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Optimization of Cutting Fluid using VIKOR Method

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ABSTRACT

Cutting fluids are utilized extensively and are crucial components of industrial sectors. But those who work nearby in its environment face a major health risk because of its use. So only after neutralization should waste be disposed of, safeguarding both people and aquatic life. This results in choosing the best option that is both environmentally beneficial and secure for both people and aquatic life. It should also function on par with cutting fluid made of mineral oil. A framework has been provided in the current study to help decision-makers choose and assess lubricants using the analytical hierarchical process (AHP) technique. Three cutting fluids—Neem oil with a 5% emulsifier, Neem oil with a 10% emulsifier, and a typical mineral oil-based cutting fluid-have been explored as options in the research that has been offered. These have been assessed based on many important factors, such as tool wear, surface roughness, and tooltip temperature. The main goal of this work is to outline the rational selection procedure for a cutting fluid and to demonstrate how the ranking or selection of a cutting fluid can alter if a parameter's priority is altered.

KEYWORDS: *Cutting Fluid, AHP, VIKOR*

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INTRODUCTION

In machining, cutting fluids are frequently employed. They do, however, raise a number of environmental and health concerns. Numerous studies on vegetable-based cutting fluids have been described in the literature, but their main objective was the substitution of mineral oil with vegetable oil, not the emulsifier, which is frequently the source of all these problems. The goal of the current effort is to create a new class of sustainable cutting fluids by trying to replace mineral oil and petroleum-based emulsifiers with vegetable-based substitutes (sesame oil and coconut-based emulsifier) [1]. While milling AISI 1040 steel, the specially prepared cutting fluids were compared to standard cutting fluid. The results indicate that in terms of cutting temperatures, tool wear, and surface roughness, the formulated fluid with a 10% vegetable emulsifier content performs similarly to the conventional cutting fluid. The 10% coconut emulsifier fluid performed better than other coconut emulsifier-containing fluids. However, using the common cutting fluid resulted in lower cutting forces. When machining at greater speeds or in conditions with low cutting forces but high cutting temperatures, the fluid formulations can be employed. The use of vegetable oil and the substitution of conventional petroleum-based emulsifiers with an environmentally friendly substitute is the work's main contribution. This study examines the effects of tool wear for the turning tests of 15-5 PH SS using dry, flood, MQL (Minimum Quantity Lubrication), and cryogenic machining with LCO2. By examining the crater wear, progressive power consumption, surface roughness, microhardness, and microstructure of the machined surface and chip, it is possible to compare the machining performance of various cutting fluids. [2,3]. Due to its lower thermal conductivity and higher hardness as a result of precipitation hardening, the tool 15-5 PH SS is less machinable. This causes tool wear with significant surface abrasion [4]. Life thus lowers both process productivity and quality [5]. Productivity is decreased by frequent tool changes and lengthy setup times. The strong cutting force that is generated increases vibration and electricity use. Dimensional accuracy and surface roughness of the machined component are both impacted by changes in tool geometry. The metallurgical and mechanical qualities of the material deteriorate at high temperatures in the cutting zone. The development of alternative cutting fluid procedures that offer the solution in terms of environmental friendliness, worker health, and productivity is advocated in light of these viewpoints. Due to their little or complete lack of use of cutting fluid, cryogenic and MQL machining are developing as sustainable technologies. The oil particles are provided in the form of mist during MQL machining to improve accessibility in the challenging tool-chip contact region. Due to a tiny quantity of oil sticking to the chip, no chip recycling process is necessary [6]. Additionally, the usage of MQL lowers the expense of the pricey mineral oil used in the flood cooling approach [7]. From the aforementioned information, it can be inferred that decreasing tool life lowers productivity as well as the quality of the machined component. Therefore, the creation of high temperatures in the cutting zone is the main cause of tool wear. Industries employ cutting fluid for cooling and lubrication to solve this issue. However, it poses a risk to the environment and human health. To solve this issue, water- or organic-based cutting emulsions are utilized in place of conventional fluids. But because of its poor thermal conductivity, it can only absorb a limited amount of heat [8]. N2 or CO2 are often delivered in liquid form to the cutting zone during cryogenic machining. By vaporization and/or expansion processes, they swiftly absorb the heat from the cutting region. They are therefore very helpful for hard-to-cut materials, particularly for those with reduced heat conductivity. Cryogenic machining, which uses no cutting oil, satisfies the three requirements of productivity, environment, and health as a sustainable machining technique.

Literature Survey:

When it came to surface finish, the wiper-equipped insert outperformed the cryo-treated insert, which performed better in terms of cutting force and tool wear. For the purpose of turning 17-4 PH SS, Sivaiah and Chakradhar [9] recently compared cryogenic machining with LN2 and flood machining in terms of cutting force, cutting temperature, tool wear, surface quality, and chip breakability. In terms of cutting force, surface roughness, cutting temperature, and tool wear, cryogenic machining was superior than flood machining by 17.62%, 44.29%,.%, and 73.4%, respectively. In a different study, Sivaiah and Chakradhar [10] compared the turning of 17-4 PH SS using dry, wet, MQL, and cryogenic machining with LN2. In comparison to dry, wet, and MQL machining, cryogenic machining with LN2 was shown to be superior in terms of decreased cutting force, cutting temperature, flank, and rake tool wear. For the machining of Ti-6Al-4V, Wstawska and Slimak [11] noted that the cooling strategy had undoubtedly impacted the cutting force, tool wear, and surface integrity of machined components. Cryogenic machining was shown to have a stronger cutting force and less tool wear than alternative cooling and lubricating methods. It was also noted that a good surface finish required careful consideration of the cryogenic fluid supply method. NiTi shape memory alloy tool life was compared by Kaynak et al. [12] under various cutting fluid techniques. In comparison to alternative cutting fluid techniques, the cryogenic machining was shown to have a reduced flank and notch wear rate. In contrast to other cutting fluid techniques, the cryogenic machining was also shown to have a reduced cutting force and a good surface quality. The impact of cryogenic machining on the total energy and power used during the milling of Ti6Al4V with progressive tool wear was examined by Shokrani et al. [13]. While there was a 1.0% increase in power consumption during cryogenic machining compared to dry machining due to the harder workpiece, 88% less specific energy was used during cryogenic machining due to the use of higher cutting parameters with the same tool wear.LN2 has been employed as a cryogenic fluid in the majority of the research studies listed above to increase the machinability of various alloys. However, the large reduction in oxygen in the machining region caused by LN2's high gas expansion value might cause respiratory problems for the employees [14]. Furthermore, LN2 as a cooling medium should not be used, according to Nguyen et al. [15], because of its quick vaporization, which prevents it from removing enough heat from the cutting zone. The aforementioned problem with LN2 may be resolved by using CO2 as a cryogenic coolant in machining. The environmental effect study for LN2 and LCO2 as cooling strategies during the machining was carried out by Pereira et al. [16]. It was discovered that LCO2 has a substantially lower global warming potential than LN2. In comparison to LN2, LCO2 was also discovered to be less respiratoryly harmful and less carcinogenic. Additionally, 17% less kilos of benzene equivalent were produced while using LCO2 as a coolant in comparison to LN2 [17]. The use of CO2 as a coolant provides a cheap and environmentally benign replacement for traditional cooling methods, according to a study of the literature [18]. Recently, Tapoglou et al. [19] examined the tool life when cutting Ti-6Al-4V under MQL and MQL with cryogenic CO_2. When combined with MQL at 80 m/min of cutting speed, CO_2 extended the tool life by 32% over MQL alone. On the basis of machining results, Mulyana et al. [20] examined dry, MQL, and supercritical CO_2 (SCCO_2) cryogenic machining with and without lubrication for the milling operation of high thermal conductivity steel. The use of SCCO_2 in conjunction with lubrication increased tool life against dry and MQL conditions by 10% and 87%, respectively, at a higher cutting speed of 120 m/min. It is evident from the aforementioned literature that a relatively small number of researchers have looked into the impact of LCO_2 on hardened materials like 1-PH SS. As a result, it was chosen to use LCO_2 as a coolant in this investigation when milling 1-PH SS. The machining performance of LCO_2 has been contrasted with that of dry, flood, and MQL machining modes in terms of progressive tool wear, power consumption, and surface roughness.

VIKOR PROCEDURE:

Multi-criteria decision-making (MCDM) is one of the most prevalent methods for resolving conflict management issues (Deng & Chan, 2011). MCDM deals with decision and planning problems by consideration of multiple criteria and the importance of each (Haleh & Hamidi, 2011). Among the many MCDM methods, VIKOR is a compromise ranking method to optimize the multi-response process (Opricovic, 1998). It uses a multi-criteria ranking index derived by comparing the closeness of each criterion to the ideal alternative. The core concept of VIKOR is the focus on ranking and selecting from a set of alternatives in the presence of conflicting criteria (Opricovic, 2011). In VIKOR, the ranking index is derived by considering both the maximum group utility and minimum individual regret of the opponent (Liou, Tsai, Lin, & Tzeng, 2011). VIKOR denotes the various n alternatives as $a_1, a_2, \ldots, a_n$. For an alternative ai, the merit of the jth aspect is represented by fij; that is, fit is the value of the jth criterion function for the alternative, *n* being the number of criteria.

The VIKOR procedure is divided into the following five steps:

Step 1: Identify the overall objective, criteria, sub-criteria, and its different alternatives. Assign a qualitative or quantitative value to each criterion and develop a decision matrix.

Step 2: Frame normalized decision matrix using equation.

Step 3: Weights (Wi) for criteria are calculated using AHP.

Step 4: Calculate the best $(Xij)_{max}$ and the worst $(Xij)_{min}$ values for all critera

Step 5: Calculate the values for Ei and Fi and Pi using equation

Step 6: On the basis of Pi arrange it in ascending order an d find the minimum values of Pi

Table-1 Calculation of Sj and Rj

Cutting Force (F)	Temperature at the tool tip (T)	Surface Roughness (S)	Tool Wear (W)	Sj	Rj
0.4	0.14	0.2	0	0.740	0.4
0.2	0	0.13	0.02	0.353	0.2
0	0.093	0.07	0.04	0.200	0.09
0.6	0.047	0	0.06	0.707	0.6

Table 2 Selection of Alternatives

Alternative	Sj	Rj	Qj	Rank
Mineral Oil	0.74	0.4	0.96	4
10%	0.35333333	0.2	0.28	2
15%	0.2	0.09	0	1
20%	0.70666667	0.6	0.94	3
S+,R+	0.2	0.09		
S-,R-	0.74	0.6		

Conclusion:

Neem oil that cannot be consumed and a biodegradable emulsifier were combined to create a unique cutting fluid with a 5% emulsifier. This outperforms the standard cutting fluid in all of the examined metrics, including temperature rise at tip, tool wear, and surface roughness. To validate the findings produced by the current method, a comparison study employing different multi-criteria decision-making techniques may be conducted in the future. The interactions between qualities may be taken into account using an analytical network process (ANP) method, and the outcomes may be compared using an interpretative structural modeling (ISM) based technique. Additionally, ranking may be done using the VIKOR approach.

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