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# EXPERIMENTAL INVESTIGATION ON SUPERNI 90 SUPER ALLOY USING AL 7178 TOOL ON EDM UNDER BLENDED DI ELECTRIC VARIENT WITH DEEP LEARNING APPROACH

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**ABSTRACT** Significant non-ferrous metals encompass aluminum, copper, lead, nickel, chromium, manganese, magnesium, titanium, and zinc, in addition to brass alloys. Typically, minerals like carbonates, silicates, and sulphides are used to obtain them. Because of their advantageous qualities, due to their distinct features such as low weight (like aluminum), high conductivity (like copper), and resistance to corrosion (like zinc), non-ferrous materials are extensively used in various industries. Electrical Discharge Machining (EDM), a precise method of metal removal involving electric spark erosion, is a commonly employed technique. In the current work it is proposed to use Al 7178 alloy as electrode and the machinability of Aluminum alloy 7178 is to be analyzed on Nickel based alloy Superni90 as workpiece to investigate the Electrical Discharge Machining process, Measurements are made of Surface Roughness (SR), Tool Wear Rate (TWR), and Material Removal Rate (MRR). In consideration of the experimental data, regression models for MRR, SR, and TWR are created and deep learning approach is used for evaluation of circularity (geometrical accuracy) of the machined workpiece.

**Keywords**: Electric discharge machining, Current (I), Voltage (V), Material Removal Rate (MRR), Tool Wear Rate (TWR), Surface Roughness (SR), Pulse on Time (Ton), and Pulse off Time (Toff).

## 1. INTRODUCTION

EDM, or Electric Discharge Machining, has evolved over the past fifty years, with advancements in technology leading to increased cutting speeds and component accuracy. The process originated in 1770 with the discovery of the erosive effect of electric discharges. In the 1980s, Computer Numerical Control (CNC) improved efficiency, and modern EDM machines can operate around the clock under adaptive control system monitoring. EDM is now used in various industries, including automobile, fields include military aviation, aerospace, nuclear, food manufacturing, motorsports, medicine, and science. This research examines the literature on die sinking EDM machining of nickel-based super alloy materials. Super alloys based on nickel may include alloy additions of ruthenium, rhenium, cobalt, aluminum, titanium, chromium, and other elements. Using super alloys, it is possible to raise the working temperature from 1200F to 1300F. Superalloys composed of nickel are frequently employed in difficult settings such as chemical processing facilities, power-generation turbines, rocket engines, and aircraft engine components.

Modern technology has created a movement for lightweight materials throughout industries, particularly in the automobile and aerospace sectors. Numerous nations and businesses are devoting significant

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resources to investigating novel, highly-strengthened aluminum alloys. Their goal is to minimize material weight while preserving mechanical stability and overall structure resistance against corrosion, thereby substituting conventional materials like steel.
Al 7XXX alloys, which mostly included Zn element, may be reinforced by heat treatment. The Al-Zn-Mg alloy, which has magnesium added, is an aluminum alloy with good thermal deformation characteristics, a wide quenching range, and high strength and weldability. Under the right heat treatment circumstances, it can

It can achieve greater strength, improved welding performance, and improved corrosion resistance. To generate the Al-Zn-Mg-Cu alloy, Cu is added to the Al-Zn-Mg alloy. Compared to Al 2XXX alloys, sometimes known as ultra-high-strength aluminum alloys, it has a greater strength. The alloy's yield strength and tensile strength are almost equal. In contrast to the low flexibility and high-temperature strength, the specific strength is likewise quite high. At room temperature or lower than 120 degrees Celsius, it can be used as a load-bearing structural element. The alloy has excellent corrosion resistance, high toughness, and ease of processing.

So, in this paper, it is mainly focused on the Study of Superni90 Super Alloy Al7178 Tool material, The industries can benefit most from this material, which also assists engineers in choosing appropriate materials for certain uses.

## 2. EXPERIMENTAL PROCEDURE

A. EDM Process

The spark erosion process caused by EDM is similar to an electrical fault that results in a minuscule hole being burned into the metal it interacts with. To ensure the effectiveness of the EDM process, it is essential for both the workpiece and the electrode to be composed of materials that are capable of conducting electricity.

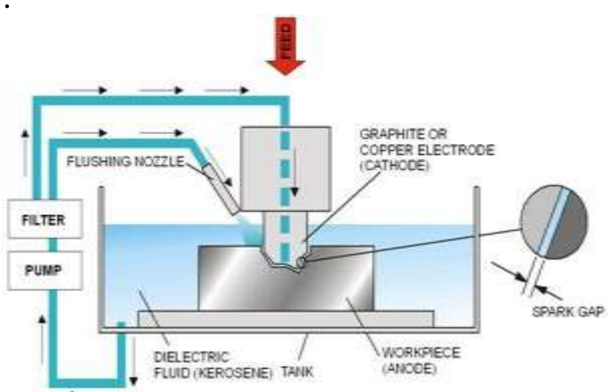


**Figure 1.** EDM Process

EDM is a method of controlled metal removal that utilizes electric spark erosion to eliminate metal. Throughout this procedure, an electric spark is used as the cutting tool to form the workpiece into the desired shape of the end product. The metal removal process entails delivering a pulsating (ON/OFF) high-frequency electrical charge through the electrode to the workpiece.

B. Aluminum 7178 Alloy

Aluminum, the world's most abundant and widely recognized metal, is the most widely used after steel. It is commonly used for foil and conductor links, but alloying with other components is essential for different applications. Aluminum alloy combinations are assigned by four digits: the primary digit identifies a main alloying component, the second identifies the starting composite, the third, and four individual compounds.

Aluminum 7178 alloy has exceptional uses in Aviation field, Automobile sector, and Structural industries. Subsequently in this study, Al 7178 alloy has been chosen for investigation.

C. Superni90 Super Alloy

Superalloys are alloys with exceptional creep and The material exhibits high mechanical strength at enhanced temperatures, along with exceptional surface stability, and resistance to oxidation and corrosion. Super alloys that are resistant to corrosion are commonly utilized in harsh conditions where the ability to withstand intense heat and corrosion is crucial for maintaining the integrity of the final product. These super alloys They are extensively utilized in the oil and gas, power generation facilities, aerospace industry, as well as chemical and petrochemical sectors processing industries.

Super alloys based on nickel are a unique category of high-performance alloys distinguished by a notable concentration of nickel. Nickel-based super alloys differ from one another primarily in their composition, which is tailored to yield particular qualities based on the intended application.

| **S. No.** | **Property** | **Metric System** |
|---|---|---|
| 1 | Density | 8.18g/cm$^3$ |
| 2 | Melting point Temperature | 850$^o$C |
| 3 | Tensile Strength | 1010MPa |
| 4 | Yield Strength | 755MPa |

**Table 1.** Properties of Superni90 work material

**Figure 2.** Superni 90.

D. Surface Roughness (Ra)

SR(Ra) is a measure of floor texture, based on deviations in the path of a surface's regular vector from its perfect shape. Large deviations indicate hardness, while small deviations indicate ease. Surface metrology typically considers roughness as high-frequency, brief-wavelength aspects of a measured floor. However, in exercise, understanding both amplitude and frequency is crucial to ensure a floor is suitable for a specific purpose.


**Figure 3.** Mitutoyo Surface Roughness Tester

E. Deep Learning (DL)

DL (Deep Learning) is a machine learning technique that combines representation learning with artificial neural networks. Supervised, semi-supervised, or unsupervised methods are possible. Various deep learning designs include convolutional neural networks, recurrent neural networks, and deep reinforcement learning. intricate neural networks, intricate belief networks, have been applied across numerous domains, yielding results that match or surpass human expert performance levels.

Deep learning involves the utilization of numerous layers within the network, which is commonly referred to as "deep." Earlier studies have demonstrated that a universal classifier can be developed using a nonpolynomial activation function with an unbounded width hidden layer. A more recent approach, known as deep learning, focuses on an infinite number of bounded layers, enabling optimal implementation and practical application while upholding theoretical universality. in mild circumstances. The layers' efficiency, trainability, and understandability can vary greatly from biologically informed connectionist models.

## 3. RESULTS AND DISCUSSION

A. Experimentation

The experiments were performed on EDM, EDM oil is selected as dielectric. The material is selected as Superni90 having dimension of 120mm diameter and 10mm thickness. Aluminum 7178 alloy. Prepare the optimum composition of AL7178 material as electrode and Nickel based Super Alloy - Superni 90 for machining investigations and process parameter optimization.

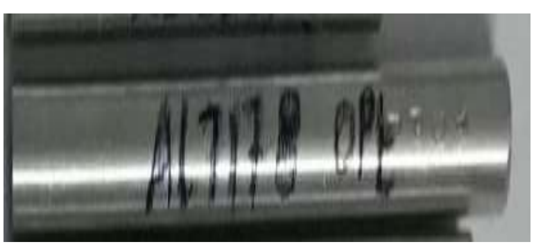

**Figure 4.** Al7178 tool

**Figure 5.** Working process of EDM

B. Material Removal Rate (MRR)

The MRR is determined by dividing the change in the workpiece's material weight before and after machining by the total machining time.

$$MRR = [(W_{wpbm} - W_{wpam})/(t*\rho)]\ mm3/min$$

$W_{wpbm}$ - Weight of the workpiece pre-machining process.

$W_{wpam}$ – Weight of the workpiece post-machining process.
t - Machining period Time 10min

C. Tool Wear Rate (TWR)

The tool's weight difference before and after machining divided by the machining time is known as TWR.

$$TWR = [(W_{etbm} - W_{etam})/(t*\rho)]\ mm^3/min$$

$W_{etbm}$ – Electrode weight Before machining
$W_{etam}$ – Electrode weight After machining
t - Machining period Time 10min
ρ – Density of Tool material

D. Experimentation on Superni90

The work material selected for experimental investigation is a super alloy which has variety of applications in defence with commercial name as Superni90. The electrode material chosen for machining on work material is Al7178 and the experiment done according to the procedure.

Researchers conduct experiments in almost every field of study, usually with the goal of learning more about a specific system or process. An experiment is a test, or set of tests, in which the system's or process's input variables are purposefully altered in order to track and determine the causes of variations in the output (response). The process of choosing the quantity of trails and operating conditions for them, which are necessary and sufficient for precisely solving the problem, is known as experiment design.


**Figure 6.** Experimentation on Superni90 work material with Aluminum7178 using EDM

E. Image Processing

Image processing is a rapidly developing technology that involves performing operations on images to improve them or extract useful data. It is a signal processing method where input is an image and output is the image or associated characteristics. Image analysis is crucial for structural characterization of porous substances and has applications in various fields. The structural properties of media can be represented by statistical and morphology aspects, such as dimensions and shapes, or topological properties. Image processing in MATLAB is used to analyze the trueness of diameter.

F. Results

The Tool Material Al7178 is performed on the workpiece material i.e., Superni90 super alloy on

EDM process.

The obtained values Material Removal Rate (MRR), Surface Roughness (SR) and Tool Wear Rate (TWR) for the Aluminum alloy 7178 Metal matrix composite which is performed on Superni90 super alloy on Electrical Discharge Machining are listed in table.

| Trial No | Current(I) (amp) | Ton(μ sec) | Toff(μ sec) | V(v) | DM (Mines) | MRR (g/hr) | TWR(g/hr) | SR(μ) |
|---|---|---|---|---|---|---|---|---|
| 1 | 4 | 100 | 50 | 30 | 0.25 | 98.696 | 35.772 | 2.03 |
| 2 | 12 | 100 | 50 | 30 | 0.25 | 206.136 | 48.78 | 3.34 |
| 3 | 4 | 1000 | 50 | 30 | 0.25 | 98.696 | 19.512 | 1.247 |
| 4 | 12 | 1000 | 50 | 30 | 0.25 | 333.744 | 45.528 | 2.08 |
| 5 | 4 | 100 | 100 | 30 | 0.25 | 98.896 | 22.764 | 4.863 |
| 6 | 12 | 100 | 100 | 30 | 0.25 | 245.4 | 71.544 | 2.622 |
| 7 | 4 | 1000 | 100 | 30 | 0.25 | 49.08 | 22.764 | 2.128 |
| 8 | 12 | 1000 | 100 | 30 | 0.25 | 49.08 | 74.796 | 1.599 |
| 9 | 4 | 100 | 50 | 60 | 0.25 | 343.56 | 22.764 | 3.128 |
| 10 | 12 | 100 | 50 | 60 | 0.25 | 215.952 | 55.284 | 3.424 |
| 11 | 4 | 1000 | 50 | 60 | 0.25 | 176.688 | 22.764 | 2.557 |
| 12 | 12 | 1000 | 50 | 60 | 0.25 | 98.16 | 65.04 | 3.798 |
| 13 | 4 | 100 | 100 | 60 | 0.25 | 274.848 | 19.512 | 3.204 |
| 14 | 12 | 100 | 100 | 60 | 0.25 | 78.528 | 78.048 | 2.412 |
| 15 | 4 | 1000 | 100 | 60 | 0.25 | 333.744 | 32.764 | 2.857 |
| 16 | 12 | 1000 | 100 | 60 | 0.25 | 29.448 | 74.796 | 4.45 |
| 17 | 4 | 100 | 50 | 30 | 0.75 | 343.56 | 19.512 | 2.363 |
| 18 | 12 | 100 | 50 | 30 | 0.75 | 107.976 | 58.536 | 2.253 |
| 19 | 4 | 1000 | 50 | 30 | 0.75 | 186.504 | 19.512 | 1.319 |
| 20 | 12 | 1000 | 50 | 30 | 0.75 | 107.976 | 55.284 | 3.88 |
| 21 | 4 | 100 | 100 | 30 | 0.75 | 206.136 | 29.268 | 2.108 |
| 22 | 12 | 100 | 100 | 30 | 0.75 | 171.008 | 39.024 | 3.516 |
| 23 | 4 | 1000 | 100 | 30 | 0.75 | 206.136 | 19.512 | 2.311 |
| 24 | 12 | 1000 | 100 | 30 | 0.75 | 274.848 | 71.544 | 3.035 |
| 25 | 4 | 100 | 50 | 60 | 0.75 | 206.136 | 16.26 | 2.909 |
| 26 | 12 | 100 | 50 | 60 | 0.75 | 166.872 | 42.276 | 3.446 |
| 27 | 4 | 1000 | 50 | 60 | 0.75 | 343.56 | 19.512 | 2.263 |
| 28 | 12 | 1000 | 50 | 60 | 0.75 | 225.768 | 52.032 | 4.22 |
| 29 | 4 | 100 | 100 | 60 | 0.75 | 559.512 | 26.016 | 1.342 |
| 30 | 12 | 100 | 100 | 60 | 0.75 | 196.32 | 71.544 | 2.815 |
| 31 | 4 | 1000 | 100 | 60 | 0.75 | 98.16 | 32.52 | 3.722 |
| 32 | 12 | 1000 | 100 | 60 | 0.75 | 284.664 | 65.04 | 4.797 |

**Figure 7.** Experimental values of (MRR, TWR, SR) for Al7178 tool on Superni90

G. Geometric Analysis

The trueness of the diameter is analyzed by image processing in MATLAB.

The evaluation of this image processing can be performed using MAT Lab software. The six images which are obtained using MATLab for surface roughness are named as crop image, Black & white, Histogram, Normalized, Normalized Histogram and Binary.

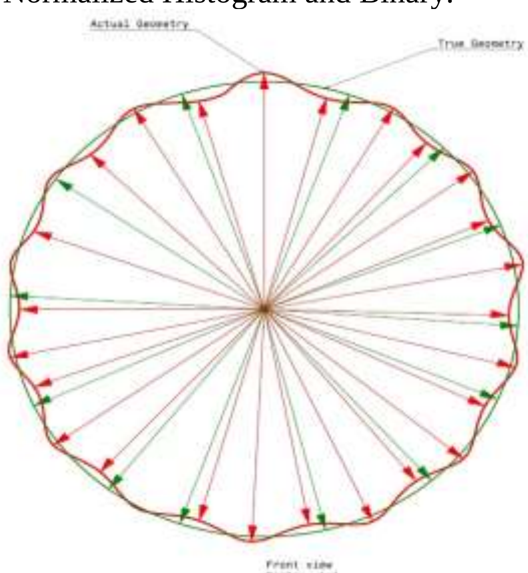


**Figure 8.** 2D image of centroid location

Geometric Analysis (Circularity Accuracy) for Al7178 tool input parameters (V = 30, I = 4, $T_{on}$ =100, $T_{off}$ =50) and the below images obtained for Trial 1

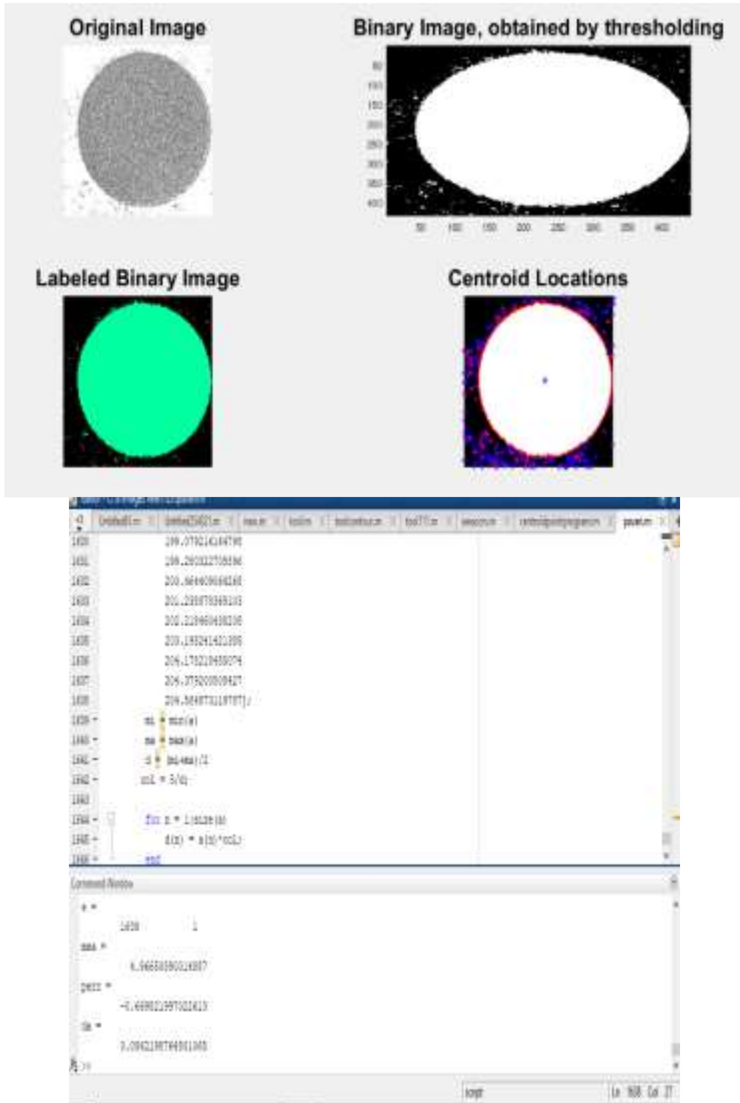


**Figure 9.** Geometric Analysis AL7178 for Trail 1

Geometric Analysis (Circularity Accuracy) for Al7178 tool input parameters (V = 30, I = 12, $T_{on}$ =100, $T_{off}$ =50) and the below images obtained for Trial 2

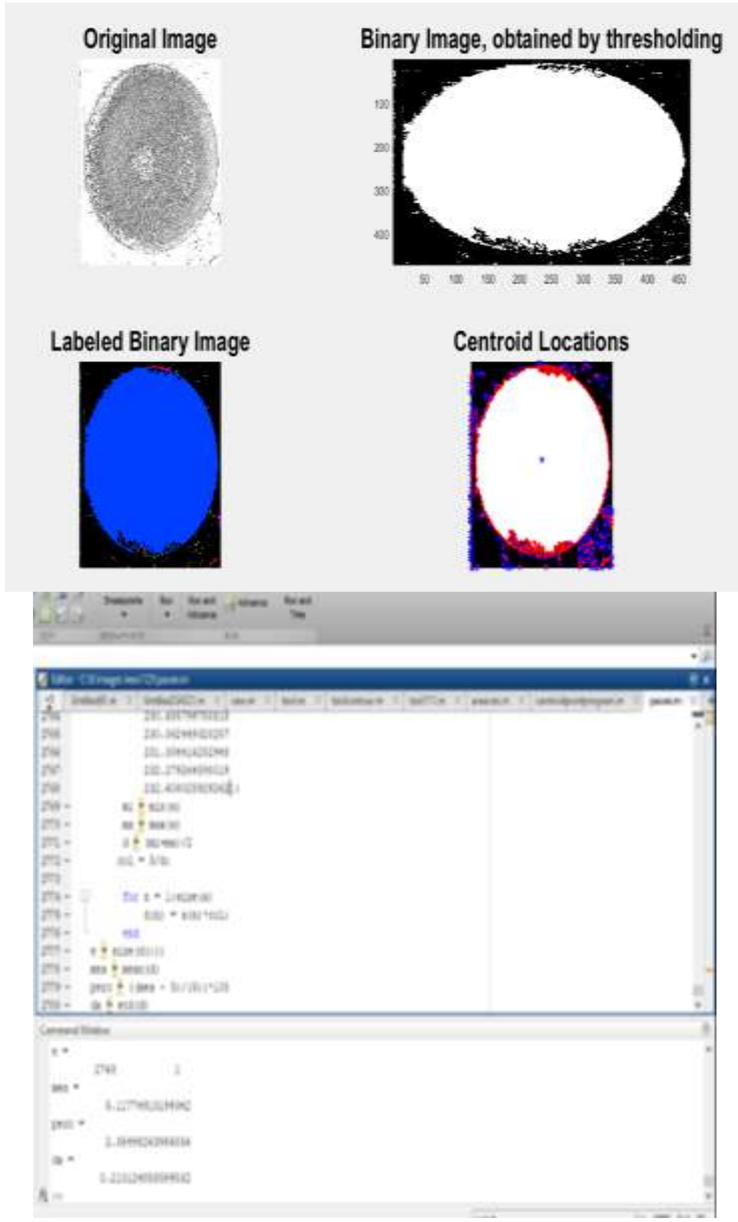


**Figure 10.** Geometric Analysis AL7178 for Trail 2

Similarily for all the input parameters Al7178 Tool on Superni90 super alloy, the Geometric Analysis (Circularity Accuracy) of Image Processing is performed for all the 32 Trails.

## 4. CONCLUSION

Based on the experimental data and results derived from the analysis, the following conclusions can be made.

a) Metal removal rate is high when I = 4amps, Ton=100 µs , Toff=100 µs, V=60volts, DF=0.75 litre
b) Tool wear rate is high when I = 12amps, Ton=1000 µs , Toff=100 µs, V=60volts, DF=0.25 litre
c) Surface roughness is high when I = 4amps, Ton=100 µs , Toff=100 µs, V=30volts, DF=0.25 litre
d) The deviation in circularity is high when I = 4amps, Ton=1000 µs , Toff=50 µs, V=60volts, DF=0.25 litre

e) The total cost is maximum for copper which comes to Rs.555 per kg.
f) The total cost is minimum for Al7178 i.e., Rs.300 per kg.
g) Hence it is recommended to use Al7178 tool for machining of super alloys when moderate accuracy preferred.

**Future Scope**

Further the work can be extended by using vegetable oils in blended form as dielectric medium and metal matrix of Al7178 as tool material

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