iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 Issue: VI Month of publication: June 2022

DOI: https://doi.org/10.22214/ijraset.2022.43798

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VI June 2022- Available at www.ijraset.com

Comparative Study of Al 7075 Sic 5%, 10% Metal Matrix in WEDM

M A Salman Khan[1], Mohammed Khizer[2], Abdullah Omar Ahmed[3], Mohammed Ahtesham Hussain[4]
[1]Assistant Professor, Department of mechanical engineering. ISLEC, Hyderabad, Telangana 500005
[2]Student, Department of Mechanical engineering, ISLEC, Hyderabad, Telangana 500005

Abstract: Aluminium matrix composites have a huge demand in automobile and aerospace industries due to their exceptional properties like specific strength, stiffness and good hardness. Silicon carbide has high strength , high density which is used in ceramics, MMC. Aluminium 7075 alloy with silicon carbide metal matrix is formed which is used because it has high wear resistance and creep resistance property. In this project the strength of metal matrix with compositions of 5% and 10% of silicon carbide is studied. Using WEDM the machinability of Al SiC is studied and the process parameters of WEDM is optimized.
Keywords: Aluminium 7075, Silicon Carbide, WEDM, Optimization

I. INTRODUCTION

Aircraft and automobile manufacturing industries have been facing more technical challenges to meet their customer requirements. Weight reduction is the major challenge among the manufacturers. Weight reduction in the aircraft can decrease fuel consumption, accommodate more passengers at a time, increase payload and enhance the performance and reduce vehicle emission in an automobile. The materials used for the construction of aircraft and automobile must have a light-weight, high specific strength, high heat resistant, fatigue load resistant, low wear rate, high corrosion and crack resistance. Earlier, ferrous metals like alloy steels were commonly used as aircraft and automobile parts. The advantages of these materials are wide availability and the low cost and disadvantages include heavy weight, high wear rate and less corrosion resistance. The properties of iron, aluminium, magnesium and titanium are presented in Table 1.1.

Table 1.1 Properties of ferrous and non-ferrous metals

Property	Fe	Al	Mg	Ti
Crystal structure	BCC	FCC	HCP	HCP
Density at 20°C (g/cm^3)	7.86	2.70	1.74	4.4
Coefficient of thermal expansion 20– 100°C	11.7	23.6	25.2	8.5
Elastic modulus	206.8	68.9	44.1	110
Tensile strength (MPa)	350	320 (for A380)	240 (for AZ91D)	434
Melting point (°C)	1536	660	650	1660

Among the various non-ferrous metals, magnesium is a light-weight metal, but banned in aircraft construction because it easily catches fire. Titanium metal consumes an equal weight of magnesium, which cost 20 to 30 times more than aluminium. Aluminum (Al) is the heavily consumed non-ferrous metal. It is in silver-white colour and a ductile member. Aluminum Alloys

Alloys are solid solution of different metallic and non-metallic elements that are combined at the atomic scale and these elements are soluble up to their solubility limits. Aluminum is the base metal in all aluminum alloys. Aluminium alloys have been the main structural material for aircraft for the last two decades due to their easy design and manufacturing and better properties.Density, hardness, tensile strength, yield strength, compressive strength, wear resistance and corrosion resistance are important properties that need to be increased..

A. *Aluminum Alloy 7075*

Aluminum Alloy 7075 is an aluminum alloy, with zinc as the primary alloying element. It is strong, with a strength comparable to many steels, and has good fatigue strength and average machinability. It has lower resistance to corrosion than many other Al alloys, but has significantly better corrosion resistance than the 2000 alloys. Its relatively high cost limits its use to applications where cheaper alloys are not suitable.

Aluminum alloy 7075 offers the highest strength of the common screw machine alloys. The superior stress corrosion resistance of the T173 and T7351 tempers makes alloy 7075 a logical replacement for 2024, 2014 & 2017 in many of the most critical applications. The T6 and T651 tempers have fair Machinability.

1) Chemical Composition

The alloy composition of AA7075 is

Table -1.2: Composition of Aluminum Alloy AA7075

METAL	MINIMUM	MAXIMUM
Silicon	-	0.4%
Iron		0.5%
Copper	1.2%	2%
Manganese	-	0.3%
Magnesium	2.1%	2.9%
Chromium	0.18%	0.28%
Zinc	5.1%	6.1%
Aluminum	87.1%	91.4%

2) Mechanical Properties

The mechanical properties of AA7075 depend greatly on the temper, or heat treatment, of the material Young's Modulus is 10×106 psi (69 GPa) regardless of temper 7075 Annealed 7075 (7075-O temper) has maximum tensile strength no more than 18,000 psi (125 MPa), and maximum yield strength no more than 8,000 psi (55 MPa). The material has elongation (stretch before ultimate failure) of 25–30%

AA7075-T4 T4 temper 6061 has an ultimate tensile strength of at least 30,000 psi (207 MPa) and yield strength of at least 16,000 psi (110 MPa). It has elongation of 16%.

AA7075-T6 T6 temper 7075 has an ultimate tensile strength of at least 42,000 psi (300 MPa) and yield strength of at least 35,000 psi (241 MPa). More typical values are 45,000 psi (310 MPa) and 40,000 psi (275 MPa), respectively.[4] In thicknesses of 0.250 inch (6.35 mm) or less, it has elongation of 8% or more; in thicker sections, it has elongation of 10%. T651 temper has similar mechanical properties. The typical value for thermal conductivity for 7075-T6 at 77 °F is around 152 W/m K. A material data sheet [5] defines the fatigue limit under cyclic load as 14,000 psi (100 MPa) for 500,000,000 completely reversed cycles using a standard RR Moore test machine and specimen. Note that aluminum does not exhibit a well- defined "knee" on its S-n graph, so there is some debate as to how many cycles equates to "infinite life". Also note the actual value of fatigue limit for an application can be dramatically affected by the conventional de-rating factors of loading, gradient, and surface finish.

3) Applications of AA 7075

AA7075 is commonly used for the following:

a) Construction of aircraft structures, such as wings and fuselages, more commonly in homebuilt aircraft than commercial or military aircraft. 2024 alloy is somewhat stronger, but 7075 is more easily worked and remains resistant to corrosion even when the surface is abraded, which is not the case for 2024, which is usually used with a thin Alclad coating for corrosion resistance.

b) Yacht construction, including small utility boats.

c) Automotive parts, such as wheel spacers.

d) some tactical flashlights

e) Aluminum cans for the packaging of food and beverages.

B. Wire Electrical Discharge Machining Process

Wire electrical discharge machining is a high-precision method for cutting nearly any electrically conductive material. A thin, electrically-charged EDM wire held between upper and lower mechanical guides forms one electrode, while the material being cut forms the second electrode. Electrical discharge between the wire and the workpiece creates sparks that rapidly cut away material. The deionized water passed between wire and workpiece and allows the debris to be flushed away.

As the charged wire never makes physical contact with the workpiece in WEDM machining, there are no cutting forces involved, making it possible to manufacture extremely small and delicate parts. Parts that require levels of accuracy and intricacy that traditional machining cannot achieve can easily be produced via wire EDM.

1) Working principle of WEDM

The basic mechanism of material removal in Wire-cut EDM is same as that of Die-sink EDM and instead of electrode, a slowly moving wire is used which travels along a prescribed path and removes material from the workpiece. A vertically oriented wire is fed into the workpiece continuously travelling from a spool to take up spool, so that it continuously renewed, since it will get worn out during the process. The material is removed by a series of discrete discharges between the wire electrode and the workpiece in the presence of dielectric fluid, which creates a path for each discharge as the fluid becomes ionized in the gap. The area where discharge takes place is heated to extremely high temperature, so that the surface is melted and removed. The removed particles are flushed away by the flowing dielectric fluids. The schematic diagram of WEDM process is shown in Figure 1.1.

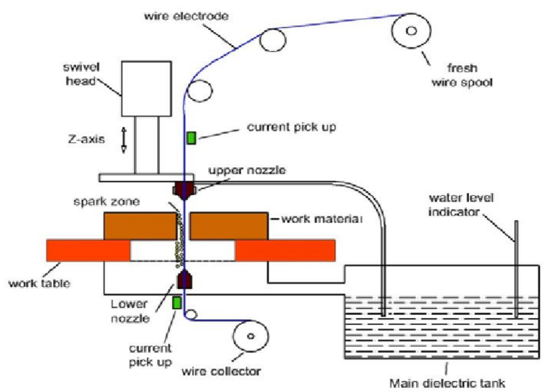

Figure 1.1 Schematic diagram of WEDM

The wire is held between upper and lower guides. The guides move in the (X-Y) plane controlled by a CNC, the upper guide can also move independently in the (Z-U-V) axis, giving rise to the ability to cut tapered and transitioning shapes and can control axes movements. This gives the Wire-Cut EDM the ability to be programmed to cut very intricate and delicate shapes. Wire EDM has no added residual stress as there is no cutting forces involved during machining. WEDM process is used for cutting intricate shapes, to make punches, dies and tools from any conductive material. The wire does not touch the workpiece, so there is no physical pressure imparted on the workpiece compared to grinding wheels and milling cutters. WEDM are used for making components in automotive, aerospace, medical, energy, die/mold, industrial and micro manufacturing.

2) Need of dielectric in WEDM

In WEDM Dielectric fluid creates path for the discharge as the fluid becomes ionized in the gap between tool and workpiece. The dielectric fluid serves lot of functions such as

a) To serve as a spark conductor in the spark gap between the tool and work material.
b) To act as a coolant to quench the spark and to cool the tool and work piece.
c) To carry away the condensed metal particles and to maintain the gap for continuous and smooth operation.

3) Advantages of WEDM

a) WEDM machines offer a broad range of benefits than other unconventional methods. Some reasons to choose a WEDM machine include:
b) Precision: When you need highly accurate machining, WEDM manufacturing is your best option. It is capable of making cuts that match your designs within ± 0.0001”.
c) Intricacy: WEDM is an excellent option for manufacturing delicate and intricate parts. With WEDM, it is possible to manufacture the same intricate part over and over again with the same accuracy.
d) Shorter lead times: Because the WEDM process is so accurate, it makes it possible to significantly shorten the lead time by getting it right on the first try. Decreasing the time it takes to get a product from the prototype phase to the marketplace.

e) Less set up time: WEDM manufacturing reduces the need for tooling, which in turn lessens the amount of time that it takes to set up.
f) Tapers: WEDM machining is useful for cutting long tapers that other machining methods cannot produce.
g) Accurate internal cuts: Square-edged internal cuts are difficult to produce with other machining methods, but Wire EDM makes it possible.
h) Better results: WEDM machining is capable of producing parts that do not have burrs or require tooling. WEDM also creates a better surface finish than other forms of manufacturing.
i) Fine hole drilling: WEDM drilling is capable of producing tiny holes that are difficult to produce with other method.

II. LITERATURE SURVEY

Ayan Pramanick et. al (2016) "Optimization of wire electrical discharge machining parameters for cutting electrically conductive boron carbide" has examined that Pure boron carbide (B_4C) was consolidated using spark plasma sintering (SPS) at 2050°C with a dwell of 10 min under 50 MPa uniaxial pressure in Argon atmosphere. The design of experiment (DOE) was arranged by L32 orthogonal array (OA) between the machining input parameters namely pulse on-time, pulse off-time, pulse peak current, dielectric fluid pressure and servo feed rate and the output responses like machining speed and surface roughness (Ra). Experimental observations were utilized to formulate the first- order regression models to predict responses of WEDM. The optimized input parameters were 27 µs pulse on time, 48 µs pulse off time 180, A pulse peak current, 7 kg/cm^2 water pressure and 2200 mm/min servo feed rate for the WEDM performance to produce an optimum machining speed and surface finish.

Nilesh Patil G et. al (2016) "Semi-empirical modelling of surface roughness in wire electro-discharge machining of ceramic particulate reinforced Al matrix composites" has investigated the study was to develop model for surface finish (Ra) based on machining process parameters, material properties, volume fraction and average ceramic particle size. The process behaviour and machined surface morphology is affected by volume fraction, size of particulated which also alters the thermal and physical properties. Therefore it was decided to include the size of particles and the volume fraction to develop a new model for surface finish. The findings of this study lead to greater insights about material removal during machining of these difficult to machine materials using WEDM. Predictions of this model have found to be in close agreement with experimental results. The results of nonlinear estimation show that the properties such as heat of fusion, coefficient of thermal expansion, thermal diffusivity and melting temperature are most significant properties in machining the composites.

Mohinder Pal Garg et. al (2017) "Prediction of optimal conditions for WEDM of Al 6063/ ZrSiO4(p) MMC" has suggested to achieve close dimensional accuracy in WEDM, the output parameter dimensional deviation is an essential response to be controlled during machining. This study investigates the dimensional deviation induced by WEDM of Al 6063/ $ZrSiO_{4(p)}$ Aluminium Metal Matrix Composite (MMC) by using Response Surface Methodology (RSM). The key WEDM input process parameters namely, pulse-on time, pulse- off time, servo voltage and peak current were varied in order to examine their influence on dimensional deviation. Significant process parameters affecting the process are identified by carrying out analysis of variance (ANOVA) technique. To aid in selecting the best combination of input parameters during WEDM of Al 6063/ $ZrSiO_{4(p)}$ Aluminium MMC the concept of desirability is utilized. Confirmation experiments have been conducted to verify the optimal parameter combinations.

Tamang S K et. al (2016) "Integrated optimization methodology for intelligent machining of Inconel 825 and its shop-floor application" has investigated the machining process aims to produce the components for desired surface quality at minimum machining time and cost. The development of an integrated optimization methodology used for optimizing the process parameters in machining Inconel 825 aerospace alloy. Turning experiments have been conducted with spindle speed (N), feed rate (f), and depth of cut (d) that are considered as process parameters and the centre line average value of surface roughness (R_a) as response. The experimental study shows that surface roughness is influenced by spindle speed followed by feed rate. An artificial neural network (ANN) model has been developed for predicting R_a. The ANN architecture having 3–12–1 is found to be optimum network and model predicts unseen data sets with an average percentage error of 6.51 %. The predictive model is integrated with Particle Swarm Optimization (PSO) approach to optimize the process parameters for desired surface roughness of jobs to be produced at minimum time.

Jonathan Busch D et. al (2013) "Flux Entrapment and Titanium Nitride Defects in Electroslag Remelting of INCOLOY Alloys 800 and 825" investigated that Electro Slag Remelted (ESR) ingots of INCOLOY alloys 800 and 825 are particularly prone to macro scale slag inclusions and micro scale cleanliness issues. Formation of these structures near the ingot surface can cause significant production yield losses (~10 pct) due to the necessity of extensive surface grinding. Slag inclusions from near the outer radius of the toe end of alloy 800 and 825 ingots were found to be approximately 1 to 3 mm in size and have a multiphase microstructure consisting of CaF_2, $CaTiO_3$, $MgAl_2O_4$, MgO, and some combination of $Ca_{12}Al_{14}O_{32}F_2$ and/or $Ca_{12}Al_{14}O_{33}$. These inclusions were often surrounded by fields of 1- to 10-μm cuboidal TiN particles. A large number of TiN cuboids were observed in the ESR electrode with similar size and morphology to those observed surrounding slag inclusions in the ESR ingots, suggesting that the TiN particles are relics from the ESR electrode production process. Samples taken sequentially throughout the Argon Oxygen Decarburization processes showed that the TiN cuboidals that are found in ESR ingots form between tapping the Argon Oxygen Decarburization vessel into the Argon Oxygen Decarburization ladle and the casting of ESR electrodes.

Yanhui Li et. al (2015) “Effects of Sulfides on the Corrosion Behavior of Inconel 600 and Incoloy 825 in Supercritical Water” investigated the corrosion tests of Inconel 600 and Incoloy 825 were performed in supercritical water containing sulfides at 520 °C and 25 MPa. The scales formed on Inconel 600 consisted of a thick outer layer of almost pure Ni_3S_2 and an inner layer predominantly of Cr-rich spinels with a Ni_3S_2 network inside. The scales of Incoloy 825 also had a multi-layered structure. The outer layer primarily consisted of Ni_3S_2 and $(Ni,Fe)_3S_4$, followed by a thicker intermediate mixture layer of chromium-rich oxides, Ni_3S_2, and $(Ni,Fe)_3S_4$, an inner layer of predominantly Cr_2O_3 and a small amount of Ni_3S_2 toward the substrate. Incoloy 825 showed slightly better corrosion resistance than Inconel 600 due to its higher Cr content. The corresponding corrosion mechanisms were discussed, based on the present investigation.

Emel Kuram et. al (2015) “Optimization of machining parameters during micro-milling of Ti6Al4V titanium alloy and Inconel 718 materials using Taguchi method” investigated the experiments done by using Taguchi experimental design method, and the influences of spindle speed, feed rate and depth of cut on machining outputs, namely, tool wear, surface roughness and cutting forces, were determined. Tool wear, surface roughness and cutting forces measured in micro-milling of Ti-6Al-4V titanium alloy and Inconel 718 workpiece materials were optimized by employing Taguchi’s signal-to-noise ratio. The regression models identifying the relationship between the input variables and the output responses were also fitted using experimental data to predict output responses without conducting the experiments. From results, it was concluded that the established regression models could be employed for predicting tool wear, surface roughness and cutting forces in micro-milling of Ti6-Al-4V titanium alloy and Inconel 718 workpiece materials.

Joseph C et.al (2017) “Taguchi-Based Optimization of Surface Roughness and Dimensional Accuracy in Wire EDM Process with S7 Heat Treated Steel” suggested the use of the Taguchi method to reduce the surface roughness and improve dimensional accuracy of parts machined by Wire Electrical Discharge Machining (EDM) with heat treated steel material. Due to its high impact toughness, the material is a candidate for a wide variety of tooling applications which require high precision in dimension and desired surface roughness. This paper demonstrates that Taguchi Parameter Design methodology is able to optimize both dimensioning and surface roughness successfully by investigating seven wire-EDM controllable parameters: pulse on time (ON), pulse off time (OFF), servo voltage (SV), voltage (V), servo feed (SF), wire tension (WT), and wire speed (WS). The temperature of the water in the Wire EDM process is investigated as the noise factor in this research. Experimental design and analysis based on L18 Taguchi orthogonal arrays are conducted.

Dara Sudhakara et. al (2017) “Parametric Optimization of Wire Electrical Discharge Machining of Powder Metallurgical Cold Worked Tool Steel using Taguchi Method” suggested the work mainly deals with optimization of surface roughness while machining Steel by Wire cut EDM using Taguchi method. The process parameters of the Wire Cut EDM is ON, OFF, IP, SV, WT, and WP. L_{27} OA is used for to design of the experiments for conducting experimentation. In order to find out the effecting parameters on the surface roughness, ANOVA analysis is engaged.

Abhishek Singh et. al (2014) “Microstructural Analysis and Multiresponse Optimization During ECM of Inconel 825 Using Hybrid Approach” Suggested that electrochemical machining of Inconel 825, a Ni- based super alloy, was carried out using tungsten as a tool electrode material and NaCl as electrolyte. The influence of various ECM parameters such as voltage (V), concentration (C) and tool feed (F) has been investigated on the evolution of the surface morphology of Inconel 825 after ECM. Different performance measures in ECM such as material removal rate (MRR), surface roughness (SR) and radial overcut (ROC) have been measured. Grey relational analysis that uses grey relational grade as performance index has been adopted to simultaneously optimize multiple performance characteristics and determine optimal combination of ECM parameters.

III. EXPERIMENTAL SETUP

A. Wire EDM Machine

The experiments are done using MAXICUT Wire EDM machine from Electronica Groups which is a Computer Numerically Controlled (CNC) machine. It has control in X, Y, Z and also in U, V directions. The maximum workpiece height that can be fixed is 200 mm.

The maximum weight that can be with stand by this Machine worktable is 300 kg and de-ionised water is used as a dielectric fluid. It can adopt a standard wire electrode diameter of 0.25 mm. The required profile to be cut is drawn and converted into NCP file and finally loaded into the CNC Wire EDM machine. The pictorial view of MAXICUT Wire EDM is shown in Figure 3.1.

Figure 3.1 Pictorial view of MAXICUT CNC Wire EDM

B. Wire Electrode

Characteristic of wire electrode is one of the major factor affecting the performance of Wire EDM**.** That is, the cutting performance and the wear of Wire in WEDM process depends upon a combination of the electrical, mechanical, physical and geometrical properties of the wire electrode. In this project work the zinc coated brass wire of diameter 0.25 mm is used for machining. Zinc coated wire has lot of advantages compared to plain brass wire.The advantages are,

1) This zinc-coated wire consists of brass wire electroplated with high purity zinc. The high plating accuracy realizes faster machining speed and also provides a better surface finish on the work piece.
2) By uniformly coating the surface of the wire with zinc, which has good discharge characteristics, it is possible to create a finer discharge compared to when using general brass wire.
3) The discharge is stable and free of irregularities.
4) Impurities are kept to the minimum, thus preventing deterioration of performance.
5) Zinc coated wire has minimum tensile strength of 883MPa which is greater than brass wire and hence the breakage of wire is reduced.
6) Higher value of thermal conduction and specific heat capacity of machined material causes the decrease of efficiency of WEDM.
7) Due to the thermal nature of WEDM, the efficiency of cutting is lower for materials with a higher melting point.
8) As far as the WEDM of cemented carbides B40 is concerned, the highest volumetric efficiency is $9.1 mm^3/min$.

C. Work Material

Al 7075 (Aluminium-Zinc) alloy is selected for automobile and aircraft structural applications. Al 7075 exhibits excellent mechanical, wear and corrosion properties. The chemical compositions of Al 7075 are given in Table 3.1. The properties of matrix and reinforcing material are presented in Table 3.2.

Table 3.1 Chemical composition of Al 7075 Alloy

Elements	Weight percentage
Zinc (Zn)	5.5
Magnesium (Mg)	2.5
Copper (Cu)	1.6
Iron (Fe)	0.5
Silicon (Si)	0.4
Manganese (Mn)	0.3
Chromium (Cr)	0.15
Titanium (Ti)	0.2
Aluminium (Al)	Remaining

D. Reinforcements

Matrix material properties have been improved with the addition of reinforcement particles into them. In AMCs, hard reinforcements such as SiC, TiC, Al2O3, B4C and so on are added to improve their properties.

1) Silicon Carbide (SIC)

Silicon Carbide is the only chemical compound of carbon and silicon. It was originally produced by a high temperature electro chemical reaction of sand and carbon.

Today the material has been developed into a high quality technical grade ceramic with good mechanical properties. It is used in abrasives, refractories, ceramics and so on.

Characteristics of Silicon Carbide are:

a) Low density
b) High strength
c) Low thermal expansion
d) High thermal conductivity
e) High hardness
f) High elastic modulus
g) Excellent thermal shock resistance
h) Superior chemical inertness

E. Process Parameters Of Wire Edm

The parameters that affect the performance of CNC Wire EDM are Pulse on Time (T_{on}), Pulse off Time (T_{off}), Wire tension (WT), Peak Current (Ip), Wire Feed (WF). The range of these parameters are tabulated in Table 3.2.

Table 3.2 Process Parameters of Wire EDM

Parameters	Range
Pulse on Time (T_{on})	1-10 microseconds
Pulse off Time (T_{off})	1-10 microseconds
Peak Current (Ip)	180-270 A
Wire Tension (WT)	0-1300 gms
Wire Feed (WF)	1-10 mm/min
Spark Voltage (Sv)	0-120 V

1) Pulse on Time (Ton): The period of EDM cycle during which electrical sparks exists between the electrode and workpiece.
2) Pulse off Time (Toff): It is the period during which no spark exists between the wire electrode and workpiece.
3) Peak Current (Ip): It is the maximum value of current passing through the electrode for the given pulse. It has significant impact on MRR
4) Wire Tension (WT): Wire tension determines how much the wire is to be stretched between upper and lower wire guides.
5) Wire Feed Rate (WF): Wire feed rate is the rate at which fresh wire is fed continuously for sparking.
6) Spark Voltage (V): The voltage required to produce a spark across a given spark gap is known as spark voltage.

F. Input Parameters

Based on the literature survey and specifications of the machine three input parameters are chosen to study the effect of response variables or output parameters. The parameters are

1) Pulse on Time (T_{on})
2) Pulse off Time (T_{off})
3) Wire Tension (WT)
4) Wire Feed Rate (WF)
5) Spark Voltage (V)

G. Output Parameters

Material Removal Rate (MRR) and Surface Roughness (Ra) are chosen as output parameters. Higher the MRR and lower the Ra gives better performance of the machine. This project deals with optimizing the three input parameters to achieve high MRR and low Ra.

1) Material Removal Rate (MRR)

Material Removal Rate is ratio between Volume of material removed and Time taken for machining

$$MRR = \frac{\text{Volume of Material Removed } (mm^3)}{\text{Time taken for machining } (min)}$$

2) Surface Roughness

Surface finish, also known as surface texture or surface topography, is the nature of a surface as defined by the three characteristics of lay, surface roughness, and waviness. It comprises the small, local deviations of a surface from the perfectly flat ideal.

Surface texture is one of the important factors that control friction and transfer layer formation during sliding. Considerable efforts have been made to study the influence of surface texture on friction and wear during sliding conditions. Surface textures can be isotropic or anisotropic. Sometimes, stick-slip friction phenomena can be observed during sliding, depending on surface texture.

H. Design Of Experiments

Design of Experiments is a process of planning the number of experiments with proper value to get the appropriate data and analysed by statistical methods, with gives us a valid and unbiased conclusion. There are various types of Design of Experiments are available. Some of the important methods are:

- Response Surface Methodology.
- Taguchi Methods.

1) *Taguchi Method:* The robust design concept is introduced by Dr Genichi Taguchi. It is defined as reducing variation in a product without eliminating the causes of the variation. In other words, making the product or process insensitive to variation. Taguchi realized that the best opportunity to eliminate the variation of a final product quality is during the design of a product and its manufacturing process.

The process has three stages:

a) System design
b) Parameter (measure) design
c) Tolerance design

2) *Requirement of Taguchi Method:* It allows for precise estimation of one or more unknown quantities of interest. One parameter estimate is more precise than another if it has a smaller variance. To get a balanced design which may not optimal in some cases. All paragraphs must be indented. All paragraphs must be justified, i.e. both left-justified and right-justified.

IV. RESULTS AND DISCUSSION

A. Input Parameters Values

Wire Feed, Wire Tension, Pulse ON Time, Pulse OFF Time, and Servo Voltage parameters which are considering the machining capacity to WEDM we used values of three levels for these parameter are given in table 4.1.

Table 4.1 Values of Input Parameters

No. of Value	Wire Tension (gms)	Pulse ON Time (µs)	Pulse OFF Time (µs)
1	900	100	60
2	1050	120	70
3	1200	140	90

1) Levels of Experiments

The Various parameters which have been optimized from the Taguchi method, we have selected the L9 of Taguchi which based on the number of parameters which have been. For five parameters and three value in each parameter the L27 is selected. These are input of our experimentation of WEDM machining. The selected set of parameter in 27 levels are given in Table 4.2.

Table 4.2 Optimized Input Parameters

Orthogonal array	Wire Tension (gms)	Pulse ON Time (µs)	Pulse OFF Time (µs)
L1	900	100	60
L2	900	120	70
L3	900	140	90
L4	1050	100	70
L5	1050	120	90
L6	1050	140	60
L7	1200	100	90
L8	1200	120	60
L9	1200	140	70

2) Machined Samples

The machined workpieces of AL7075 combined with 5% and 10% SiC are shown in the Figure 4.1 and 4.2.

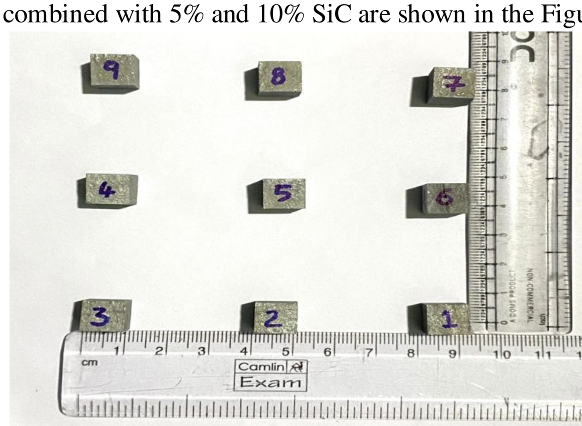

Figure 4.1 Machined samples of AL7075 Combined with 5% SiC

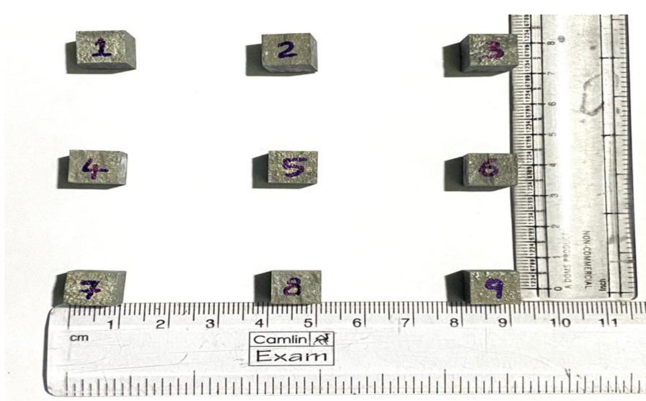

Figure 4.2 Machined samples of AL7075 Combined with 10% SiC

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VI June 2022- Available at www.ijraset.com

B. Experimentation Values

Material removal rate and Surface roughness of AL7075 combined with 5% and 10% SiC when machined through WEDM with the above input parameter.

1) Material Removal Rate

The material removal rate of the AL7075 combined with 5% and 10% SiC when Machined by WEDM with the Square Profile is given below. Material removal rate has been calculated through ratio of multiplying thickness of the material with perimeter of the profile to the time taken for machining have chosen.

$$MRR = \frac{Vm}{t} \ (mm^3/min)$$

Where, MRR = Material Removal Rate (mm^3/min).

T = Time taken for machining (min).

V_m = Volume of Material Removed (mm^3)

$$V_m = P_p \times T_m \times T_w$$

$$Vm = 80 \ mm^3$$

Where, P_p = Perimeter of Square Profile (mm).

T_m = Thickness of Material (8 mm).

T_w = Thickness of Wire (0.25mm).

$$MRR = \frac{80}{9.25} = 8.64 mm^3/min$$

2) Surface Roughness

Surface finish is the nature of a surface, defined by the three characteristics of lay, surface roughness, and waviness. It comprises the small, local deviations of a material surface from the perfectly flat ideal. Roughness plays an important role in determining how a real object will interact with its environment.

Figure 4.3 Computer controlled Surface Roughness Testing Machine

In tribology, rough surfaces usually wear more quickly and have higher friction coefficients than smooth surfaces. Roughness is often a good predictor of the performance of a mechanical component, since irregularities on the surface may form nucleation sites for cracks or corrosion. Computer controlled Surface Roughness tester is used to find the surface roughness. Computer control Surface Roughness used for measurement is shown in Figure 4.3.

We have taken three sides of surface from the specimen for Surface Roughness test. The surface roughness graph and reference image of specimen is shown in Figure 4.4

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VI June 2022- Available at www.ijraset.com

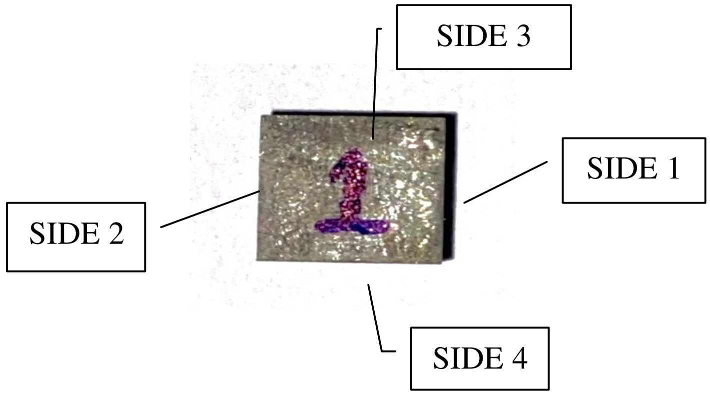

Figure 4.4 Reference image for Surface Roughness

To Find the Average Surface Roughness

Surface Roughness $(Ra)_{avg}$ = (Side 1 + Side 2 + Side 3) / 3

Example of average surface roughness is shown in Table 4.3.

Table 4.3 Average Surface Roughness

Exp. No.	Surface Roughness Ra (µm)				
	Side 1	Side 2	Side 3	Side 4	Average Ra
1	4.52	3.56	5.64	4.52	4.56

C. Experimentation Results

From Table 4.4, shows that the Material Removal Rate and Surface Roughness values for 27 Experiments.

Table 4.4 Experimentation Results

S. No.	Wire Tension (gms)	Pulse on time Ton (µs)	Pulse off Time Toff (µs)	Material Removal rate MRR S1 (mm^3/min)	Surface Roughness S1 Ra (µm)	Material Removal rate MRR S2 (mm^3/min)	Surface Roughness S2 Ra (µm)
1	900	100	60	8.64	4.56	8.05	4.56
2	900	120	70	9.21	4.26	9.58	4.76
3	900	140	90	10.2	4.35	9.52	4.09
4	1050	100	70	9.68	4.54	8.83	4.18
5	1050	120	90	8.43	4.62	8.64	4.9
6	1050	140	60	9.19	4.08	8.66	4.55
7	1200	100	90	8.57	4.92	8.62	4.36
8	1200	120	60	8.97	4.99	9.3	5.01
9	1200	140	70	8.76	4.45	9.06	6.21

1) Effect of Input Parameters on Responses for AL7075 Comined with 5% AND 10% SiC

The Experimental Result of Machining AL7075 combined with 5% and 10% SiC using WEDM machine with input parameters as Wire Tension (gms), Pulse ON Time (µs), Pulse OFF Time (µs).The output parameters as Material Removal Rate (mm^3/min) and Surface Roughness (µm). Variation of each output parameter is discussed with each input parameters.

2) Effect of Input Parameters on Material Removal Rate (MRR)

a) Variation of MRR with WT

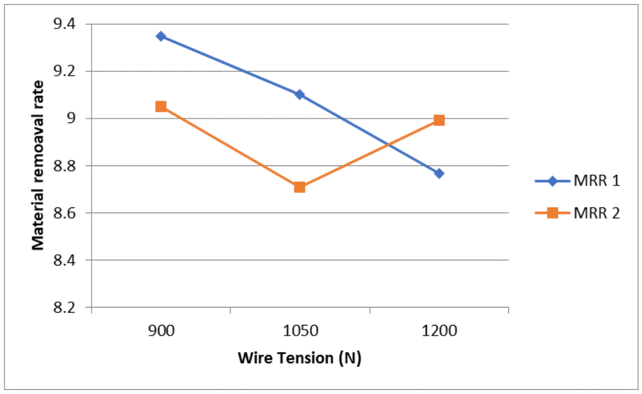

Figure 4.5 Variation of MRR with WT

The Variation of MRR with Wire tension is shown in figure 4.5. it is observed that with increase in wire tension there is slow decrease of MRR in Sample 1 but whereas, in sample 2 there is a sudden decrease. In sample 1 with further increase of wire tension there is increase in MRR. In sample 1 there is a less concentration of Silicon Carbide which initially does not support for conduction which leads to decrease in MRR.

b) Variation of MRR with Pulse ON Time

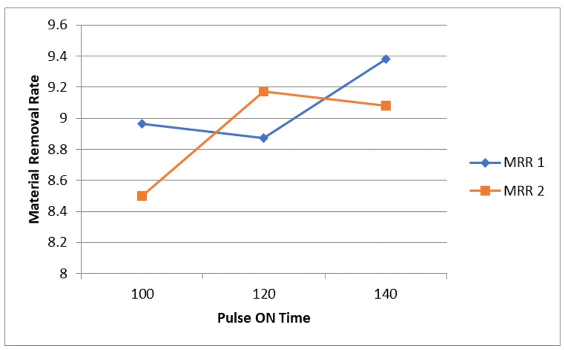

Figure 4.6 Variation of MRR with TON.

The Variation of MRR with Pulse on time is shown in figure 4.6. In Sample 1, with increase in pulse ON there is slow decrease n MRR, Then with further increase of Pulse ON Time there is sudden increase in MRR, Whereas, In Sample 2 with increase in Pulse ON Time there is a large increment in MRR. Then there is a decrease in MRR with increase of pulse ON.

c) Variation of MRR with Pulse OFF Time

The Variation of MRR with Pulse off time is shown in figure 4.7. In sample 1, with increase of pulse OFF, initially there is increase in MRR, Then decreases. The same trend is followed in sample 2.

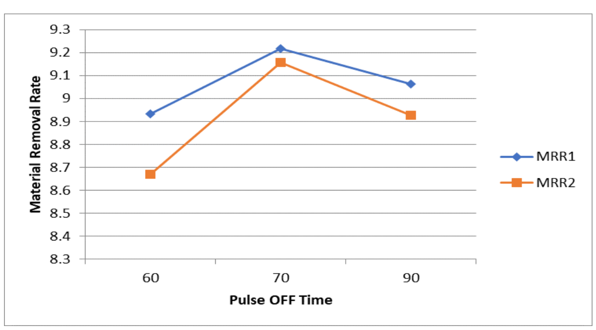

Figure 4.7 Variation of MRR with TOFF.

D. Effect of Input Parameters On Material Removal Rate (MRR)

a) Variation of Surface Roughness with WT

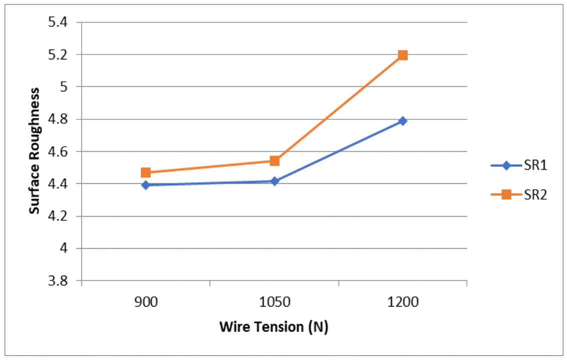

Figure 4.8 Variation of Surface Roughness with WT.

The variation in surface roughness with Wire tension is shown in Fig. 4.8.In sample 1, initially there is slow growth in surface roughness with increase in wire tension, thereby there is a sudden increase in roughness of the surface. Sample 2 also follows the same trend, whereas the variation is larger than sample 1.

b) Variation of Surface Roughness with TON

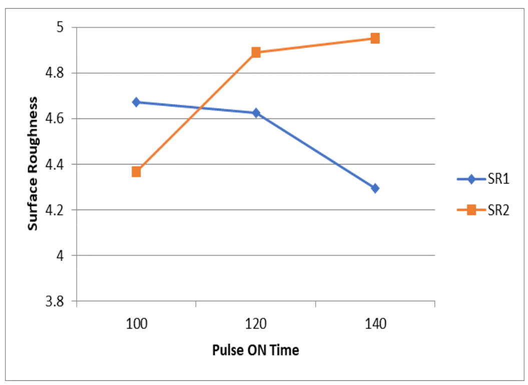

Figure 4.9 Variation of Surface Roughness with TON

The variation in Surface roughness with Pulse on time is shown in Fig 4.9. In sample 1, surface roughness decreases with increase in pulse ON time, whereas in sample 2, reverse of the trend happens.

c) Variation of Surface Roughness with TOFF

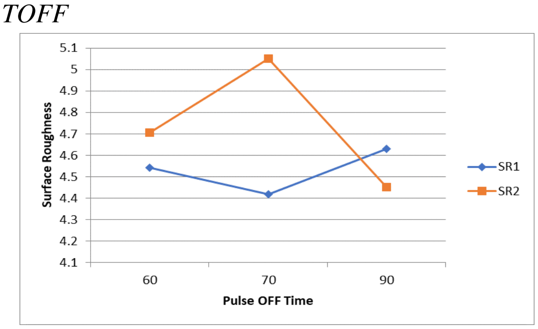

Figure 4.10 Variation Of Surface Roughness with TOFF

The variation in Surface roughness is shown in figure 4.10. In sample 1, there is decrease in surface roughness with pulse OFF time initially, but further increase of pulse OFF time increases the roughness. Whereas, In sample 2 initially there is increase in roughness and further decreases.

V. CONCLUSIONS

1) It Has Been Observed That Increase In The Percentage Of Silicon Carbide In Al7075 Leads To Improve Its Strength And Toughness.
2) The Machining Of Al7075 Wit 5% Of Silicon Carbide Is Much Easier Than Al7075 With 10% Of Silicon Carbide In Wedm Because Of Irregularities In The Composition Leads To Less Conduction Of Electricity Which Makes It Difficult For Machining.
3) It Is Observed That Wire Tension Plays A Vital Role In Machining Among The Three Chosen Parameters.
4) It Is Observed That The Pulse On Time Plays A Vital Role In Getting Good Surface Finish.

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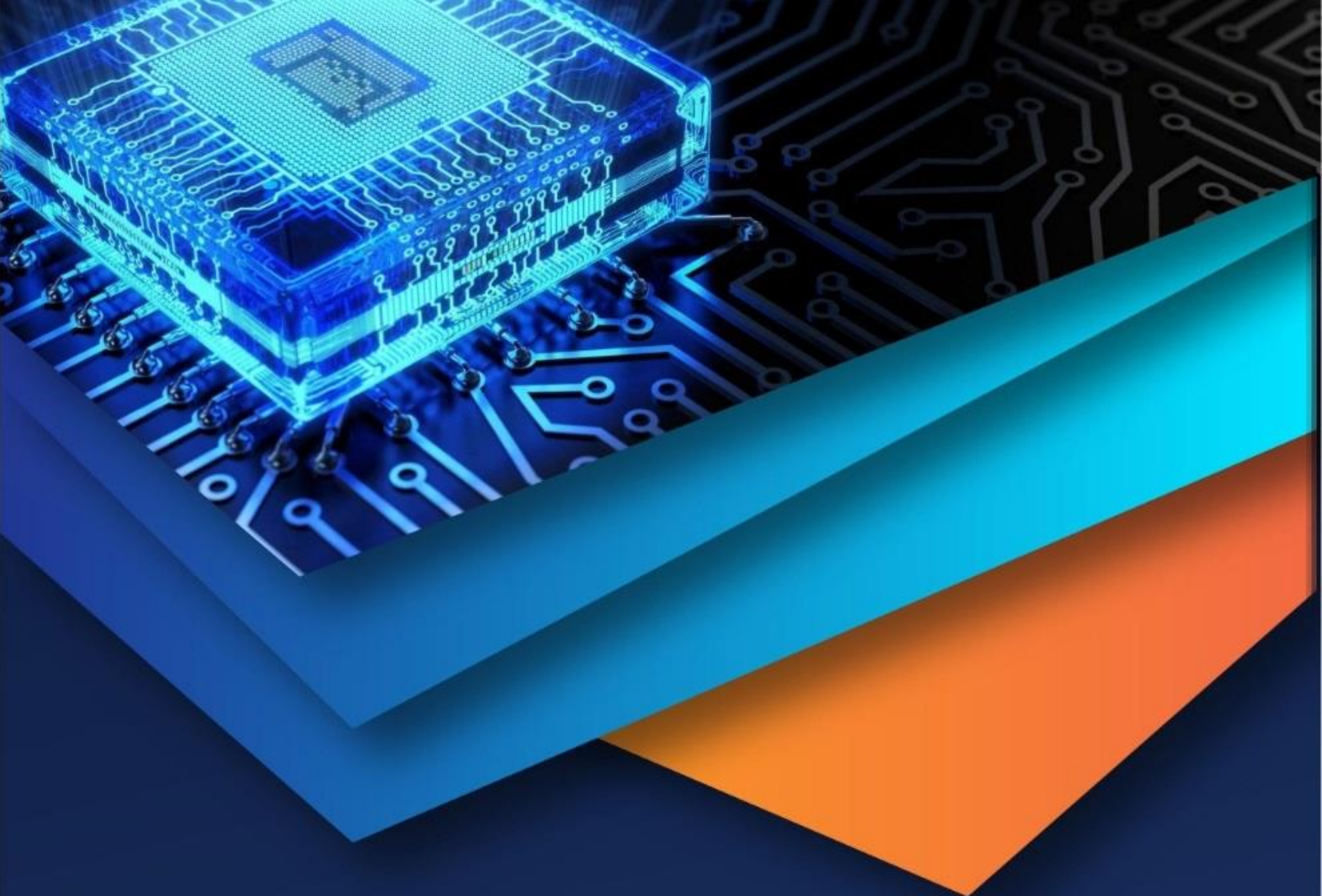

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