Total vertical travel z-axis (mm)	250
Max. dielectric over table (mm)	300
Electrode weight carrying capacity (Kg)	30
Max. daylight (distance between table and quill) (mm)	480

Figure7. EDM setup with specification.

All the results are recorded in the tabular form then the metal removal rate and tool wear rate is calculated using the following formula

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Figure 8. Workpiece and tool after experimentation.

$$MRR = \frac{SUPERNI718\ wt.beforemachinig - SUPERNI718\ wt.ftermachining}{SUPERNI718\ densityxmachiningtime}$$

$$MRR = \frac{(w1-w2)/machining\ time}{SUPERNI718\ densityxmachining\ time}$$

WI = Initial weight of the work piece before machining

W2 = Final weight of the work piece after machining

Machining time 10 minutes

$$TWR = \frac{W_{tpbm} - W_{tpam}}{Electrode\ tool\ denisty\ x\ machining\ time}$$

W_{tpbm} = Electrode tool weight before machining

W_{tpam} = Electrode tool weight after machining

The weights of Super Ni 718 Super Alloy and Hybrid AL 7 (075+178) before and after machining of each impression have been recorded. These weights have been used to calculate the MRR and TWR of the work material and tool respectively. After calculation of MRR and TWR, these values were taken to run the DoE derived out of Taguchi method in Minitab software. The weights, MRR, TWR values are taken accordingly in the Minitab software and a model has been activated for different combinations. The parameters, weight outputs of work piece, MRR and TWR for machining using Die-Electric Medium with abrasives and without abrasives are given in Table 3 & Table 4.

Table 3. Design Matrix with output parameters without abrasives.

Trail No	T_{ON} (µs)	T_{OFF} (µs)	Voltage (V)	Current (A)	DEM(with Abrasives)	Initial Wt. (g) (W_1)	Final Wt. (g) (W_2)	MRR (g/min)	TWR (g/min)
1	100	100	30	3	0.25	129.41	128.97	0.044	0.00257
2	100	100	30	9	0.75	128.97	128.46	0.051	0.00257
3	100	500	50	3	0.25	128.46	128.09	0.037	0.00343
4	100	500	50	9	0.75	128.09	127.71	0.038	0.00257
5	1000	100	50	3	0.75	125.63	125.21	0.042	0.00257
6	1000	100	50	9	0.25	125.21	124.33	0.088	0.00429
7	1000	500	30	3	0.75	124.33	123.74	0.059	0.00343
8	1000	500	30	9	0.25	123.74	123.35	0.039	0.00257

Table 4. Design Matrix with output parameters with abrasives.

Trail No	T_{ON} (µs)	T_{OFF} (µs)	Voltage (V)	Current (A)	DEM (w/o Abrasives)	Initial Wt. (g) (W_1)	Final Wt. (g) (W_2)	MRR (g/min)	TWR (g/min)
1	100	100	30	3	0.25	129.41	128.97	0.036	0.00429
2	100	100	30	9	0.75	128.97	128.46	0.033	0.00858
3	100	500	50	3	0.25	128.46	128.09	0.074	0.00429
4	100	500	50	9	0.75	128.09	127.71	0.034	0.00257
5	1000	100	50	3	0.75	125.63	125.21	0.055	0.00343
6	1000	100	50	9	0.25	125.21	124.33	0.037	0.00257
7	1000	500	30	3	0.75	124.33	123.74	0.072	0.00429
8	1000	500	30	9	0.25	123.74	123.35	0.05	0.00171

From the Minitab software the following regression model for MRR and TWR is obtained

MRR = 0.0406 + 0.000016 Ton - 0.000032 Toff + 0.000150 V + 0.00142 I - 0.0090 DF

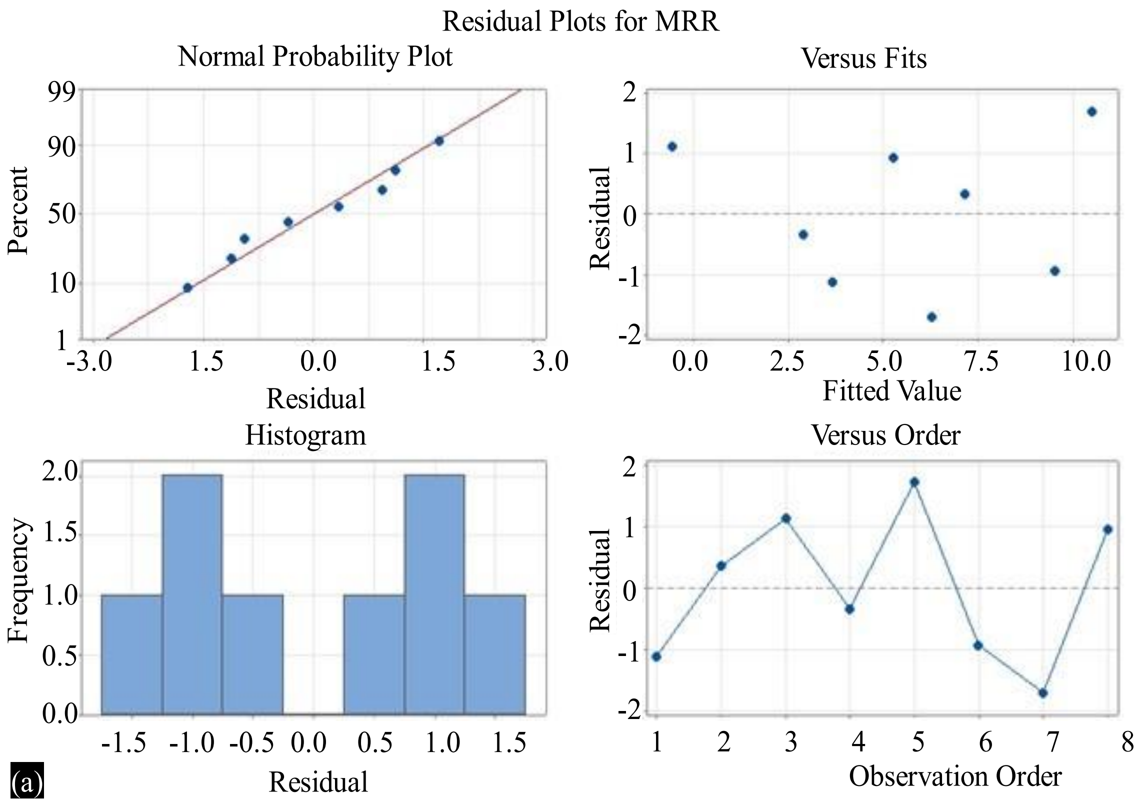
TWR = 0.00231 + 0.000000 Ton - 0.000000 Toff + 0.000022 V + 0.000000 I - 0.00086 DF

From the Minitab software the following regression model for MRR and TWR is obtained

MRR = 0.0692 + 0.000010 Ton + 0.000043 Toff + 0.00225 V - 0.001038 I - 0.0015 Df

TWR = 0.00746 - 0.000002 Ton - 0.000004 Toff - 0.00150 V - 0.000011 I + 0.00300 Df

Graphical Analysis for MRR & TWR



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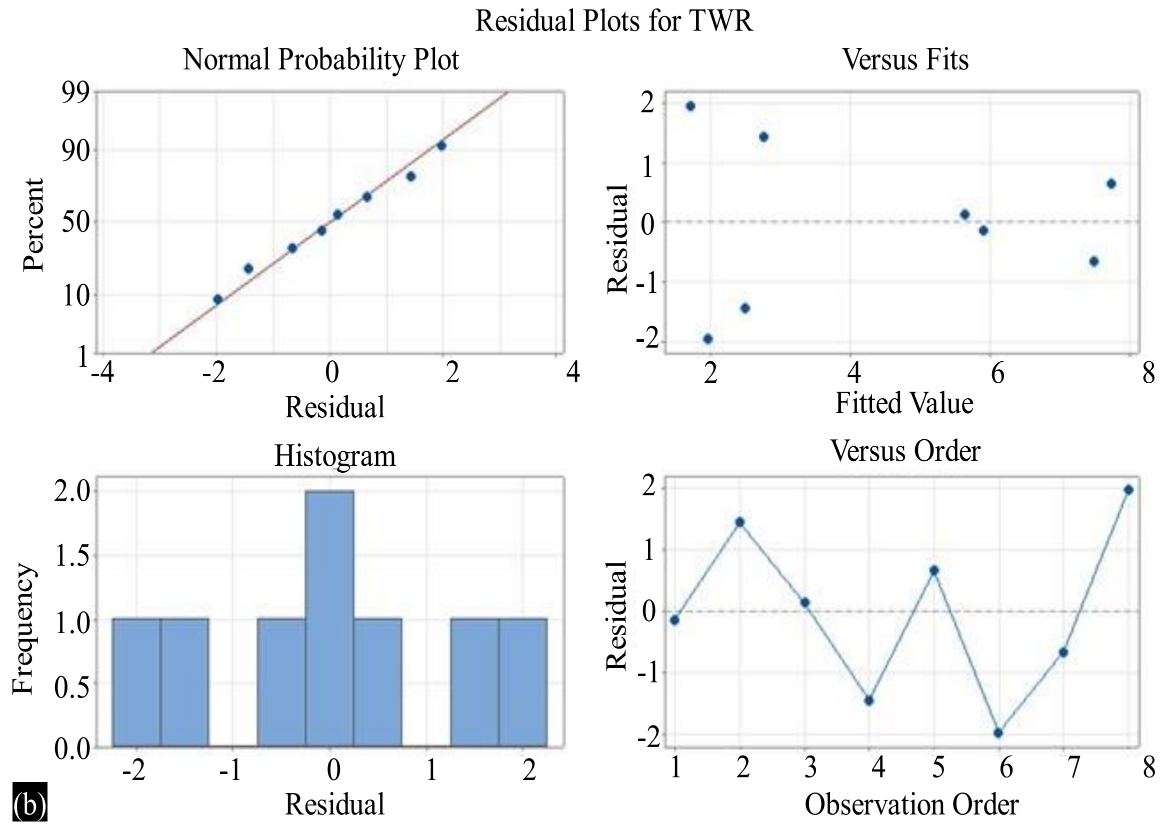
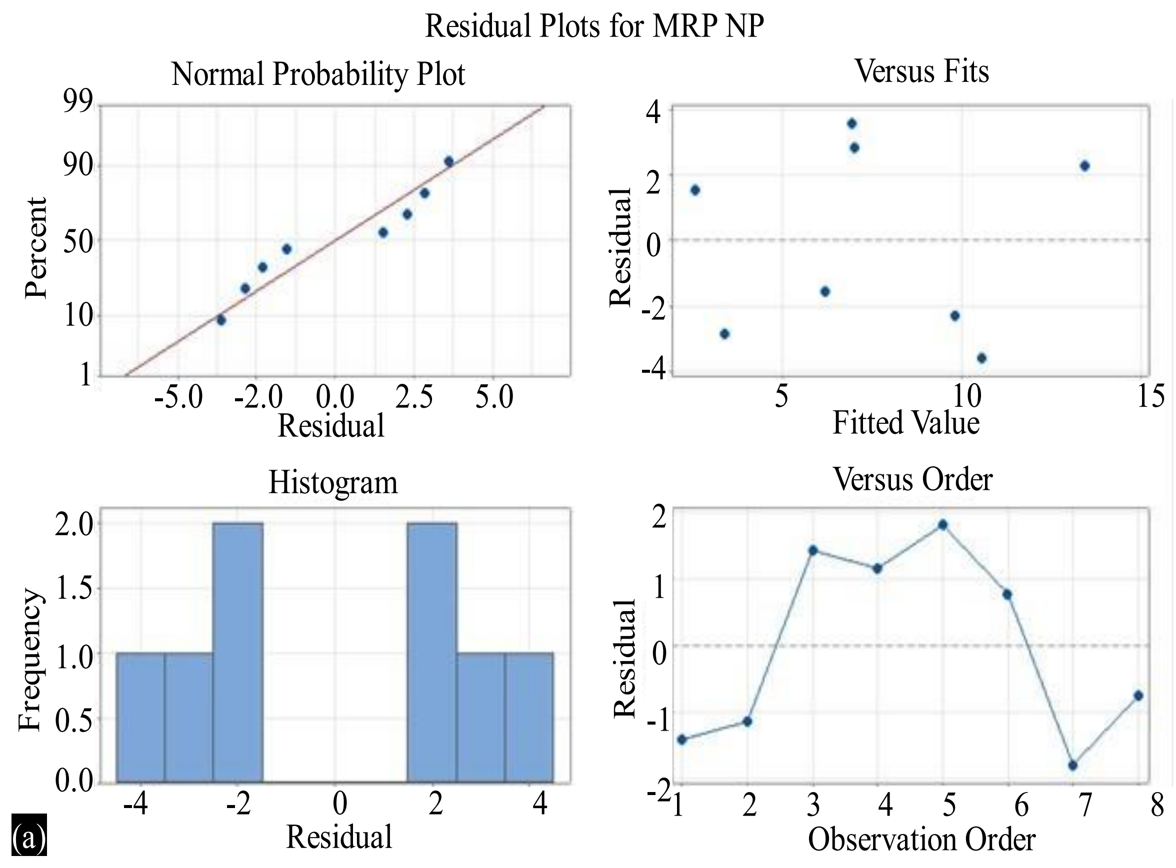


Figure 9. (a) & (B). Plots for MRR and TWR without Abrasives.



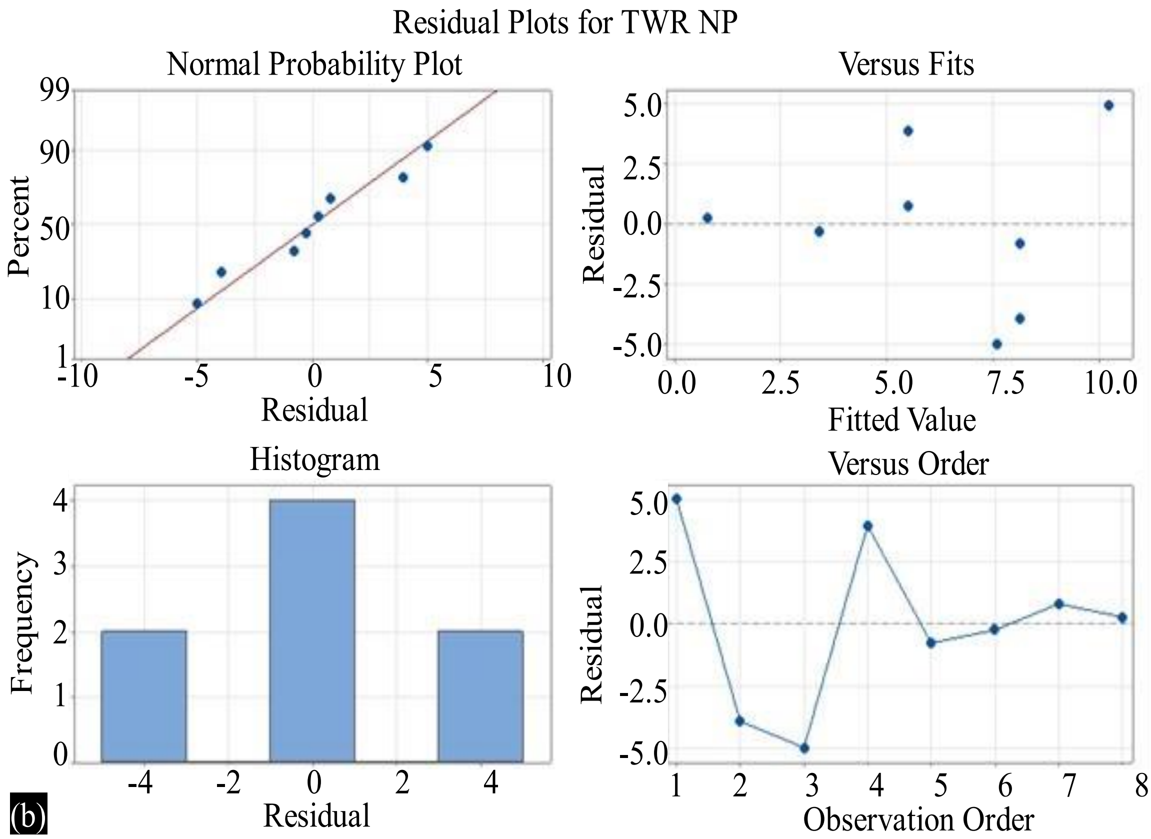
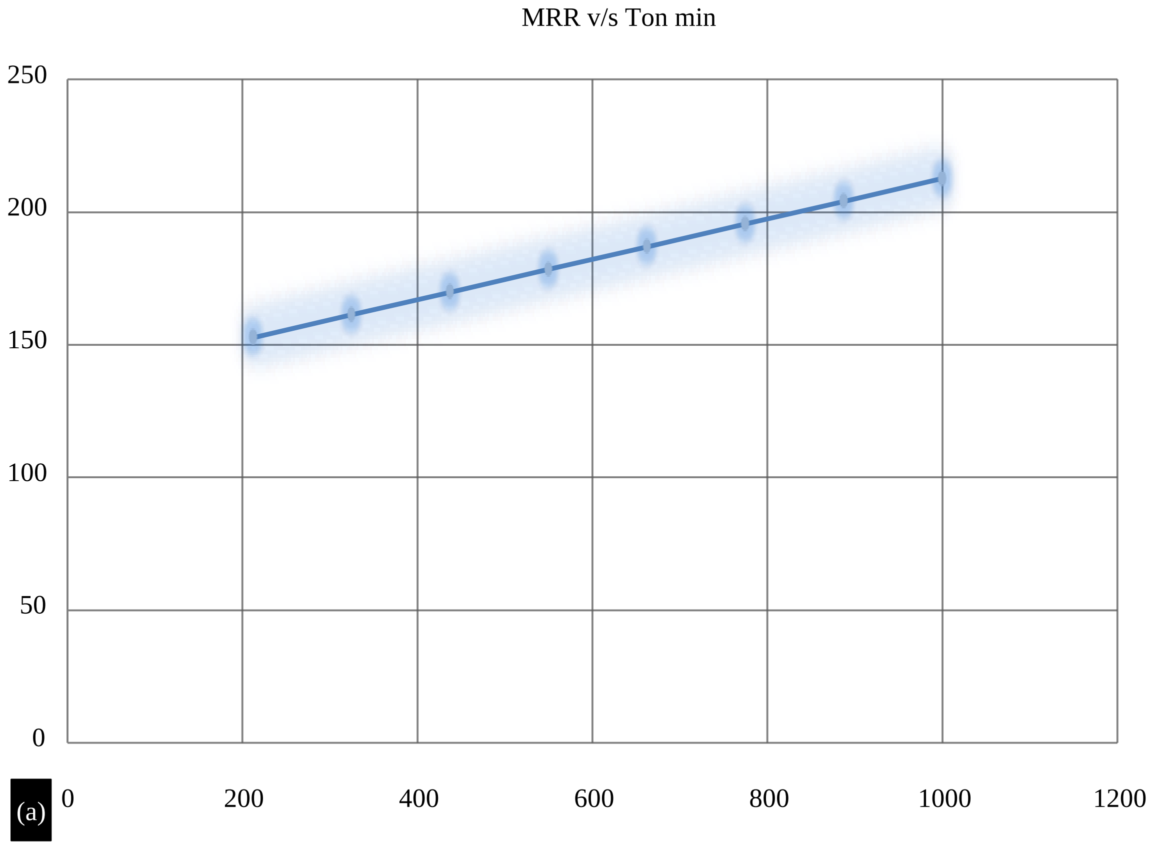


Figure10. (a) & (B). Plots for MRR and TWR without Abrasives.



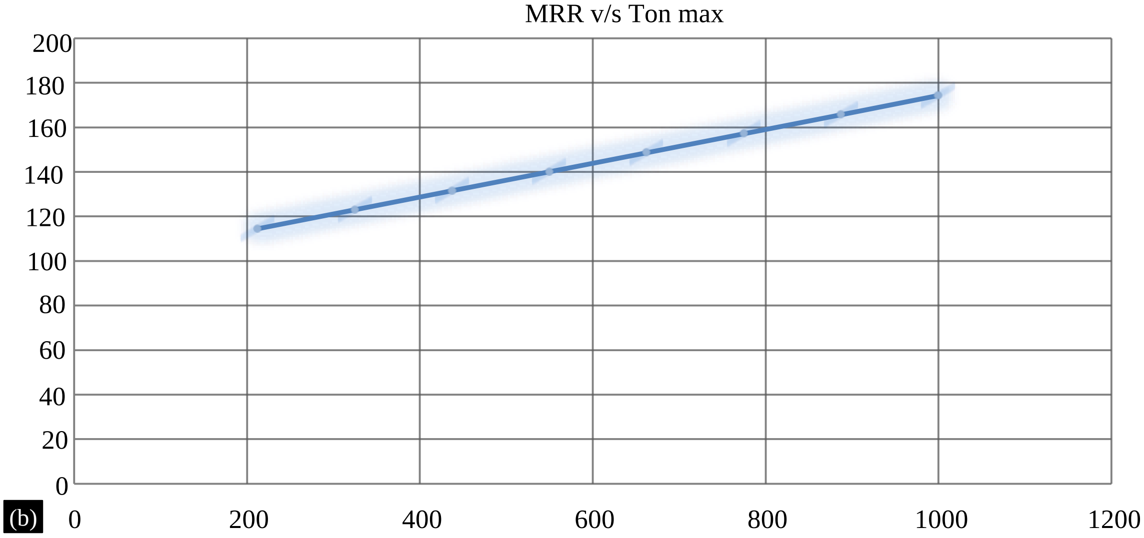
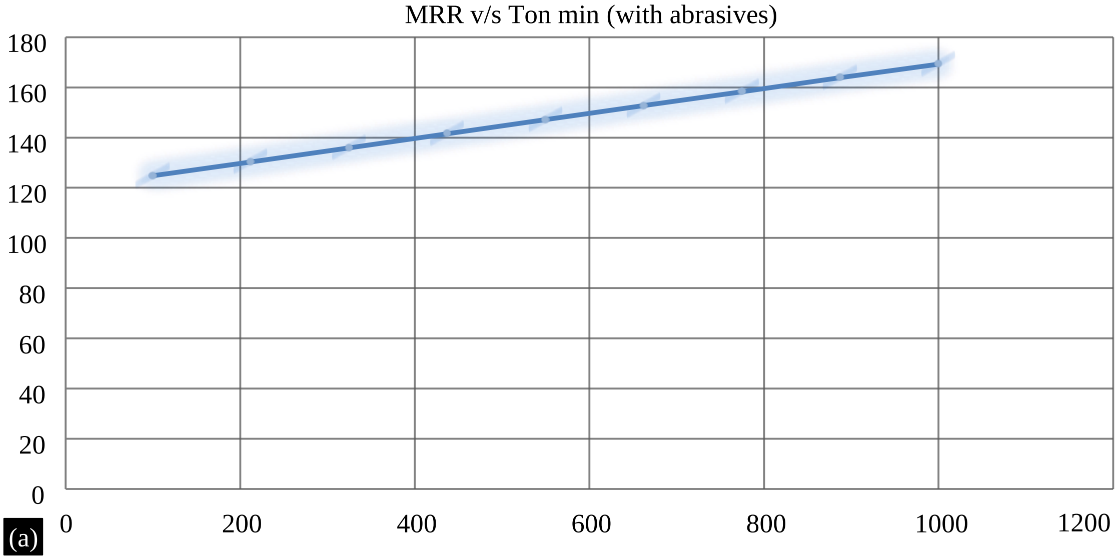


Figure 11. (a & b). Graphs for MRR v/s T_{ON} (min& max) without Abrasives.



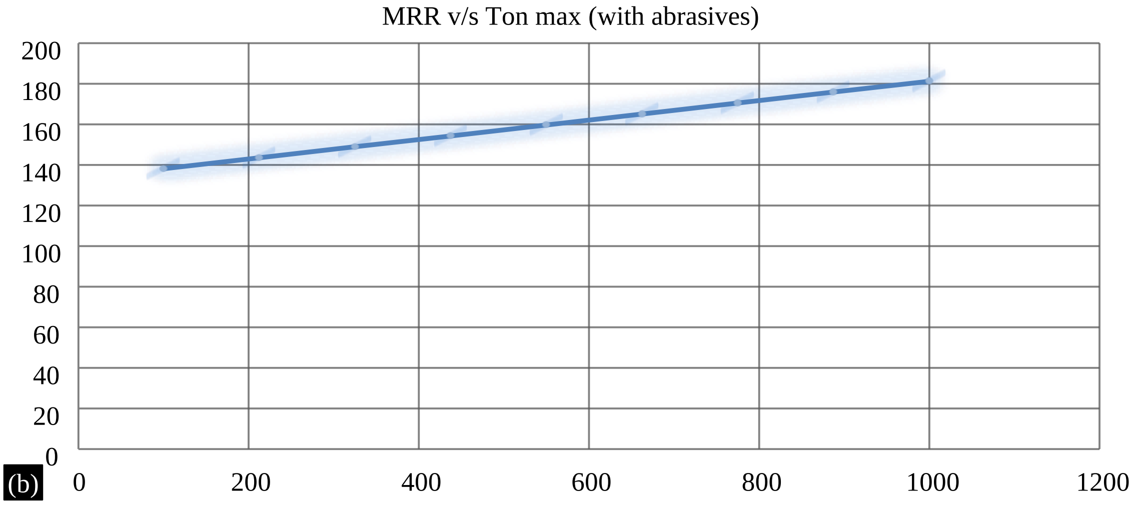


Figure 12. (a & b). Graphs for MRR v/s T_{ON} (min& max) with Abrasives.

Cost Analysis

As far as economics is concerned, cost benefit analysis was also carried out between Al metal matrix alloy and Cu based materials, which are generally used as electrodes in various types of EDM. The analysis justifies that Al alloy is a cost-effective solution. This paper gives out the cost figure pertaining to single electrode of hybrid alloy as ₹ 350/- whereas the market cost of Cu electrode is ₹ 1,500/-. The inputs of material costs as well as manufacturing costs of Al and Cu used in maching industry, have also been ascertained and collated to supoort our cost analysis.

The Hybrid Al 7(075 + 178) electrode costs us about Rs 2000/- for 6 electrodes which makes it about Rs350/- for one electrode. The market cost for a Copper electrode is about Rs1500/- for a single electrode. This makes the Hybrid Electrode about 1/4th the cost of Copper Electrode with almost half the efficiency of Copper Electrode. This makes it efficient in businesses and industry.

CONCLUSION

This work aimed to prepare a blend of two most commonly used AA in the aerospace industry dealing with structural applications. High performance aluminium alloys with excellent mechanical and maching properties are used to produce a hybrid blend. Al 7075 and Al 7178 alloys have been die casted to get an optimum composition of hybrid AA metal matrix alloy 7(075+178) with improved strength and enhanced comprehensive properties. The composition of four alloying elements was varied namely copper, magnesium, zinc and chromium, whereas the remaining alloying elements were kept in a fixed proportion. Two levels of minimum and maximum percentages of these 4 selected parameters have been used to develop the model. These 4 parameters and 2 levels resulted into composition of eight trails, hence, developing a Taguchi L8 Orthogonal array(OA). The values of Max MRR and Min TWR with and without abrasive in dielectric fluid are given in the Table 5 & 6,7.

Table 5. Cost Analysis for Al (7075+7178).

Tool Material	Material Cost(Rs./Kg)	Manufacturing Cost(Rs.)	Total Cost (Rs.)
Al 7(075+178)	4500	500	5000
Copper	18000	2000	20000

Table 6. Obtained Parameters for Dielectric Medium without abrasives.

T_{ON} (µs)	T_{OFF} (µs)	Voltage (V)	Current (A)	Die electric medium (without Abrasives)	MRR (gm/mm²)	TWR (gm/mm²)	Remarks
1000	100	50	9	0.25	0.088	0.00429	Max MRR
100	100	30	3	0.25	0.044	0.00257	Min TWR

Table 7. Obtained Parameters for Dielectric Medium with abrasives.

T_{ON} (µs)	T_{OFF} (µs)	Voltage (V)	Current (A)	Die electric medium (With Abrasives)	MRR (gm/mm²)	TWR (gm/mm²)	Remarks
100	500	50	3	0.25	0.074	0.00429	Max MRR
1000	500	30	9	0.25	0.05	0.00171	Min TWR

With the continued focus on sustainability and the circular economy, the demand for structural aluminium alloys is expected to grow continuously in the future. Comprehensive research into aluminium alloy structures with various section profiles subjected to varied loading scenarios is being continuously conducted, to verify their structural response, assess the applicability of codified design provisions and formulate improved design methods leading to an appreciable amount of applications in different sectors like aerospace, defence, military, and other industrial applications. Therefore, the hybrid metal matrix blend, with enhanced comprehensive properties, will definitely serve as a working material in aerospace, automotive and structural applications where weight and strength is of concern.

Lastly it can be summed up that the hybrid electrode is as cheap as ¼th of the total cost that makes it efficient for a wider usage in industrial applications especially in the field of aerospace structures. The purpose of development of blend of hybrid Metal Matrix AA with the help of different reinforcements will lead to huge amount of applications in different sectors like Aviation, Automobile, Defence, Military and other Engineering sectors.

Disclosure Statement

No potential conflict of interest was reported by the author(s).

Availability of Data and Material

No data available to deposit as private. There are no rights

Compliance with Ethical Standards

Yes, this article complies with the ethical standards of the journal.

Consent for Publication

Yes. All permissions granted

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