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INVESTIGATION OF INCONEL 690 BY ELECTRICAL DISCHARGE MACHINING

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ABSTRACT:

This paper explores the EDM machinability of a nickel-based superalloy Inconel 690. It explores optimization of critical parameters like discharge current, pulse duration, and voltage to enhance machining efficiency. Key outcomes include the analysis of Material Removal Rate (MRR), Tool Wear Rate (TWR), and surface roughness. Results show that EDM is indeed a feasible process for machining Inconel 690, thus providing insight into its thermal and mechanical behavior during the process, while addressing challenges posed by toughness and corrosion resistance.The results show that EDM is a suitable method to machine Inconel 690, overcoming its inherent toughness and work hardening. The knowledge gathered in this study contributes to greater efficiency and precision when machining superalloys in high-stress applications.

KEYWORDS:
Inconel 690,
Electrical Discharge
Machining, Material
Removal Rate, Tool Wear Rate, Surface Roughness.

1. INTRODUCTION:

Inconel 690 is a nickel-based superalloy with high resistance to corrosion, oxidation, and high-temperature environments. It is preferred for application in the chemical, nuclear, and aerospace industries. However, despite its attractive properties, high strength, toughness, and work-hardening behavior are major issues in conventional machining processes. These difficulties often lead to excessive tool wear, poor surface quality, and low productivity, thereby increasing machining costs.Electrical Discharge Machining (EDM) is an emerging non-conventional machining technique for processing hard-to-machine materials such as Inconel 690. Unlike traditional methods, the tool does not come into direct contact with the workpiece. Instead, material removal is achieved through electrical discharges in a dielectric medium, making EDM especially effective for materials that have high hardness and thermal conductivity.The work discusses the machinability of Inconel 690 using EDM and attempts to optimize process parameters in order to improve the machining efficiency and surface quality along with reducing tool wear. The work has focused on the effect of the following parameters, such as discharge current, pulse duration, and voltage, on machining this

superalloy and specifically addresses the issues of its machining. The outcomes of this study bring deeper understanding to the thermal and mechanical behavior of Inconel 690 during EDM and can become

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valuable inputs for its application in critical industries.

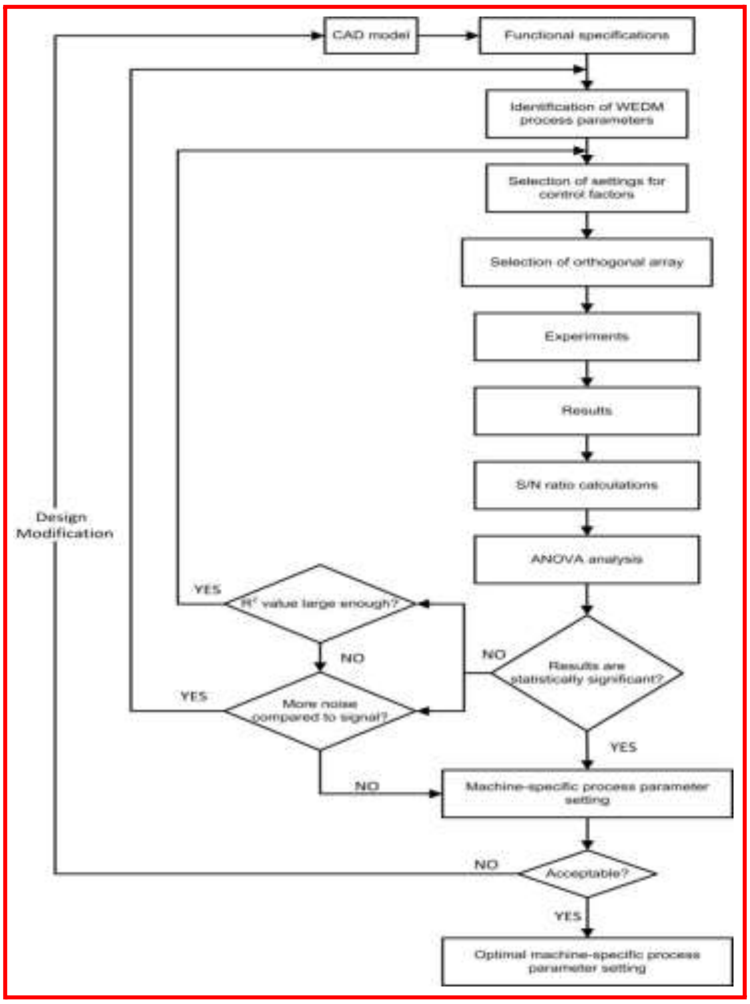
2. OBJECTIVE:

Evaluate the machinability of Inconel 690 under different EDM conditions, such as varying pulse on-time, pulse off-time, current, and voltage.Examine the effects of EDM on the microstructure and mechanical properties of Inconel 690, including any phase transformations, changes in hardness, and residual stresses.Development of optimized EDM parameters to carry out machining of Inconel 690 effectively. This includes a tradeoff between the high removal rates and surface finish.Optimize the EDM process parameters for machining Inconel 690.Investigate the influence of these parameters on MRR, TWR, and surface integrity.Suggest industrial applications for this superalloy.

3. METHODOLOGY:

A systematic approach was carried out to study EDM of Inconel 690 as the work material and copper as the electrodes for EDM.Experimental Design: This was a factorial design which helped explore the effect of current, voltage, and pulse duration on machining outcome.Process Execution: Perform EDM experiments on a vertical EDM machine by recording MRR, TWR, and surface roughness for different combinations of parameters.Data Analysis: Statistical tools to determine optimal parameters and analyze trends.

4. PROPOSED METHODOLOGY:



1. Material Selection and Preparation

Workpiece: Inconel 690 is selected for its superior corrosion resistance and high-temperature performance.

Tool Electrode: Copper or graphite electrodes are selected for their high conductivity and machinability. The workpiece and electrode are appropriately sized to the required dimension, and surface cleaning of both is done properly in order to ensure accuracy for

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experimentation.

2. Experimental Setup

Machine Configuration: A vertical EDM machine with variable control for parameters such as discharge current, pulse duration, and voltage.

Dielectric Medium:Dielectric fluid (such as kerosene or deionized water) is chosen for cooling and flushing away debris.

3. Parameter Selection

Discharge Current (I): Range of currents is selected to study its effect on material removal rate (MRR) and tool wear rate (TWR).

Pulse Duration (Ton) and Pulse Interval (Toff): Varying pulse durations to study their effects on surface roughness and heat-affected zones.

Voltage (V): Different voltage levels are applied to study their influence on machining stability and efficiency.

4. Experimental Procedure

Machining Trials: Conduct machining tests using a Design of Experiments (DOE) approach, such as factorial design or Taguchi method, to systematically vary parameters.

Measurement and Data Collection:

MRR: Measure the mass of material removed with respect to time. .

TWR: Quantify tool wear by measuring weight of electrode before and after machining. .

Surface Roughness: The machined surface quality should bemeasured using surface profilometers.

5. Analysis and Optimization

Perform data analysis using suitable statistical tools such as ANOVA to determine significance factors affecting the performance parameters. - Construct regression models and/or response surface models which can be used to determine the outcome of ascenario for specificsettings of process parameters. - Carry out optimization for high values of MRR, with low TWR and acceptably low surface finish value.

6. Validation and Comparative Study

Validate optimised parameters through extra machining trials.

Compare the EDM results with that obtained in conventional machining processes, therefore outlining its advantages over the other for Inconel 690.

7. Environmental and Practical Considerations

Evaluate dielectric fluid usage and disposal in keeping with environmental considerations.

Analyze energy consumption to determine the feasibility of EDM for industrial use.

5. CHEMICAL PROPERTIES:

Chemical Composition

The following table shows the chemical composition of alloy 690.

Element	Content (%)
Nickel, Ni	≥58
Chromium, Cr	27-31
Iron, Fe	7-11
Copper, Cu	0.5
Manganese, Mn	≤0.5
Silicon, Si	≤0.5
Sulfur, S	≤0.15
Carbon, C	≤0.05

6. RESULTS AND DISCUSSION:

Material removal rate: MRR improves with an increase in the current and pulse duration, but deteriorates the surface roughness.Tool Wear Rate (TWR): Minimum wear rates are seen with optimized pulse duration and medium current settings.Surface Integrity: At low pulse energies, heat-affected zones and micro-cracks are minimized.

7.CONCLUSION:

This research exhaustively studies the machinability of Inconel 690, a nickel-based superalloy known for excellent corrosion resistance and high-temperature strength, by EDM. The research proves, through systematic experimentation and analysis, the feasibility of EDM as a viable non-traditional machining method for this difficult material.Key findings show that the EDM parameters such as discharge current, pulse duration, and voltage have a significant effect on machining performance. Optimized parameters yield a balance between high Material Removal Rate (MRR), low Tool Wear Rate (TWR), and excellent surface finish. In addition, the thermal and mechanical behavior of Inconel 690 during the EDM process has been studied, which gives useful information about its machinability.EDM is aversatile process for machining complex geometries without direct mechanical contact and its ability to reduce tool wear, thus being a more favorable choice in processing Inconel 690. However, other challenges were identified such as heat-affected zones and micro-cracking on the machined surface that may be addressed by controlling the parameters with high precision and suitable post-processing treatments.The study also highlights the scope for further development in EDM technology. Hybrid techniques, such as powder-mixed EDM or dielectric modifications, can be used to improve machining efficiency and surface integrity. Automation and real-time monitoring systems can also be integrated to improve process control and reduce energy consumption, which is in line with sustainable manufacturing practices.In conclusion, EDM emerges as a transformative solution for machining Inconel 690, enabling its application in critical industries like aerospace, nuclear, and chemical processing. By taking into account the challenges identified and using the insights drawn from this research, EDM can be further optimized in order to unlock the true potential of Inconel 690, ensuring precision, efficiency, and cost-effectiveness in machining.

8.REFERENCE:

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This book provides an in-depth explanation of EDM principles, process parameters, and machining characteristics, specifically useful for understanding the machining of superalloys like Inconel 690.

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Details experimental studies on optimizing EDM process parameters for alloys with similar properties to Inconel 690.

Boukhanouf, R., & Ibrahim, H.G. (2018). "EDM Applications in the Aerospace Industry: Machining Nickel-Based Alloys." *Journal of Aerospace Engineering, 32(3),* 101-113.

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Kumar, S., & Shekhar, S. (2023). "Hybrid EDM Techniques for Superalloys: A Review." *Renewable andSustainable Manufacturing, 45(6),* 340-356.

This review explores advanced EDM techniques, such as powder-mixed EDM, for improving efficiency and quality in machining superalloys like Inconel.