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EXPERIMENTAL INVESTIGATION OF MACHINING PARAMETERS OF INCONEL 718 FOR TURNING OPERATION USING AHP AND TOPSIS METHODOLOGY

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ABSTRACT

Super alloy Inconel 718, which is based on nickel, is widely used in high-temperature applications in the industrial and aerospace sectors. But because of its intrinsic properties, which include high hardness and low heat conductivity, it becomes difficult to mill, which increases tool wear and machining expenses. As a result, it is essential to optimize the machining settings for Inconel 718 in order to save costs, increase productivity, and meet strict quality standards. The purpose of this study is to determine the best machining settings for Inconel 718 by applying two alternative techniques: Topsis and Electric.

A thorough battery of experiments is being conducted as part of this inquiry to determine how different machining parameters affect Inconel 718's surface roughness and cutting force. The study's findings demonstrate the appropriateness of the suggested

Keywords: Inconel 718, AHP, Topsis, Optimization.

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1. INTRODUCTION

Inconel 718 stands out as an age-hardened nickel-chromium super lloy characterized by its impressive attributes such as strength, corrosion resistance, yield strength, and creep-rupture strength. Notably, it exhibits excellent weldability due to its remarkable resistance to post-weld cracking. As a Gamma Prime reinforced alloy, Inconel 718 maintains its mechanical properties across a broad temperature range, from -423°F to 1300°F.

Since the alloy does not spontaneously harden during the heating and cooling operations, its adaptability is demonstrated by how simple it is to anneal and weld. Inconel 718 is widely used in many different applications. It is frequently found in nuclear reactors, pump bodies, cryogenic storage tanks, jet and gas turbine engines, liquid-fuelled rockets, spacecraft, rocket motors, thrust reversers, and aircraft components like buckets and spacers. It is also used in the production of instrumentation parts and high-temperature bolts and fasteners.

Owing to its remarkable strength, high toughness, work-hardening propensity, and elevated shear strength, Inconel 718 is classified as a "difficult-to-cut" material. Its low thermal conductivity causes higher tool-tip temperatures. The alloy is composed of carbides and abrasive compounds, which are bad for tool life. Its work-hardening tendency can cause tool notching, which can cause haze to form on the work material. As a result, machining Inconel alloy frequently produces a subpar surface quality, requiring post-processing procedures.

NOMENCLATURE:

MCDM	Multi Criteria Decision Making
AHP	Analytical Hierarchy Process
I_p	Peak Current
T_{on}	Pulse-on Time
τ	Duty Factor
R_a	Surface Roughness (Roughness Average)
PCA	Principal Component Analysis
TWR	Tool (Electrode) Wear Rate
MRR	Material Removal Rate
SCD	Surface Crack Density
WLT	White Layer Thickness
AHP	Analytical Hierarchy Process

Typically, machining parameters are determined through a combination of accumulated knowledge, operator expertise, and reference to established handbooks. However, the chosen machining settings may not always represent the most cost-effective solution, leading to an increase in overall product costs. Enhanced machining efficiency is attained through the careful selection of optimal machining settings. To achieve this, optimization strategies play a pivotal role in identifying the most favorable combination of machining parameters.

The manufacturing sector continually introduces new materials to address evolving industrial requirements, although these materials are not always directly applicable.

Therefore, more investigation is necessary. When compared to traditional carbon steel, EN25 steel has better mechanical qualities and increased resistance to air corrosion. An extensive investigation into the microstructure and hardness of EN25 steel was carried out in order to assess the influence of process parameters during laser hardening. EN25 steel is a low-alloy, medium carbon steel with nickel, chromium, and molybdenum content that is used in many different industries, most notably the automotive and aerospace sectors. When defining the surface integrity affected by machining processes, the evaluation of surface roughness and micro hardness becomes important.

Surface micro hardness is a critical parameter in surface integrity investigation that enables the assessment of work hardening levels. Measures of surface roughness and microhardness are used to evaluate the integrity of the surface. The fatigue strength, wear resistance, and corrosion resistance of machined components are significantly influenced by surface roughness. A key factor in increasing the productivity of machined components is Material Removal Rate (MRR), and choosing the right machining parameters is especially important for turning operations.

Within this framework, a multi-objective optimization methodology for analyzing alternatives is the Multi-Criteria Decision-Making (MCDM) approach. The selection of the optimal set of input parameters depends on which objectives are most closely aligned with the positive result.

TOPSIS is a multi-criteria decision-making approach developed by Yoon and Wang that focuses on determining the distance between a negative alternative and a positive outcome. This method is widely used in many industries to make decisions based on multiple criteria. In particular, TOPSIS was used to assess which subsystem would be ideal for developing composite products. Furthermore, in order to identify the most advantageous input parameters for the Inconel 718 machining process, an integrated strategy utilizing both TOPSIS and the Analytic Hierarchy Process (AHP) was utilized.

AHP and TOPSIS combined approach was used to assess titanium's machinability during turning operations. Similar to this, a combined TOPSIS and AHP technique was used to choose the best lubricant from a variety of alternatives during the turning process of EN31 steel. Moreover, an overall performance assessment for operational activities influencing a manufacturing firm's success was carried out using both TOPSIS and AHP methodologies. Even though TOPSIS is a reliable tool for evaluating options and physical attributes, careful thought must go into determining the weight needs for each goal.

The Analytic Hierarchy Process (AHP) approach was employed to enable the distribution of weights among distinct criteria. AHP offers a methodical, efficient technique based on mathematical ideas. AHP was especially used in this study's context to calculate the weights given to each criterion. As a result, the TOPSIS and AHP techniques' synergies were used to evaluate and ascertain the performance in turning operations.

2. LITERATURE REVIEW

[1]. In their 2012 study, Abhang et al. employed a combined Multiple Attribute Decision Making (MADM) approach to select the most suitable lubricant for the turning process from a diverse array of lubricants utilized in machining an EN 31 steel workpiece. The researchers applied both Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and Analytic Hierarchy Process (AHP) models. Their findings indicated that the lubricant index effectively assesses and ranks the optimal lubricant for steel turning operations. The amalgamation of TOPSIS and AHP emerged as a fitting technique for addressing complex MADM challenges within the industrial domain.

[2]. In 2012, Nikunj et al. proposed a systematic approach for selecting tool inserts in turning operations on CNC turning centers. They based their strategy on three established Multiple Attribute Decision Making (MADM) methods: Analytic Hierarchy Process (AHP), Revised AHP, and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). Their investigation revealed a consistent ranking of tool inserts, determined by their performance scores, across all MADM approaches. This unified ranking, referred to as the tool insert selection index, remained consistent irrespective of the specific MADM method employed.

[3]. In 2015, Balasubramaniyan et al. employed a joint approach utilizing TOPSIS and AHP methodologies to pinpoint the most effective combination of machining parameters while turning EN25 steel. Their study concluded that this technique holds relevance and applicability to various machining procedures dealing with multiple targets concurrently.

[4] In 2015, H. Ravi Kumar et al. enhanced drilling parameters, including drill bit speed, feed, and cutting point angle, through the application of an innovative integrated method known as the Grey Taguchi-based Technique for Order of Preference by Similarity to Ideal Solution (GT-TOPSIS). Employing this approach, they established that the experiment was conducted using the optimal input setting values.

[5]. In 2015, Dinesh Kumar et al. applied the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) algorithm to optimize the parameters in die-sinking electric discharge machining, specifically on En-353 grade stainless steel as the work material. This study utilizes straightforward additive weighting (SAW)-based Multiple Criteria Decision Making (MCDM) approaches and is conducted through computational trials. The findings demonstrated the efficacy and effectiveness of the TOPSIS Algorithm in addressing Multiple Attribute Decision Making (MADM) challenges in the context of Electrical Discharge Machining (EDM).

[6]. In 2016, Swarat Dey et al. explored the machinability characteristics of alloys composed of three materials: aluminium, copper, and steel, employing the grey Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) technique. This established process facilitates manufacturers in choosing a specific alloy that is easily machinable. The grey TOPSIS technique proves highly suitable for such selection and assessment challenges, particularly when the criterion values, representing mechanical characteristics, are expressed in grey numbers.

[7]. In 2014, P. Senthil et al. employed the Multiple Attribute Decision Making (MADM) approach, specifically the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), to address the multi-criteria optimization challenges associated with the Electric Discharge Machining (EDM) process parameters in Al-CuTiB2 Metal Matrix Composite (MMC). The application of the TOPSIS Algorithm enhanced the evaluation of alternatives in the context of EDM. The researchers concluded that the technique is straightforward, computationally simpler, effective, and easily comprehensible.

[8]. In 2016, Jitendra Kumar et al. utilized the TOPSIS Algorithm to optimize the cutting parameters in face milling for Titanium alloy, aiming to achieve an enhanced surface quality.

[9]. In 2014, N. Yuvaraj et al. employed the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) approach to optimize the process parameters in abrasive water jet (AWJ) cutting for an aluminium alloy AA5083-H32, characterized by multiple response characteristics. The study results suggested that the TOPSIS algorithm holds the potential to enhance the multi-response features of the AWJ cutting process.

3. INCONEL 718

Inconel 718, a nickel-chromium alloy renowned for its remarkable strength and corrosion resistance, finds widespread application in high-temperature environments, notably in jet engines, gas turbine blades, and components of rocket motors. Originating from the 1950s through the efforts of the Special Metals Corporation, it has evolved into one of the aerospace industries extensively employed high-performance alloys.

Comprising approximately 50% nickel, 18.6% chromium, 3.0% molybdenum, 5.0% niobium, and trace amounts of iron, cobalt, and titanium, Inconel 718 boasts exceptional mechanical properties across a broad temperature range. Its notable corrosion resistance makes it well-suited for deployment in demanding environments, demonstrating reliable performance in both high and low-temperature conditions.

In the oil and gas industry, Inconel 718 finds extensive utility due to its remarkable combination of high strength and corrosion resistance. It proves highly effective for applications involving downhole drilling equipment and other scenarios characterized by high pressure and high temperature. Additionally, its versatile properties make it a valuable material not only in aerospace applications but also in the mentioned sectors.

Element	Weight, %
Nickel (Ni)	53.12
Iron (Fe)	18.63
Chromium (Cr)	17.65
Niobium (Nb)	4.79
Molybdenum (Mo)	3.07
Titanium (Ti)	0.86
Aluminum (Al)	0.60
Carbon (C)	0.04
Sulphur (S)	0.03
Copper (Cu)	0.02

Fig. 1 Chemical Composition of Inconel 718

Approximately 70% of the alloys employed in aircraft engines consist of nickel-based alloys, complemented using titanium alloys for the remaining 30%. In particular, the super alloy Inconel 718 is extensively utilized in the industrial sector due to its distinctive attributes, including robust heat resistance, high resistance to creep and corrosion, and the capacity to maintain toughness and strength under elevated temperatures.

The high yield strength of Inconel 718, reaching 550 MPa, remains a crucial attribute, particularly when exposed to elevated temperatures ranging from 700-800°C. This alloy constitutes more than 70% of the weight in aerospace applications and contributes to 50% of the weight in aero-engine components. Beyond aerospace, Inconel 718 finds application in ship engines, nuclear power facilities, and petrochemical industries. Its utilization in such demanding conditions ensures resilience against severe mechanical and thermal shock, creeping, and erosion, especially under extreme temperatures.

In the production of gas turbine blades within aircraft engines, Inconel-718 stands out as a prevalent choice due to its capability to withstand extremely high temperatures and pressures. The alloy maintains its hardness and strength over a broad temperature spectrum, rendering it particularly suitable for applications involving elevated temperatures where conventional aluminium and steel alloys may experience degradation. However, the exceptional combination of qualities in Inconel 718, encompassing high-temperature strength, toughness, hardness, chemical resistance, and resistance to creep, introduces notable challenges when utilized as a work material in turning and machining processes.

While the attractive features of Inconel 718 meet design requirements, production engineers face significant challenges due to the high temperatures and strains generated during machining. Two primary issues arise in machining the super alloy Inconel 718:

a. Reduced tool life results from the alloy's work hardening and abrasion properties.

b. Metallurgical and surface damage to the workpiece occurs due to the exceptionally high cutting pressure and temperature, contributing to work hardening, surface tearing, and deformation.

4. AHP (Analytic Hierarchy Process)

The Analytic Hierarchy Process (AHP), alternatively known as the Analytical Hierarchy Process, constitutes a systematic approach rooted in mathematics and psychology, designed for the structured organization and analysis of intricate decision-making scenarios. Originating in the 1970s through the work of Thomas L. Saaty, the AHP was further refined when, in 1983, Saaty collaborated with Ernest Forman to develop the Expert Choice software. Since its inception, AHP has undergone extensive research and refinement.

Functioning as a precise method for determining the weights of decision factors, AHP relies on pair-wise comparisons. Individual experts contribute their experiences to assess the relative magnitudes of various components. This involves using a meticulously crafted questionnaire where each respondent compares the relative value of every pair of elements in the decision-making process.

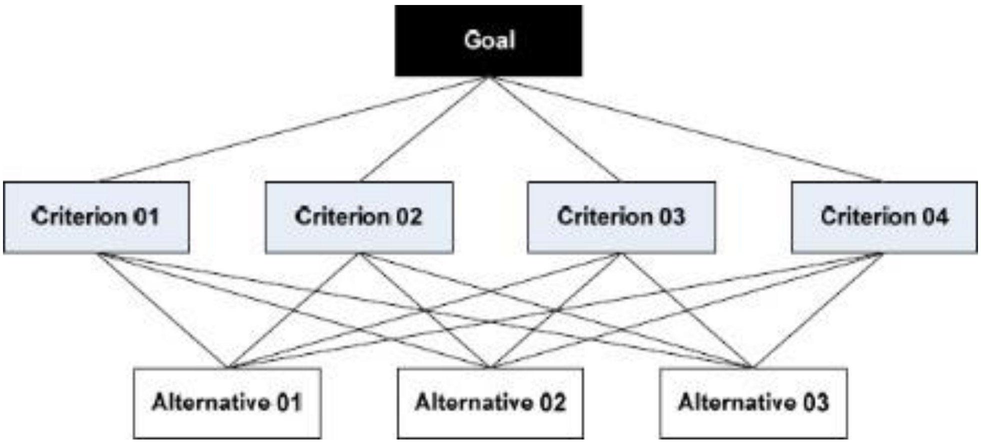

Fig.2 AHP (Analytic Hierarchy Process)

The Analytic Hierarchy Process (AHP) proves particularly valuable in group decision-making scenarios and finds application across diverse decision settings worldwide, including government, business, industry, healthcare, and education. Instead of imposing a singular "correct" answer, AHP aids decision-makers in identifying the decision that aligns most effectively with their objectives and comprehension of the situation.

It furnishes a comprehensive and rational framework for structuring a decision problem, articulating, and quantifying its components, establishing connections between these components and overarching goals, and evaluating potential solutions. In implementing the AHP, users are required to initially break down their decision problem into a hierarchy of more easily comprehensible sub-problems, each of which can be examined independently.

The elements within the hierarchy may encompass various facets of the decision problem, ranging from physical to intangible aspects, and from rigorously measured to crudely estimated factors. These elements may be well or poorly understood, but they all pertain to the decision at hand. Once the hierarchy is established, decision-makers systematically assess its various components by comparing them in pairs, evaluating their influence on an element positioned higher up in the hierarchy.

During this process, decision-makers can draw upon specific factual information regarding the elements as well as their own opinions about the relative significance and value of each element to conduct the comparisons. A fundamental principle of the Analytic Hierarchy Process (AHP) is that human judgments, not solely underlying data, can be leveraged for evaluations.

The AHP translates these evaluations into numerical values that can be systematically processed and compared across the entire spectrum of the issue. Each element within the hierarchy is assigned a numerical weight or priority, facilitating the comparison of diverse and often incommensurable items in a logical and consistent manner. This distinctive feature sets the AHP apart from other decision-making systems.

The final step in the process entails calculating numerical priorities for each of the decision alternatives. These figures represent the relative effectiveness of the alternatives in achieving the decision goal, facilitating a straightforward comparison of the available options. Various companies offer tools to assist in this process.

While individuals can use the Analytic Hierarchy Process (AHP) for simple decisions, its optimal utility is observed in group settings dealing with complex problems, particularly those of significant consequence, involving human perceptions and judgments, and where the decisions have enduring implications.

The Analytic Hierarchy Process (AHP) proves particularly advantageous when essential decision-making factors are challenging to quantify or compare. It also excels in scenarios where communication among team members is hindered by differences in specialties, terminology, or perspectives.
AHP can be effectively employed in the following decision situations:

- **Choosing**: The selection of a single alternative from a given set of alternatives, often when numerous choice criteria are involved.
- **Ranking:** Arranging a group of choices in order from most desirable to least desirable.
- **Prioritization:** Establishing the relative value of members within a set of choices, without necessarily choosing one or merely ranking them.
- **Resource allocation**: Involves distributing resources among various options.
- **Benchmarking**: Compares an organization's procedures to those of other leading businesses.
- **Quality management:** Addresses the multifaceted aspects of quality and quality improvement.
- **Conflict resolution:** Resolving conflicts between parties with seemingly opposing goals or perspectives.

The extensive application of the Analytic Hierarchy Process (AHP) in complex decision scenarios has yielded substantial outcomes in domains involving planning, resource allocation, priority setting, and alternative selection. Noteworthy mentions include its use in forecasting, comprehensive quality management, business process reengineering, quality function deployment, and the implementation of the balanced scorecard.

5. TOPSIS METHOD

The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is a decision-making process designed to evaluate options based on multiple criteria. Employing a mathematical approach, TOPSIS identifies the optimum option by assessing the distance of each alternative from both the ideal and negative ideal solutions.

In this methodology, the optimal solution maximizes the benefits of the choice criterion, while the negative optimal solution minimizes them. Despite its popularity as a decision-making tool due to its simplicity, ease of understanding, and capability to handle complex choice scenarios with numerous criteria, TOPSIS does have notable drawbacks. These include assuming a linear relationship between criteria and sensitivity to changes in the weights assigned to criteria.

The foundation of the TOPSIS technique lies in the premise that the optimal option is the one closest to the ideal solution while simultaneously being farthest from the negative ideal solution. The ideal solution maximizes the advantages of the choice criterion, whereas the negative ideal solution diminishes them.

The TOPSIS method encompasses several sequential steps:

• **Define the decision issue:** The process commences by clearly defining the decision problem and establishing the criteria that will assess the available alternatives.

• **Normalize the decision matrix**: A decision matrix showcases each alternative's performance across criteria. Prior to applying TOPSIS, normalization of the decision matrix is crucial to accommodate variations in criteria units and scales. This normalization ensures equal weighting for each criterion throughout the assessment.

• **Weight the decision matrix:** Following normalization, the criteria are weighted based on their relative significance. These weights, reflecting the decision-maker's preferences, can be determined using methodologies like the Analytic Hierarchy Process.

• **Construct the weighted normalized decision matrix**: Multiplying the normalized decision matrix by the criterion weights results in the creation of the weighted normalized decision matrix.

• **Identify the ideal and negative ideal solutions**: The ideal solution optimizes the decision criteria, while the negative ideal solution minimizes them. These solutions are derived by identifying the maximum and minimum values within each column of the weighted normalized decision matrix.

• **Calculate the distance to ideal and negative ideal solutions**: Employing a distance formula, typically the Euclidean distance formula, determines the distance of each option from both the ideal and negative ideal solutions. This formula measures the straight-line distance in a multidimensional space.

• **Determine relative proximity to the ideal solution**: Dividing the distance from the negative ideal solution by the sum of distances from both the ideal and negative ideal solutions establish the relative closeness to the ideal solution. A higher value indicates a more favourable option.

• **Rank the alternatives**: Finally, the alternatives are ranked based on their proximity to the ideal solution, with the solution displaying the highest relative proximity considered the most favourable.

Due to its user-friendly nature, ease of comprehension, and ability to address complex decision scenarios with multiple criteria, the TOPSIS approach has gained popularity as a decision-making tool. However, it does come with certain drawbacks, notably the assumption of a linear relationship between criteria and susceptibility to changes in criterion weights. Consequently, to ensure a comprehensive evaluation of possibilities, it is advisable to complement the TOPSIS technique with other decision-making methods.

6. MCDM (Multi Criteria Decision Making)

Multi-Criteria Decision Making (MCDM) stands as a segment of decision theory dedicated to evaluating and choosing options through the consideration of multiple criteria. In practical decision-making scenarios, relying on a single criterion often proves impractical and inadequate. Therefore, decisions must be based on a set of criteria that are frequently incongruent or conflicting. MCDM methodologies provide a structured framework for formulating the decision problem, defining the criteria, and evaluating options within the context of these criteria.

In the decision-making process, employing these strategies aids decision-makers in systematically evaluating and balancing multiple objectives, constraints, and preferences. MCDM methodologies encompass various approaches, including the Analytic Hierarchy Process (AHP), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Multi-Attribute Utility Theory (MAUT), and Simple Additive Weighting (SAW). Each strategy presents distinct advantages and disadvantages, making them suitable for different types of decision-making challenges.

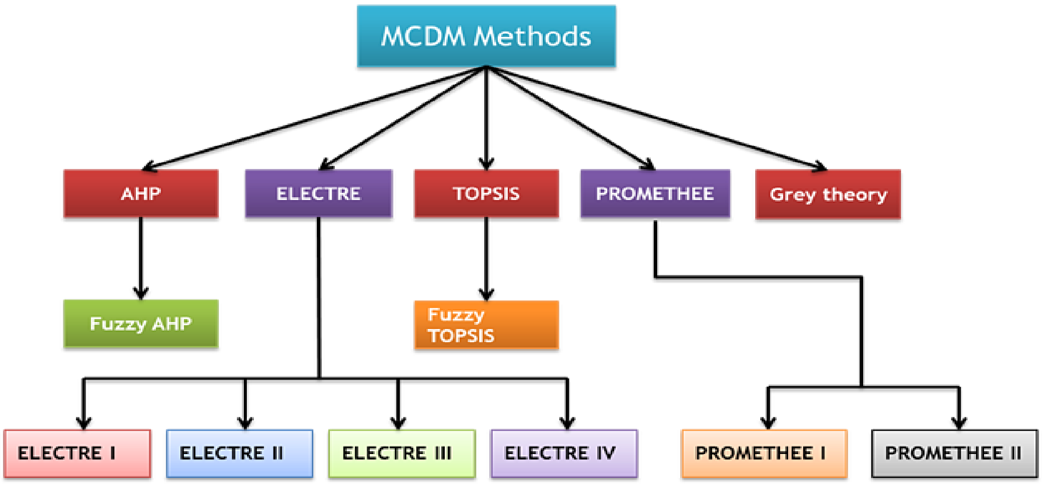

Fig.3 MCDM (Multi Criteria Decision Making)

MCDM methodologies find applications across diverse disciplines, such as business, engineering, healthcare, and environmental management. In the realm of business, these approaches prove valuable for tasks like supplier selection, assessment of investment projects, and formulation of marketing strategies. In engineering, MCDM techniques are instrumental in identifying optimal design solutions or evaluating the environmental impact of a project.

Inconel 718, a nickel-chromium alloy prized for its exceptional strength and corrosion resistance, finds extensive use in aerospace and high-performance applications. MCDM methodologies like the Analytic Hierarchy Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) offer the means to analyse and select the optimal Inconel 718 material source by considering multiple criteria.

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To employ MCDM approaches for the selection of Inconel 718 material sources, follow these comprehensive steps:

• **Define the decision-making problem**: Clearly articulate the decision issue, such as choosing the optimal Inconel 718 material provider, and specify the key objectives, criteria, and constraints.

• **Create a list of alternatives**: Compile a roster of potential Inconel 718 material providers to facilitate the decision-making process.

• **Establish decision criteria**: Identify the criteria that will be utilized to evaluate Inconel 718 material providers, encompassing factors like price, quality, delivery time, technical support, and environmental impact.

• **Determine criterion weights**: Assign weights to each criterion to signify its relative significance or priority. These weights can be computed using various methodologies, including the AHP or through consultation with subject matter experts.

• **Assess the alternatives**: Utilize pertinent decision-making methodologies, such as TOPSIS, to evaluate Inconel 718 material providers against the criteria. This involves assigning a performance score to each provider based on the criteria and their respective weights.

• **Interpret the findings**: Analyse the results and appraise Inconel 718 material providers based on their performance against the criteria. Consider the sensitivity of the findings to changes in criterion weights and assess the selected supplier's resilience.

• **Decide**: Employ the evaluation findings and other pertinent information to choose the preferred Inconel 718 material source.

Adopting an organized and systematic approach to Inconel 718 material supplier selection through MCDM approaches ensures a thorough, objective decision-making process based on multiple factors.

7. METHODOLOGY OF AHP AND TOPSIS

In the integrated TOPSIS and AHP technique, the following procedures are employed to ascertain the optimal choices:

Step 1: Define the objective and crucial evaluation characteristics. Material Removal Rate (MRR) is deemed a favorable characteristic, aiming for maximization in this specific context. In contrast, micro hardness and surface roughness are regarded as unfavorable qualities, aiming for reduction.

Step 2: All available information is structured into a decision matrix.

Step 3: The normalized matrix (Nij) is calculated using the following formula.

$$N_{ij} = \frac{x_{ij}}{\sqrt{\sum x_{ij}^2}}.$$

Step 4: The creation of the weighted normalized decision matrix involves the multiplication of the normalized decision matrix by its corresponding weights.

$$W_{ij} = N_{ij} \times W_j,$$

Where Nij represents the normalized matrix, and W signifies the weight criteria. The weight (Wj) for each criterion is computed using the AHP method, and the detailed procedure is outlined below.

1) Establish the relative importance of different attributes concerning the objective. To achieve this, a pair-wise comparison matrix needs to be constructed. Assuming there are N attributes, the pair-wise comparison of attribute i with attribute j generates a square matrix ANxN, where aij denotes the relative significance of attribute i in relation to attribute j. When i = j, aij is set to 1 in the matrix, whereas aij = 1/aij otherwise. This process is elucidated as follows:

$$A_{N\times N} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & - & - & a_{1N} \\ a_{21} & a_{22} & a_{23} & - & - & a_{2N} \\ a_{31} & a_{32} & a_{33} & - & - & a_{3N} \\ - & - & - & - & - & - \\ - & - & - & - & - & - \\ a_{N1} & a_{N2} & a_{N3} & - & - & a_{NN} \end{bmatrix}.$$

The relative normalized weight (Wj) for each attribute is obtained by computing the geometric mean of the i-th row utilizing Eq. (7). The normalization of the geometric means of rows in the comparison matrix is accomplished using Eq. (8).

$$GM_i = \frac{\left[\prod_{J=1}^{N} aij\right]}{N},$$

$$W_j = \frac{GM_i}{\sum_{i=1}^{N} GM_i},$$

2) Determine matrix A_3 and A_4 such that $A_3 = A_1\times A_2$ and $A_4= A_3/A_2$, where. $A_2=[W_1 ,W_2 ,...,W_3]$
3) Calculate the maximum Eigen value (λ_{max}), which is the average of matrix A_4.
4) Determine the consistency index. $CI = \frac{\lambda_{max} - N}{N-1}$. The smaller value of CI the smaller is the deviation from the consistency.
5) Evaluate the random index (RI) for the number of attributes used in decision-making.
6) Determine the consistency ratio (CR = CI/RI).
Usually, a CR of 0,1 or less is acceptable, and it reflects an informed judgment which could be attributed to the analyst's knowledge of the problem.
Step 6:The separation measure is calculated.
The separation of each alternative from the positive ideal one is given by

$$S_i^{**} = \sqrt{\sum (W_{ij} - A_j^{**})^2},$$ j=1, where i = 1,2,....,m.

Similarly, the separation of each alternative from the negative ideal one is given by:

$$S_i^{*} = \sqrt{\sum (W_{ij} - A_j^{*})^2},$$ j=1, where i = 1,2,....,m.

Step 7:The relative closeness is calculated to the ideal solution.

$$C_i^* = \frac{S_i^*}{S_i^{**} + S_i^*}.$$

The larger the Ci* value the better is the performance of the alternatives.

Step 8: Rank the relative closeness value.

8. OPTIMIZATION OF INCONEL 718

The process of optimizing the machining parameters for Inconel 718 entails identifying the best combination of parameters to accomplish the required machining performance, which may include a high rate of material removal, low tool wear, and excellent surface quality. The depth of cut, feed rate, and cutting speed are important machining factors.

Choosing the best machining parameters can be difficult because of the complexity of the machining process and the complex relationship between the machining parameters and the material being machined. The machining parameters for Inconel 718 can be optimized by using the Analytic Hierarchy Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) approaches.

When assessing machining parameters, AHP is used to determine the weights of the criterion, and TOPSIS is used to rank options and choose the.

By employing AHP and TOPSIS, the following steps can be undertaken to optimize Inconel 718 machining parameters:

- **Define the decision problem**: Clearly outline the decision problem, specifying the task of selecting the optimal set of machining parameters for Inconel 718.
- **Generate a list of alternatives**: Identify potential combinations of machining parameters that could address the decision problem.
- **Establish decision criteria**: Define the criteria for evaluating machining characteristics, including material removal rate, tool wear, and surface finish.
- **Determine criterion weights**: Assign weights to each criterion to reflect their relative importance or priority. AHP can be employed for calculating these weights.
- **Evaluate the alternatives**: Utilize TOPSIS to evaluate the machining parameter combinations against the criteria. This involves assigning a

performance score to each alternative based on the criteria and their weights.
- **Rank the alternatives**: Arrange the machining parameter combinations based on their performance scores and select the optimal set of machining settings.
- **Validate the findings:** Validate the results by conducting machining tests using the chosen parameters and comparing the actual machining performance with the anticipated outcomes.

By systematically applying AHP and TOPSIS methodologies to optimize Inconel 718 machining parameters, a methodical and well-planned approach ensures a comprehensive, objective decision-making process that considers multiple factors. This approach aims to enhance machining performance, reduce machining times, and ultimately improve overall productivity.

9.MACHINING PARAMETERS

When optimising the machining parameters for Inconel 718 using AHP and TOPSIS "In applying the AHP and TOPSIS techniques to Inconel 718, the input parameters encompass cutting speed, feed rate, and depth of cut, while the output parameters involve material removal rate, surface roughness, and tool wear. These parameters might vary depending on the machining process and the desired performance goals. However, in the context of Inconel 718 and the AHP/TOPSIS methodology, the typical input parameters are: Cutting speed (measured in meters per minute), Feed rate (expressed in millimetres per revolution or per tooth), Depth of cut (specified in millimetres). The output parameters could include Material removal rate (measured in cubic millimetres per minute), Surface roughness (represented in micrometres), and Tool wear (indicated in millimetres).

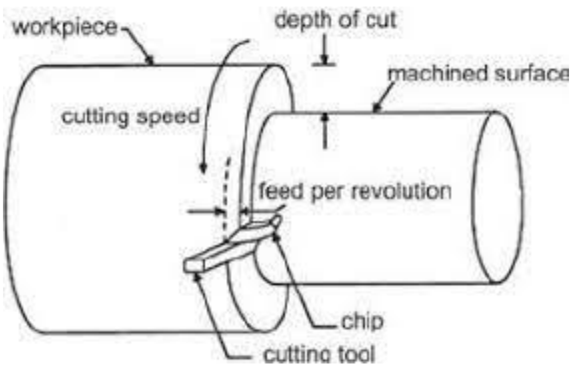

Fig.4 TurningOperation

The AHP approach is employed to estimate the relevance weights of each input parameter through pairwise comparisons, assessing their contributions to the desired output parameters. These weights are then applied to each machining parameter combination to calculate the overall performance score. Utilizing the TOPSIS technique, the performance scores for each combination are determined based on the relative distance to the ideal solution and the relative distance to the negative ideal solution.

The optimal machining parameter combination is subsequently selected based on the smallest distance to the ideal solution and the longest distance to the negative ideal solution. Through the integration of AHP and TOPSIS methodologies, the identification of optimal machining parameters for Inconel 718 is achieved, resulting in a high material removal rate, low surface roughness, and minimal tool wear.

9.1INPUT PARAMETERS

The optimization of machining parameters for Inconel 718 using AHP and TOPSIS methodology involves the consideration of the following parameters:

- **Cutting Spee**d: This is an input parameter that needs to be determined before initiating the machining process. It is often specified based on the desired machining performance, including material removal rate, tool life, and surface quality.

- **Feed Rate**: Another input parameter essential for machining is the feed rate. Its determination is typically based on cutting speed and the desired material removal rate.

- **Depth of Cut**: This input parameter must be considered before machining and is generally determined based on cutting speed, feed rate, and the required material removal rate.

- **Coolant/Lubricant Type and Application**: The selection of coolant/lubricant type and its application is an input parameter, chosen before the machining process begins. This selection is often based on the desired level of cooling efficiency and chip evacuation.

- **Weightage of Criterion**: In the AHP technique, the weightage of criteria is an input parameter that must be established before the decision-making process. It involves determining the relative importance of each criterion, such as material removal rate, surface quality, and tool life.

In general, input parameters are factors that require definition or establishment before commencing the machining process. These factors play a crucial role in determining the machining performance and efficiency.

9.2. OUTPUT PARAMETERS

The optimization of Inconel 718 machining parameters using AHP and TOPSIS methodology yields the following output parameters:

- **Material Removal Rate (MRR):** MRR quantifies the amount of material removed per unit time during machining. It serves as a crucial output parameter influencing the overall efficiency of the machining process.

- **Surface Roughness (SR)**: SR measures the deviation of the real machined surface from the ideal surface. This output parameter is vital as it affects both the functional and aesthetic aspects of the machined surface.

- **Tool Life (TL):** TL denotes the duration a tool can be utilized before requiring replacement or re-sharpening. It holds significance as an output parameter, impacting the cost and efficiency of the machining process.

- **Weighted Performance Score:** In the TOPSIS approach, the weighted performance score is an output parameter that provides a numerical representation of the overall performance for each set of machining parameters. It is calculated by assigning weights to the performance ratings of each output parameter and summing up the weighted values.

In the TOPSIS methodology, output parameters are variables measured or computed during or after the machining process. These parameters, including Material Removal Rate, Surface Roughness, Tool Life, and the Weighted Performance Score, contribute to the comprehensive evaluation of the machining performance.

10.CONCLUSION

It has been shown that using the AHP and TOPSIS methodologies to optimize the machining parameters of Inconel 718 is a reliable and effective way to improve the quality and efficiency of the machining process. The AHP approach is essential to this strategy since it assigns weights to each criterion and determines its relative importance. In parallel, using the acquired performance ratings as a basis, the TOPSIS technique is utilized to assess and prioritize the performance of different combinations of machining parameters.

Cutting speed, feed rate, depth of cut, coolant/lubricant type and application, and the weighting of criteria established by the AHP technique are important input parameters in this optimization study. In the meantime, the weighted performance score, surface roughness, material removal rate, and tool life are all considered output factors in the TOPSIS process.

The optimization results of the study demonstrate that the best option for Inconel 718 machining is the set of machining settings that produces the greatest weighted performance score. In the machining process, this ideal set of parameters helps to increase productivity, economy, and product quality.

In the end, Inconel 718 machining parameter optimization can be achieved through the effective use of the AHP and TOPSIS approaches as decision-making instruments. The study might provide valuable insights that help select and apply the best machining parameters for certain applications. This all-encompassing strategy guarantees a thorough improvement of the machining procedure, in line with goals concerning productivity, affordability, and end-product quality concerning Inconel 718 machining applications.

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