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Multi-Objective Optimization in Non-Conventional Composite Metal Machining to Improve Efficiency

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ABSTRACT

The relevance of non-conventional machining methods (NCMPs) in today's production environment has been highly acknowledged. For optimal utilization of the capabilities and advantages of different NCMPs, selection of the most suited NCMP for a specific machining application needs evaluation of several conflicting criteria. In order to address NCMP selection, which has been specified taking into account various performance criteria of the four most popular NCMPs, this study applies a modern MCDM method, namely the multi-objective optimization on the basis of ratio analysis (MOORA) method. A pairwise comparison matrix of the analytic hierarchy procedure was utilized to ascertain the relative importance of the quality criteria under consideration. The outcomes derived from the MOORA approach and the order preference technique demonstrated a perfect correlation.

KEYWORDS: Non-conventional machining processes, Multi-criteria decision making, Selection, MOORA method.

1. INTRODUCTION

Many non-conventional machining methods (NCMPs) are being employed more and more in today's industry to process various technical materials. Various multi-criteria decision making (MCDM) techniques have been used to solve NCMP selection issues, according to observations. Situations where a decision maker must rank a number of competitive choices and choose the best option while taking into account a number of conflicting criteria are the focus of MCDM. The main goal of an MCDM method is to identify the pertinent selection problem criteria, evaluate the alternative's information pertaining to those criteria, and develop methodologies for determining the relative significance of each criterion in order to assess the competitive alternatives' overall performance. It has been noted that this method's performance is on par with that of other well-known and often applied MCDM techniques. Furthermore, the method is easy to implement and has a relatively simple computational structure. First, an MCDM model that can be utilized to choose the best NCMP based on several performance criteria has been described in this study. After determining the relative importance of the quality criteria under consideration using a pairwise comparison matrix of the AHP technique, the competing NCMPs were rated using the MOORA approach. The TOPSIS approach was also used to solve the NCMP selection problem in order to confirm the entire rankings of NCMPs that were acquired using the MOORA method.

2. LITERATURE REVIEW

The majority of earlier research has focused on the creation of expert and decision support systems, as well as the use of various MCDM techniques to address NCMP selection issues. Notably, only a small number of earlier studies—like the one Temuçin et al. (2013) presented—were devoted to the creation of decision models for NCMP selection, with the bulk of them taking into account decision matrices from the literature. An NCMP selection process based on a combination of the technique for order preference by similarity to ideal solution (TOPSIS) and the analytic hierarchy process (AHP) was proposed by Yurdakul and Cogun (2003). The criteria weights, or relative importance of the criteria, are determined using the AHP approach, while each possible NCMP is ranked using the TOPSIS method. A systematic methodology for choosing the optimal NCMP under material and machining constraints was described by Chakraborty and Dey (2006). In order to facilitate decision-making, the authors also demonstrated the creation of an expert system based on AHP that has a graphical user interface. To choose the best NCMP for a given work material and shape feature combination, Chakladar and Chakraborty (2008) suggested combining the TOPSIS and AHP approaches.

2.1 LITERATURE ON MACHINING

A thorough analysis of several tooling systems has been conducted by Manna and Bhattacharya. The findings indicated that the rhombic fixed tool works well at high speed and low depth of cut, the rotary circular tooling has good wear resistance, the fixed circular tooling performs better at high depth of cut, and low surface finish is produced by high speed and RCT. Paulo Davim studies the impact of cutting parameters. The Sic particles in MMCs are tougher than tungsten carbide, which justifies the use of polycrystalline diamond (PCD) in turning operations. According to Tomac and Tonnessen, PCD tools are superior to carbide tools (K10), although they come with a hefty machining cost. Despite being the best among other common materials, Hung and colleagues have found that diamond and cubic boron nitride tools have limited shape and high tool costs. According to Ding et al. PCD tools are superior to PCBN ones due to their great abrasion and fracture resistance. However, Brun and Lee claim that at moderate speed, the PCD also has a comparatively lower tool life. Teti discovered that when it comes to machining the brake drum composed of aluminum MMC, the diamond-coated tools manufactured using CVD might be better than those made with PCD. His research indicates that rather than cutting settings, reinforcing and matrix hardness have a significant impact on machinability. Muller and Monaghan have machinated MMCs using various unconventional techniques.

3. NCMPS SELECTION PROBLEM

NCMPs are among the most widely utilized machining methods in the industry today because of their capacity to machine sophisticated materials while meeting the demands of high dimensional accuracy and surface polish. For NCMPs, quality performances are crucial because they assist achieve the necessary cut quality and tolerance, which removes the need for post-processing. These depend on the thickness and kind of material being cut, the machine tool and its control capabilities, the machining process parameter settings, and the actual machining process itself. When choosing the best NCMP, process performance is another crucial factor. A number of indicators, including specific cutting energy, specific cutting speed, specific cutting power, and similar ones, can be taken into consideration, either separately or in combination. One of the most crucial of these is cutting speed, which also happens to be one of the main technoeconomic performances of NCMPs.

3.1. FORMULATION OF THE NCPM SELECTION MODEL

The present MCDM problem is based on the evaluation of four NCMPs i.e. LBM, PAM, EDM and AWJM considering 9 criteria. The NCMPs selection problem was defined considering:

i. **Work piece material (WM):** This criterion is concerned with the ability of a given NCMP to machine a given work piece material. It is preferable that a given NCMP has the ability to machine a wider range of materials.

ii. **Temperature of the cut (TC):** This criterion incorporates the fact that during different NCMPs there exist temperature effects which may have important impacts on metallurgical properties of the work piece material.

iii. **Economical work piece thickness (EWT):** Although the considered NCMP can machine a wide spectrum of material thicknesses, for each NCMP there is an interval range of material thickness for which the given NCMP is particularly suitable. In other words, the use of a given NCMP within this range is economical.

iv. **Machining accuracy (MA):** The machining accuracy is determined by the characteristics of the coordinate worktable (positioning accuracy) and the quality of the control unit of machine tool.

v. **Kerf taper (KT):** Kerf taper is a special and undesirable geometrical feature inherent to all NCMPs. Kerf taper is normally expressed by kerf taper angle. Reduced kerf taper angle is very important since it allows better positioning of parts, elimination of post-processing and finally saving of material.

vi. **Kerf width (KW):** Kerf width and kerf taper are one of the most important quality performance criteria that directly affect final dimensions of the workpiece. It can be defined as the width of material that is removed by a given NCMP. Each NCMP removes a different amount of material i.e. creates different kerf width. The more precise process, the smaller the kerf width is. Generally, it is mainly influenced by the cutting speed.

vii. **Quality of surface roughness (QSR):** Assessment of the surface roughness includes the shape and size of irregularities and in practice comes down to analysis of particular sections on the cut surface. Surface roughness parameters defined by international standards are related to the characteristics of the irregularities profiles. Most frequently used parameters for surface roughness are maximum height of the assessed profile (Rz) and the arithmetic mean deviation of the profile (Ra).

4. THE MOORA METHOD

It provides a fairly straightforward computational process and can concurrently consider any number of criteria. This approach requires the fewest mathematical calculations because it is based on a straightforward ratio system. Decision-makers gain from this in two ways. On the one hand, a solid foundation in operational research and mathematics is not always necessary to apply the MOORA technique. However, all of the MOORA's mathematical computations may be completed with ease in Microsoft Excel, in contrast to many other MCDM approaches that need software tools to effectively answer a particular MCDM problem. In terms of the necessary application stages for resolving decision-making issues, the MOORA method is superior to other MCDM techniques. The TOPSIS approach requires nine steps to solve a certain decision-making method, but the MOORA method only requires five [22]. Additionally, in contrast to many other MCDM techniques, the decision matrix is normalized using a vector normalization mechanism that uses a single normalization equation, independent of the kind of criterion (benefit or non-beneficial). This eliminates the need for extra normalization formulas or the conversion of unfavorable criteria into favorable ones, and vice versa. Another significant benefit of this approach, as mentioned by Chakraborty [12], is that, unlike other MCDM methods, its computation process remains unaffected by the addition of further factors.

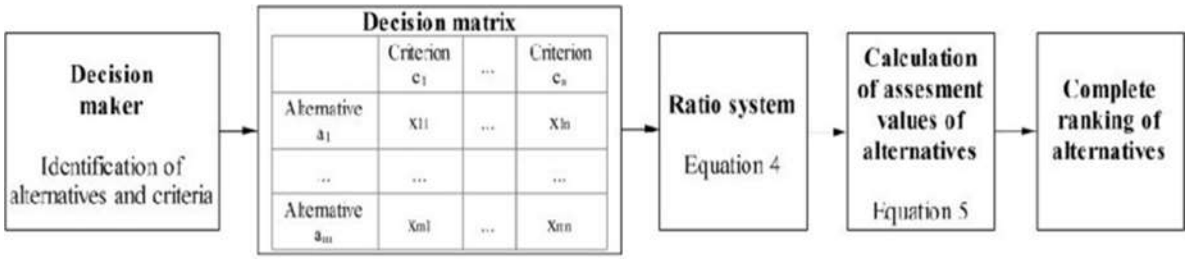

Fig-1 Application Procedure of MOORA method.

4.1 NON-CONVENTIONAL MACHINING METHODS

Since they have a wide range of uses, the so-called non-conventional machining techniques may no longer be referred to as "non-traditional." Furthermore, the more conventional machining procedures are frequently in competition with these electro-physical and electro-chemical material removal technologies.

Complex forms can be machined using these unconventional machining techniques, in part due to the utilization of cutting-edge CNC technology. The usage of these procedures is frequently suggested by the material's cutability, such as in the case of hard steel alloys and specific composite materials.

Evidence of these unconventional manufacturing techniques' increasing economic significance and wider range of applications is shown. This is demonstrated by several concrete cases. Additionally mentioned are several recent advancements and emerging trends.

Some of these strategies can compete with traditional manufacturing methods, as demonstrated by a few industrial examples. They are frequently the sole effective way to realize particular industrial products. When combined with traditional machining techniques, better results could be obtained.

Because reinforced materials are harder to cut, metal matrix composites are more challenging to machine than monolithic materials. However, because of their high strength-to-weight ratio, high ultimate tensile strength, resilience to temperature, and exceptional structural stability, metal matrix composites are becoming more and more significant in the manufacturing sector globally. Conventional, non-conventional, and hybrid machining techniques were among the approaches used to enhance the machining behavior of metal network composites. In order to obtain improved results, this paper focuses on examining and investigating various metal matrix composite machining cycles. It is found that hybrid machining is more effective than other methods at machining metal matrix composites because of its superior machining capabilities. In order to accomplish the goal, non-conventional machining is also essential because hybrid machines are not readily available and require expert operators. Because of the material's heterogeneity, heat sensitivity, and high abrasiveness of the reinforcing fibers, composite materials are challenging to machine. This leads to extremely high tool wear and damage being introduced into the work piece. Here, novel techniques including laser, waterjet, electro-chemical spark, electro-discharge, and ultrasonic machining are taken into consideration. These different methods have been used for metal matrix and ceramic matrix composites, as well as organic matrix composites reinforced with glass, graphite, and aramid fibers.

NON-CONVENTIONAL MACHINING PROCESSES

- The non-conventional machining method involves the use of modern and advanced technology for machine processing.
- There is no physical contact between the tool and the workpiece in such a process.
- Tools used for cutting in unconventional methods are laser beams, electric beam, electric arc, infrared beam, Plasma cutting, and so on depending on the type of working material.

ADVANTAGES OF NON-CONVENTIONAL MACHINING PROCESS

i. It has good accuracy.

ii. It provides a good surface. iii.Complex shapes can be made easily.

iv. It has longer tool life.

v. The rate of metal removal is high.

DISADVANTAGE OF NON-CONVENTIONAL MACHINING PROCESS

i. The cost of this process is high.

ii. It requires skilled operators.

iii. Its setup is difficult.

4.2 BACKGROUND AND MOTIVATION

Composite materials are crucial to engineering and advanced manufacturing in response to the extraordinary demands of technology brought about by the fast evolving aerospace, automobile, and aircraft sectors. Because of their low specific gravity, these materials have strength and modulus that are far better than those of many conventional engineering materials, like metals. The development of new composite materials with enhanced mechanical and physical properties is now feasible due to extensive research into the underlying nature of materials and a deeper comprehension of the relationship between their structure and qualities. High performance composites, like reinforced composites, are among these novel materials. Composite materials are now used in an increasing number of diverse applications due to ongoing developments. The fact that more than 200 of the more than 1600 engineering materials now on the market are composites speaks volumes about the significance of composites as engineering materials.

4.3 COMPOSITES

Typically, composite materials are either naturally occurring or created materials composed of two or more constituent elements with radically different physical or chemical properties that, at the macroscopic or microscopic scale, remain separate and distinct within the final structure. Despite acting in unison, the elements do not disintegrate or totally melt into one another; rather, they maintain their identities. Constituents are the separate components that combine to form composites. The two main components of most composites are reinforcement (fibers, particles, flakes, and/or fillers) and a binder or matrix (polymers, metals, or ceramics). The reinforcement, which gives the composite its favorable qualities, is often far stiffer and stronger than the matrix. The reinforcements are arranged in a systematic manner within the matrix. The matrix also aids in load transfer between the reinforcements because they are typically discontinuous.

4.4 COMPONENTS OF A COMPOSITE MATERIAL

The reinforcing phase must be securely bound and held in place by the material used as a matrix. The matrix serves as a bridge to keep the components in place while isolating them from one another to stop abrasion and the development of new surface imperfections. A good matrix should be able to transfer load onto the materials, deform easily under applied force, and concentrate stress uniformly. With remarkable success, a few metals, polymers, and inorganic materials have been used as matrix materials in the creation of structural composites. When loaded under tension and compression, these materials exhibit reduced failure strain and maintain their elasticity until failure. Metal matrices [7], ceramic matrices [6], and polymer matrices [4, 5] are a few that are frequently employed as matrices. The strength that gives a composite its identity is provided by reinforcing elements. However, they also give stiffness, resistance to corrosion, and heat resistance or conduction, among other functions. Depending on the needs, reinforcement can be designed to carry out all or some of these tasks. A reinforcement that enhances the strength of the matrix needs to be more robust and rigid than the matrix and able to alter the failure mechanism to the composite's benefit. This means that the composite should be as brittle as possible and have very little or no ductility.

4.5 APPLY RESEARCH METHODOLOGY

It is frequently employed in engineering, including automatic control systems, electronic design automation, and optimal design challenges that arise in mechanical, chemical, civil, and aerospace engineering. A lot of work has been put into creating algorithms for resolving different kinds of optimization issues, examining their characteristics, and creating high-quality software implementations since the late 1940s. The objective of this competition is to identify the model that best fits a set of observed data from a family of possible models. In this case, the model's parameters are the variables. The multi-response performance characteristics index (MPCI), a hybrid optimization technique that combines principal component analysis (PCA) with a fuzzy inference system, is used to combine multiple responses into a single response in order to identify the factor level settings that optimize the performance of the quality characteristics in a single setting. Lastly, the Taguchi methodology is used to determine an empirical link between process parameters and MPCI. Weighted principal component analysis (WPCA), another solo optimization methodology, is utilized to assess the validity of this hybrid optimization method. Here, the best settings from both methods are contrasted and examined. Finding the best feasible parametric combination that yields the best quality characteristics—something that has not been investigated during experimentation—is made easier with the development of a valid model.

5. OBJECTIVES OF RELATED RESEARCH

i) To Complex shapes can be made easily.

ii) To make the work-piece is free from any stress after machining.

iii) To Extremely hard and brittle materials can be easily removed.

iv) To provides good surface finishing with excellent accuracy.

6. RESULTS AND FUTURE SCOPE

The MOORA approach has been used in this thesis to define and solve an MCDM model for choosing the best NCMP based on several factors, especially those pertaining to quality performance. According to the results, EDM is the second-best option, and AWJM is the best. The third and fourth options in the rank were LBM and PAM. The TOPSIS approach was used to solve the NCMPs selection problem in order to validate the ranks of NCMPs that were generated through the use of the MOORA method.

THE ADVANTAGES AND BENEFITS of the MOORA method over other available MCDM methods are reflected in the following facts:

(i) the application of the MOORA method for solving a particular decision making problems requires fewer application steps,

(ii) single equation is required for the purpose of decision. Most of the researchers were tried their work in only EDM and ECM. There is lot of scope to machine composite materials in other non-traditional machining process.

7. CONCLUSION

There has been discussion on the study conducted during the past 20 years. The MOORA method, one of the numerous non-traditional machining techniques examined in this article, is currently widely employed in industry to machine NCMPs. The quantity of papers addressing these processes reflects this. The goal of every technique that is introduced and used in the machining process is the same: to improve the machining performance, i.e., the rate at which material is removed and the surface finish, and to obtain a superior final product. It was found that the competitive NCMP rankings matched precisely. The MOORA method's primary benefit is its ability to consider an infinite number of quantitative and qualitative criteria while providing a straightforward computational process. Furthermore, using specific software programs and having a solid background in mathematics and operational research are not prerequisites for implementing the MOORA technique. For the problems under consideration, the effectiveness of the full multiplicative MOORA method and the reference point approach is also evaluated. It has been noted that all three of these approaches offer nearly precise rankings for the material options and are extremely straightforward to comprehend and apply.

8. REFERENCES

[1] Shoba Ch, Ramanaiah, Nageswara Rao D. “Effect of reinforcement on the cutting forces while machining metal matrix compositese An experimental Approach”. Int. J Eng Sci Tec 2015; 18: 658-663

[2] Nilrudra Mandal, Doloi B, Mondal B, Reeta Das. ‘Optimization of flank wear using Zirconia Toughened Alumina (ZTA cutting tool: Taguchi method and Regression analysis”. Measurement 2011; 44: 2149–2155

[3] Rajesh Kumar Bhushan “Multiresponse Optimization of Al Alloy-SiC Composite Machining Parameters for Minimum Tool Wear and Maximum Metal Removal Rate”. J Mater Sci Eng 2013; Vol. 135 / 021013-1.

[4] Ramulu M, Paul G, Patel J. “EDM surface effects on the fatigue strength of a 15 vol% SiCp/Al metal matrix composite material”. Compos Struct. Vol. 54(1):79-86.

[5] S. Singh and M.F Yeh., “Optimization of Abrasive Powder Mixed EDM of Aluminium Matrix Composites with Multiple Responses using Gray Relation Analysis”, Journal of Materials Engineering and Performance 21:481–491.