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A COMPARISION STUDY BETWEEN WIRE CUT EDM AND POWDER MIXED EDM

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ABSTRACT

This paper investigates the multifaceted nature of EDM processes for various types of materials and a range of applications by conducting two experiments. The first experiment on PMEDM of BeCu alloys examines the effect of gap current and powder concentration on MRR. It was observed that increment of both parameters leads to higher MRR values due to more intense spark formation and the energy density contribution from powder particle addition. The second experiment is focused on WEDM of a hybrid aluminum matrix composite (Al2024/Al2O3/W), with the objective of minimum dimension deviation. This article discusses the influence of cryogenically treated wire electrodes and various machining parameters on dimensional accuracy. Results show that the cryogenically treated wires had greatly minimized the dimensional errors, especially length, vertex angle, and curvature radius, compared to the untreated wires. The authors have emphasized that PMEDM experiment aims for maximum material removal in order, whereas WEDM experiment aims at high dimensional accuracy. These unique goals illustrate the versatility of EDM processes in addressing the specific machining needs for various material requirements.

Keywords: Wire Cut EDM, Powder Mixed EDM, MRR, Surface finish, Dimensional Accuracy.

I. INTRODUCTION

Electrical Discharge Machining, commonly abbreviated as EDM is one of the non-traditional machining processes applied in shaping various metals of high hardness to achieve very precise components. It works by wearing out material from a workpiece through a series of electro-discharges (sparks) between the tool and workpiece. The process occurs in the presence of dielectric fluid that cools the tool and aids in the removal of debris.

Among these machinable processes for cutting of hard-to-cut materials such as carbide, hardened steel, and titanium beside complex shapes with very fine details or features, EDM is one of the most efficient. Standard kinds of EDM include die-sinking EDM for making complex shapes and wire-cut EDM for clean cuttings of deep punctures with intricate designs. Its precision and ability to work on materials not easily obtainable by means of standard machining make it have widespread applications in aerospace, automotive industries and other tool and die manufacturing industries.

Electric discharge machining-EDM is a general term for the general types of processes developed for the precise machining and shaping of a wide range of materials, often provided in contour forms unattainable by traditional means. Among these is a pair of special kinds: Wire Cut EDM and Powder Mixed EDM.

The EDM 'Wire Cut' process specializes in fabricating complex profiles and contours in electrically conductive workpiece materials with a thin wire as a tool. It is very precise and useful to make complex parts with intricate forms, such as for dies, gears, aerospace components, to mention a few. It is especially valuable for materials that are difficult to cut by other traditional machining methods.

Basically, Powder Mixed EDM enhances the characteristics of traditional EDM by incorporating fine powders within the dielectric fluid. This alters the discharge behavior and results in an improved MRR, higher surface qualities, and reduced heat-affected zones. The process is utilized in cases requiring high accuracy and superior surface finishes such as aerospace, automotive, and mold manufacturing.

These two advanced EDM techniques show capabilities and flexibilities of modern manufacturing in EDM processes, where highly precise components with complex geometries can be produced and their performance will be enhanced.

II. METHODOLOGY

Experimental validation of powder mixed electric discharge machining (PMEDM) of BeCu alloys

Materials used for the experiment

The experiment utilizes a number of crucial materials required in the PMEDM process. The workpiece, or object to be machined, is made of a beryllium copper (BeCu) alloy. This alloy consists of high strength, nonmagnetic properties, and resistance properties against wear, corrosion, and fatigue. One key property of it is that it won't spark. That's why it's typically used for hazardous environment tools and very precise measuring instruments. These properties, however, lead to difficulties in machining this material using conventional methods, which is why PMEDM was used. The Physical, mechanical and chemical properties of Be-Cu(Beryllium copper) was shown in the Table 1.

Table 1: Properties of Be-Cu [5]

Copper	97.9
Beryllium	1.9
Co + Ni	0.2
Density	8.25 g/cc
Tensile strength, ultimate	1210 MPa
Tensile strength, yield	1030 MPa
Melting point	865 °C

Table 2: Properties of copper [5]

Copper	99.9%
Density	8.94 g/cc
Tensile strength, ultimate	220.632 MPa
Tensile strength, yield	68.947 MPa

The tool electrode, that portion of the electrode through which electrical discharges are given to the workpiece is made of electrolytic copper. Electrolytic copper is used because of the high thermal conductivity; therefore, it can easily transfer heat for the machining process. In the Table 2 the Physical, mechanical and chemical properties of copper was shown.µ

Commercial EDM oil seems probable as the dielectric fluid surrounding the workpiece and tool electrode, though this is not stated to be the source. To that dielectric fluid, aluminum oxide (Al2O3) powder of 150 µm particle mesh size has been added. This adds to the powder mixture for high-speed removal of material during the PMEDM process.

Wire Cut EDM

This paper deals with minimizing dimensional deviations for wire electric discharge machining of a squeeze casted hybrid aluminum matrix composite. The investigation work shall examine the impact of cryogenically treated wire electrodes and machining variables upon dimensional accuracy through a sensible mix of experimentation and statistical methods. This paper is expected to publish the following material preparation methods as follows.

Material Composition:

Table 3: Chemical composition of Al2024/W [10]

Chemical composition of composite material Al2024/Al_2O_3/W.

Elements	Reinforcement particles		Base alloy (Al2024)						
	Al_2O_3	W	Ti	Ni	Si	Mn	Mg	Cu	Al
Wt%	3	1.5	0.02	0.03	0.15	0.60	1.21	3.84	Balanced

Workpiece Material Preparation:

The workpiece material that the investigation is made on was a high performance hybrid Aluminum Matrix Composite fabricated by squeeze casting and selected Al2024 aluminum alloy as the matrix alloy to which 3wt% aluminium oxide (Al2O3) particles of average size 10 nm and 1.5wt% tungsten (W) particles of average size 200 nm are added. First, the Al2O3(Aluminum oxide) and W(Tungsten) particles were preheated at 950°C for 3 hours to enhance the wettability in the molten aluminum. In parallel with this, Al2024 was melted in the electric resistance furnace at a superheat temperature of 825°C. A twofold stirring mechanism provided homogeneous dispersion of the preheated Al2O3 and W particles in the molten Al2024 without forming bundle(bunch). The molten mixture was then cast into a preheated metallic die at 225°C. With the highest pressure of up to 100 MPa applied for 2 minutes, this mixture will thus be solidified in the die.

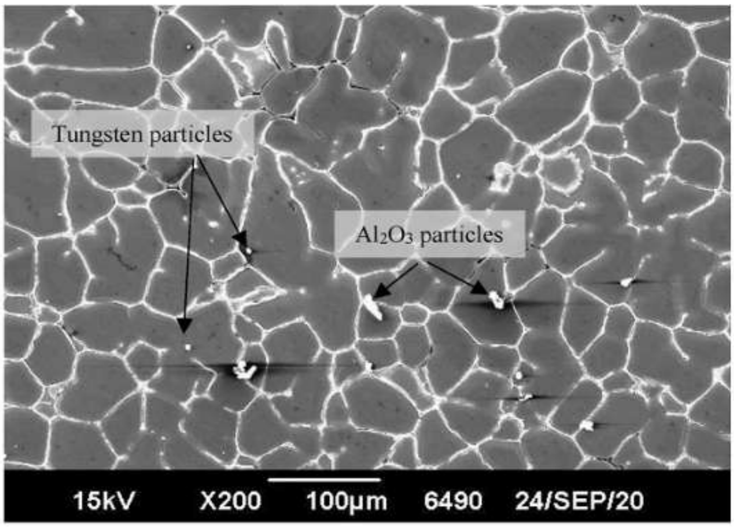

Figure 1: Microstructure of Al2O3 [10]

From the microstructural analysis, a cylindrical billet of the height 140 mm and diameter 56 mm was produced with uniform distribution reinforcement particle. The billet was then machined into slices of a thickness of 10 mm for the experiments in WEDM. The manufactured AMC had a hardness of 165 HV along with a tensile strength of 441 MPa, establishing its superior mechanical properties.

Electrode Treatment and Selection:

The investigation here focuses on enhancing the dimension accuracy of WEDM on cutting a challenging material, squeeze-casted hybrid aluminium matrix composite (Al 2024/Al2O3/W). The cryogenic treatment effect on zinc-coated brass wire electrodes was investigated specifically. Zinc-coated brass wire electrodes were chosen because it was highly utilized in WEDM. They treated these electrodes cryogenically to enhance their performance. It is a treatment process where they expose the electrode to extremely low temperatures for a long time, 24 hours, to a temperature of -70°C. The cryogenic treatment is meant to enhance the electrical conductivity and microstructural stability of the electrode. Improved electrical conductivity due to the removal of micro-cavities in the wire's microstructure causes smoother flow of electrons. The electrical conductivity improved by 24.8% in the cryogenically treated electrodes, reaching 15.6 × 10⁶ S/m; the electrical conductivity for the untreated wires is 12.5 × 10⁶ S/m. The paper compares the performance of these cryogenically treated wires with their untreated counterparts, zinc-coated brass wires and evaluates their effect on the dimensionally accurate hybrid AMC made through WEDM.

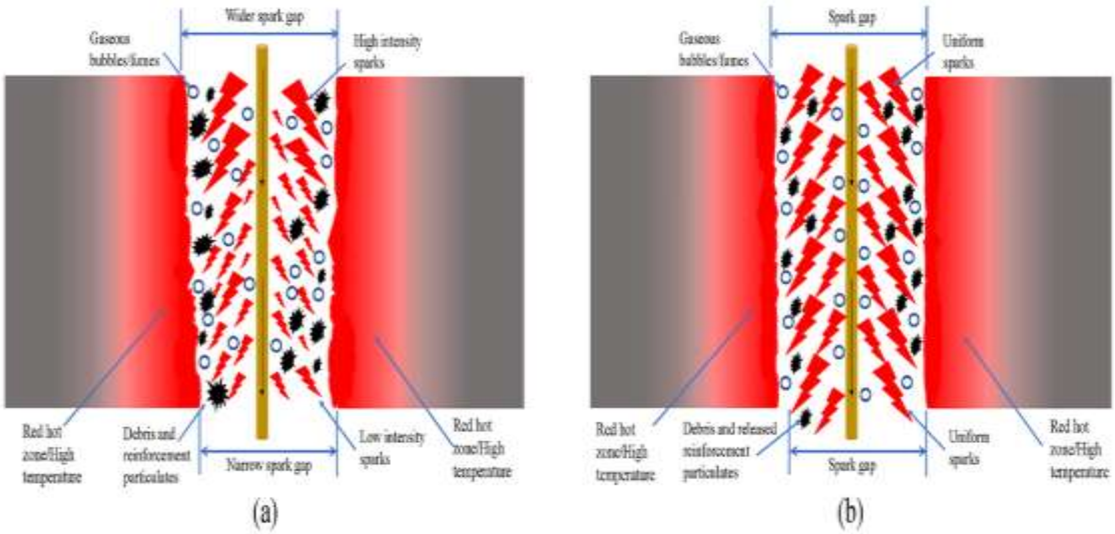

Figure 2: Spark mechanism (a) Non treated (b) Cryogenic treated wires [10]

Table 4: Machining variables [10]

Variables	Definition	Ranges
Pulse duration (T_{ON})	The time gap in which sparks are produced	1-5 µs
Wire feed rate (V_R)	The rate at which wire goes through the directed path in the transverse direction of cutting	10-16 m/min
Wire runoff speed (V_W)	Wire velocity along the longitudinal direction of the specimen	5-11 m/min
Wire tension (T_W)	Mechanical stress maintained in the wire	4-10 g

Table 5: Constant machining parameters [10]

Machining parameters	Description
Pulse off time (µs)	26
Dielectric flushing pressure (Kg/cm^2)	4.5
Gap voltage (V)	45
Servo voltage (V)	48
Dielectric fluid	Water: Resin (MBQR400) = 30:1

Experimental procedure:

Powder Mixed EDM

The experimental setup of PMEDM for BeCu alloys was developed to find the effect of gap current and powder concentration on material removal rate. The researchers decided to take BeCu alloy for conducting the experimentation since BeCu is characterized by high strength, non-magnetic properties, good wear and corrosion resistance, high fatigue strength, and their non-sparking properties make it challenging to machine conventionally. Electrolytic copper, having rather high thermal conductivity was chosen as the tool electrode material. Samples in the form of work pieces of dimensions 30 mm x 20 mm x 20 mm and copper tool electrode dimensions are h3 mm x 90 mm. The conditions should follow to conduct the experiment was shown in the table7.

Table 6: Materials used in experiment [5]

Work piece material	BeCu alloys
Tool electrode	Copper rod
Dielectric medium	Commercial EDM oil
Gap current (A)	8, 10, 12, 14
Powder concentration (g/l)	2, 4, 6

The die-sinking electric discharge machine used in the machining process was an Electronic make, which machined a square hole 5 mm deep in each workpiece of BeCu. Commercial EDM oil used as the dielectric medium contained aluminium oxide Al_2O_3 powder with a particle mesh size of 150 mm. A stirrer and a separate flush

pump with 18 W were also supplied to make sure the powder is uniformly distributed and debris is efficiently removed. The gap current was varied by four values: 8, 10, 12, and 14 A, whereas the powder concentration varies from three values: 2, 4, and 6 g/l, and the remaining other parameters such as gap voltage is constant as 55 V, pulse on time: 38 ms, pulse off time: 7 ms, and flushing pressure is constant as 0.5 kg/cm^2. MRR is evaluated using the weight difference of the workpiece before machining and after from the workpiece density and machining time. With this holistic approach, it was possible to intensely study the performance of PMEDM on BeCu alloys.

Wire Cut EDM

Response Surface Methodology: RSM is a statistical technique that describes and designs experiments and analyses the relationship between multiple input variables and output responses.

Box-Behnken Design: One of the specific RSM designs adopted in this study was the Box-Behnken design. It has ample efficiency and can estimate the effects of the individual variables along with interaction.

Four main machining parameters were taken into consideration:Pulse Duration (TON): The time of generation of sparks between 1 and 5 µs.

Wire Feed Rate (VR): The velocity of down-working along the work piece between 10 to 16 m/min

Wire Runoff Speed (VW): The velocity at which wire travels longitudinally, between 5 and 11 m/min

Wire Tension (TW): The mechanical tension put on wire during feeding and is in the range of 4 to 10 g.

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This design led to 30 experiments for each of the NT and CT types of wire electrodes, resulting in a total of 60 experiments.

III. RESULT ANALYSIS

Powder Mixed EDM

The gap current and the powder concentration study on Material Removal Rate (MRR) in Powder Mixed Electric Discharge Machining of Beryllium Copper (BeCu) alloys were investigated. An Electronic make die-sinking electric discharge machine was used to machine a square hole with a depth of 5 mm in each workpiece of BeCu. The gap current is varied at 8, 10, 12, and 14 A, and the powder concentration in the mixture at 2, 4, and 6 g/l, keeping all the other parameters constant for instance, gap voltage 55 V, pulse on time 38 ms, pulse off time 7 ms, and flushing pressure 0.5 kg/cm². The Table 4 shows the Material Removal Rate obtained from the experiment.

Table 7: MRR obtained from experiment [5]

Sr. no.	Gap current (A)	Powder conc. (g/l)	MRR (mm^3/min) (Expt.)
1	8	2	3.965
2	10	2	4.400
3	12	2	5.373
4	14	2	5.575
5	8	4	6.324
6	10	4	8.162
7	12	4	14.427
8	14	4	17.176
9	8	6	3.926
10	10	6	5.898
11	12	6	9.591
12	14	6	14.417

The machining time, the difference in weight of workpiece, and the density of the workpiece were used to calculate the MRR. Results obtained showed that increase in gap current and powder concentration made MRR increase. This is because the increased gap current results in a more significant spark that melts and vaporizes more materials. Similarly, for a given powder concentration, an increase in the powder concentration further increases the number of particles in the spark gap, thus increasing collisions and energy density, thereby increasing material removal.

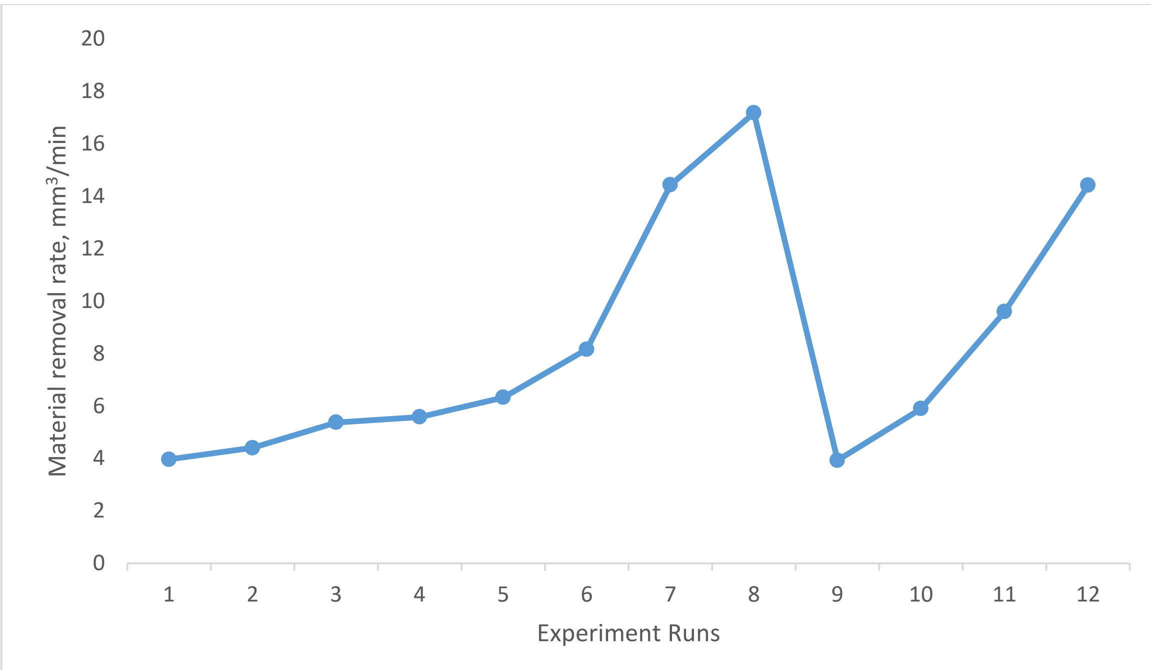

Figure 3: MRR for the experiments [5]

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Wire Cut EDM

Analysing the Influence of Machining Variables and Electrode Treatment.

The numerous analyses are done to realize how various machining parameters and cryogenic treatment of wire electrodes influence the dimensional accuracy of machined hybrid aluminum matrix composite (AMC) specimens. Here is an explanation of each analysis in detail:

1. Parametric Effect Analysis

This analysis included visually looking at the trends and patterns of dimensional errors in machined specimens with regard to variation of each of the four machining variables. Among these three major dimensional errors, there were two from the substantial machinability aspects. These were,

Length Error: The difference between the designed length and the actual machined length of the cone-shaped specimen.

Vertex Angle Error: The amount that the machined vertex angle differs from the desired designed angle.

Curvature Radius Error: The difference between the designed value, and the actual measured radius of curvature of the curved section of the cone.

The four parameters considered in the machining phase are:

Pulse Duration (TON), Wire Feed Rate (VR), Wire Runoff Speed (VW), Wire Tension (TW)

The graphed figures to see these relationships for both the NT and CT wire electrodes. This way, they could look for trends related to the changes in their variables with respect to dimensional errors. For example, they observed that increasing pulse duration at first reduces errors then sharply increases past this value. This implied that there existed an optimal pulse duration for minimizing the dimensional deviations.

2. Total Surface Analysis:

This analysis incorporated an optical examination of the machined surfaces of the specimens in order to understand the correlation of the surface characteristics with the measured dimensional errors. Specimens were imaged using a digital microscope over those showing the minimum and the maximum magnitude of dimensional errors. It was possible, based on this analysis, to see

Cutting Alignment: The proximity of the actual cutting path taken by the wire electrode to the intended path.

Material Removal Patterns: The patterns found as the machining parameters affected the amount of material that could be removed from the workpiece and how that material would leave the workpiece.

Surface Defects: Craters, voids, and other irregular features found on the machined surfaces. By comparing the surface characteristics of specimens with various dimensional errors, they could visually assess the influence of the machining variables and the treatment of the electrode on the cutting process and the quality of the surface built.

Table 8: Experimental results with non treated and cryogenic treated wires [10]

Exp. No.	Machining variables				Response measures					
					Non treated brass wire			Cryogenic treated brass wire		
	Pulse duration	Wire feed rate	Wire runoff speed	Wire tension	Length error	Vertex angle error	Curvature radius error	Length error	Vertex angle error	Curvature radius error
	µs	m/min	m/min	g	mm	°	mm	mm	°	mm
1	1	10	8	7	0.781	0.823	0.768	0.394	0.494	0.479
2	5	10	8	7	0.976	0.957	0.741	0.441	0.599	0.429
3	1	16	8	7	0.476	0.562	0.499	0.257	0.399	0.323
4	5	16	8	7	0.909	0.807	0.842	0.377	0.457	0.482
5	3	13	5	4	0.651	0.456	0.508	0.214	0.376	0.281
6	3	13	11	4	0.461	0.367	0.548	0.159	0.219	0.375
7	3	13	5	10	0.419	0.166	0.524	0.120	0.190	0.354
8	3	13	11	10	0.238	0.163	0.324	0.093	0.227	0.199
9	1	13	8	4	0.646	0.644	0.555	0.266	0.374	0.355
10	5	13	8	4	1.261	0.872	0.831	0.474	0.461	0.456
11	1	13	8	10	0.528	0.474	0.585	0.284	0.290	0.302
12	5	13	8	10	0.645	0.635	0.573	0.249	0.376	0.364
13	3	10	5	7	0.689	0.660	0.631	0.252	0.391	0.379
14	3	16	5	7	0.504	0.388	0.527	0.178	0.329	0.329
15	3	10	11	7	0.574	0.549	0.551	0.189	0.375	0.335
16	3	16	11	7	0.349	0.249	0.464	0.129	0.224	0.312
17	1	13	5	7	0.584	0.611	0.638	0.307	0.382	0.437
18	5	13	5	7	0.992	0.846	0.741	0.424	0.507	0.418
19	1	13	11	7	0.529	0.476	0.503	0.280	0.318	0.326
20	5	13	11	7	0.772	0.619	0.760	0.316	0.425	0.454
21	3	10	8	4	0.699	0.683	0.558	0.235	0.413	0.302
22	3	16	8	4	0.678	0.429	0.578	0.177	0.283	0.384
23	3	10	8	10	0.554	0.546	0.545	0.170	0.304	0.374
24	3	16	8	10	0.242	0.242	0.336	0.099	0.195	0.197
25	3	13	8	7	0.571	0.562	0.482	0.182	0.370	0.331
26	3	13	8	7	0.580	0.559	0.494	0.183	0.359	0.322
27	3	13	8	7	0.562	0.537	0.471	0.193	0.349	0.327
28	3	13	8	7	0.543	0.549	0.518	0.194	0.363	0.326
29	3	13	8	7	0.530	0.575	0.469	0.190	0.351	0.336
30	3	13	8	7	0.525	0.542	0.465	0.188	0.356	0.323

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3. Microscopic Analysis

This analysis concerned the observation of machined surface morphology, primarily for microscopic defect definition and correlation thereof with machining parameters and type of wire electrode used. The microscopy examination of the specimens surface machined under different conditions was carried out at a very high magnification of microscope. Researchers could, therefore, observe:

Crater Size and Distribution: The size, shape, and distribution of craters that form on the surface as a result of the spark discharges.

Micro-voids: Presence of tiny voids inside the material; this may be due to uneven removal of material or due to some material defect.

Surface Roughness: The overall texture and smoothness of the machined surface.

This would have given them an insight into what exactly cryogenic treatment was doing to the material removal process and the eventual quality of surfaces.

For example, they mentioned craters tended to be deeper in size, and also that macrovoids were more likely to be found under the NT wires as opposed to the CT wire. Hence, it indicates lesser controlled material removal in the case of NT wires.

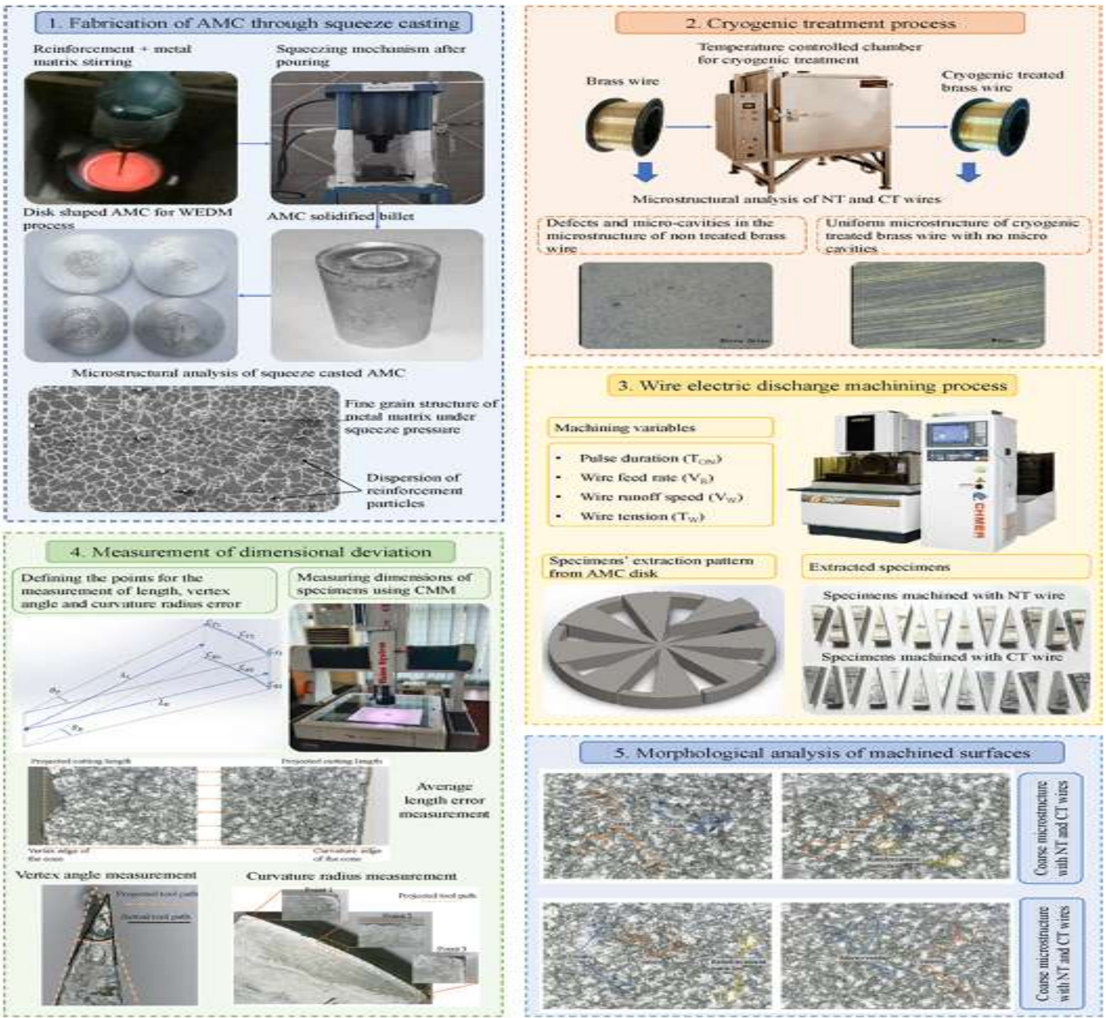

Figure 4: Experimental procedure and Microstructure Analysis of Machined Surfaces [10]

4. Analysis of Variance (ANOVA) :

ANOVA is an analytic method that applies statistics to determine the effect of various factors and their interaction on the measured response. In this case, this study applied ANOVA to analyze the impact of the four machining variables: TON, VR, VW, TW on the three-dimensional errors, namely, length, vertex angle, and curvature radius and both NT and CT wire electrodes.

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The ANOVA results, depicted in Table 9, showed the following information:

Table 9: Analysis of variance showing different types of errors [10]

Source	Length error				Vertex angle error				Curvature radius error			
	NT wire		CT wire		NT wire		CT wire		NT wire		CT wire	
	p-value	% Contr.	p-value	% Contr.	p-value	% Contr.	p-value	% Contr.	p-value	% Contr.	p-value	% Contr.
Model	<0.001	98.42	<0.001	99.32	<0.001	99.16	<0.001	98.88	<0.001	99.25	<0.001	99.58
T_{ON}	<0.001	25.12	<0.001	6.89	<0.001	10.66	<0.001	10.52	<0.001	14.24	<0.001	6.18
V_R	<0.001	7.72	<0.001	6.11	<0.001	19.27	<0.001	15.44	<0.001	5.40	<0.001	4.51
V_W	<0.001	5.21	<0.001	3.23	<0.001	6.77	<0.001	4.88	<0.001	2.44	<0.001	2.38
T_W	<0.001	19.46	<0.001	7.12	<0.001	8.36	<0.001	9.60	<0.001	8.57	<0.001	5.43
$T_{ON} \times V_R$	0.006	1.06	0.006	0.45	0.034	0.30	0.108	0.22	<0.001	7.37	<0.001	8.01
$T_{ON} \times V_W$	0.044	0.51	0.003	0.56	0.076	0.20	0.535	0.03	0.004	0.38	<0.001	3.99
$T_{ON} \times T_W$	<0.001	4.62	<0.001	5.04	0.188	0.11	0.987	0.00	<0.001	4.48	<0.001	1.50
$V_R \times V_W$	0.602	0.03	0.577	0.01	0.567	0.02	0.006	0.77	0.596	0.01	0.042	0.14
$V_R \times T_W$	0.001	1.58	0.563	0.02	0.317	0.06	0.450	0.04	<0.001	2.82	<0.001	12.36
$V_W \times T_W$	0.906	0.00	0.143	0.11	0.099	0.17	<0.001	3.65	<0.001	3.07	<0.001	11.42
T_{ON}^2	<0.001	27.02	<0.001	60.07	<0.001	28.25	<0.001	25.36	<0.001	44.80	<0.001	35.20
V_R^2	0.156	0.23	0.006	0.47	0.011	0.48	0.002	1.05	<0.001	2.75	<0.001	1.04
V_W^2	0.001	1.98	0.002	0.64	<0.001	9.65	<0.001	4.85	0.116	0.14	0.573	0.01
T_W^2	0.0564	0.45	<0.001	2.35	<0.001	7.27	<0.001	14.80	<0.001	1.20	<0.001	3.57
Model summary												
R^2	0.9842		0.9932		0.9916		0.9888		0.9925		0.9958	
$R^2_{Adjusted}$	0.9694		0.9868		0.9838		0.9784		0.9855		0.9919	
$R^2_{Predicted}$	0.9170		0.9640		0.9560		0.9407		0.9691		0.9802	
Adq. precision	36.134		46.662		49.351		42.211		47.981		65.536	

Significance of Each Variable: In terms of whether a specific machining variable had a statistically significant effect on the dimensional error, which was determined by the p-value. Here, a p-value less than 0.05 will indicate that it is statistically significant.

Contribution Percent: It is the contribution percent of each variable towards the overall variation of the dimensional error. This was helpful in establishing the most influential variables.

Significance of Interactions: Whether interaction of two or more variables was individually significant or not. This aspect helped understand whether some variations of variable combinations were more prone to indicating a higher dimensional accuracy than others.

Results of ANOVA analysis. Pulse duration and wire tension were the most critical factors influencing errors in length and curvature radius. The most significant effect on the vertex angle error, the pulse duration, and the rate of feed of the wire were related.

5. Qualitative Comparison of Electrodes:

Although the previous analyses brought out some qualitative and statistical evidence for the differences between NT and CT wire electrodes, the authors carried out a quantitative comparison as well to more firmly establish the conclusion. In this respect, the dimensional errors realized with the two types of electrodes were compared at the centre point conditions of the experimental design such as TON = 3 µs, VR = 13 m/min, VW = 8 m/min, and WT = 7 g, as shown in Figure 16.

This comparison indicated that, generally, CT wires were consistently associated with lower dimensional error values than those of NT wires. The percentage reductions were 65.5% in length errors, 35.3% in vertex angle errors, and 33.4% in curvature radius errors. This quantitative analysis presented strong evidence that the cryogenic treatment of the wire electrodes can significantly improve the dimensional accuracy of WEDM in hybrid AMC.

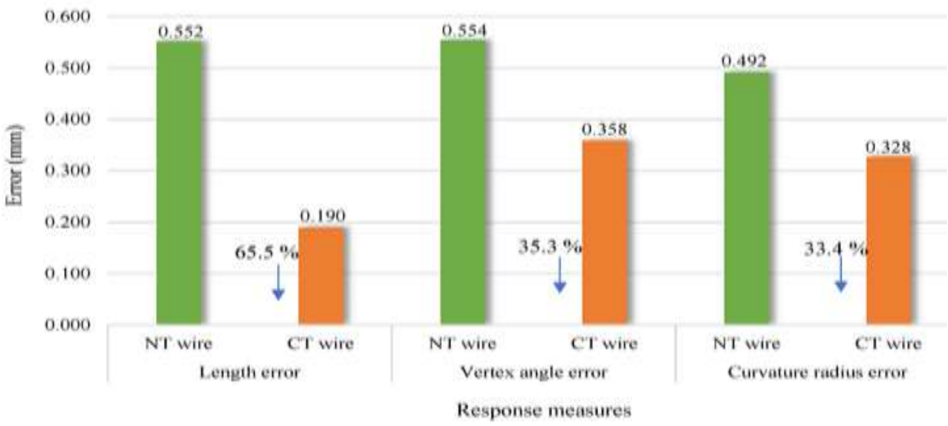

Figure 5: Quantative Analysis of Dimensional errors for two different electrodes [10]

IV. COMPARATIVE ANALYSIS:

PMEDM of BeCu Alloys

Powder Mixed EDM involves an experiment that investigates how gap current and powder concentration affect Material Removal Rate (MRR) in PMEDM of BeCu alloys.

Key Findings: With the gap current and powder concentration, MRR increased. According to researchers, this is due to the material removed being melted and vaporized by the higher intensity of the spark created by increased gap current and the number of powder particles in the spark gap contributing to a higher number of collisions; therefore, more energy density contributes to an increase in material removal.

Wire Electric Discharge Machining of Hybrid Aluminum Matrix Composite

This study is to reduce the dimensional errors in WEDM of a squeeze cast hybrid aluminum matrix composite (Al 2024/Al2O3/W). In this study, investigation of cryogenically treated wire electrodes and different machining parameters on dimensional error was done.

Key Findings: The results showed that cryogenically treated (CT) wire electrodes resulted in significantly lower dimensional errors compared to untreated (NT) wires. It is of particular interest that significant reductions occurred in the dimension errors of length (65.5%), vertex angle (35.3%), and curvature radius (33.4%) using CT wires. This implies that cryogenic treatment of wire electrodes can significantly improve the dimensional accuracy of WEDM in hybrid aluminum matrix composites.

Comparison of the Two EDM Processes

Material: The workpiece in the PMEDM experiment was BeCu alloy characterized by high strength, non-magnetic properties, resistance to wear, corrosion, and fatigue. In contrast, the workpiece used for the experiment in WEDM was a squeeze-casted hybrid aluminum matrix composite Al 2024/Al2O3/W.

EDM Type: PMEDM involves adding fine powder to the dielectric fluid, influencing discharge behavior and improving MRR, surface quality, and reducing heat-affected zones. In contrast, WEDM utilizes a thin wire as the tool to fabricate complex profiles and contours in electrically conductive materials.

Focus: The PMEDM experiment was conducted mainly to study the effect of gap current and powder concentration on MRR. In contrast, the WEDM experiment was designed with the objective to reduce dimensional deviations and examine, in detail, the effect of cryogenically treated wire electrodes and other machining parameters on dimensional accuracy.

Analysis Methods: There were distinct analysis methods in the two studies. The PMEDM experiment mainly focused on observing a relationship between varied parameters such as gap current and powder concentration and MRR. The WEDM experiment was significantly analytical including parametric effect analysis, total surface analysis, microscopic analysis, and Analysis of Variance (ANOVA) to determine the effect of machining variables and electrode treatments on dimensional accuracy.

Overall, both experiments show that EDM processes are versatile and can be applied to different materials to achieve specific requirements. The PMEDM process shows the possibility of increasing the material removal rate using powder additives, while the WEDM experiment highlights the significance of treating the electrode and machining conditions to realize high-dimensional accuracy.

V. CONCLUSION

Studies covered in the available sources clearly elucidate the flexibility of EDM processes for a range of materials and end products. In the PMEDM test, it is possible to show how fine powder added to the dielectric fluid leads to material removal rate increases by charge distribution modification and consequently energy density enhancement. This method can be further used for processing challenging-to-machine BeCu alloys. In contrast, the WEDM experiment underlines the importance of the cryogenically treated wire electrodes to ensure higher dimensional accuracy, especially when machining complex geometries in hybrid aluminum matrix composites. The cryogenic treatment enhances the electrical conductivity property of the wire and thereby yields a smoother material removal process and lesser dimensional errors. Both experiments provide information on the capability of EDM processes in modern manufacturing and its adaptability. Depending upon the material as well as desired outcome, they provide possible solutions to achieve specific machining requirements, be it for material removal rate maximization or dimensional deviation minimization.

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