APPLICATION CRITERIA DECISION IN SELECTION OF CUTTING FLUID BASED ON DIFFERENT OPERATING CONDITION

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ABSTRACT

With the recent advancement in computer aided engineering tools, the designers have experienced extensive changes in design methodologies, especially in the field of computational design and optimization. In this work a comprehensive study of choosing cutting fluid on the basis of feed force, cutting force, surface roughness, radial force and its application has been carried out using TOPSIS and VIKOR method. For parametric design MS-excel is extensively used by the designers which give efficient results. Once the design sheet is made, there is no requirement to perform any calculations manually, by varying the value of variables i.e. feed force, cutting force, surface roughness, radial force and weight criteria for factors influence cutting in the MS-excel sheet and it will be easier to find the appropriate cutting fluid for turning process. For machining cylindrical work piece of mild steel the single point cutting tool is used. . The results are shown in the form of graphs. These graphs indicate the relative closeness value for different cutting fluids by VIKOR and TOPSIS. By observing the graph, the best cutting fluid for several cutting speeds and feeds is found out.

This work represent the effects of a well-known parameter coolant flow on surface finish along with other elements such as spindle speed, feed, depth of cut, cutting force. As cutting fluid effects many parameters, therefore there is a need of developing an optimization method for selecting appropriate cutting fluid during turning process. This work is developed an optimization model to help the designer/manufacturer during selection of appropriate cutting fluid for turning process.

Keyword: - Turning, Cutting Fluid, Cutting Force Measurement, Surface Roughness, Instrumentation and Experimentation, Cutting Parameter, Mild Steel.

1. INTRODUCTION

The process parameters optimization is required to lessen the cutting force during machining as the large cutting force may result in unfavourable circumstances, like- high power consumption, greater surface roughness, tool life reduction, poor surface finish etc. cutting forces control various process parameters such as; depth of cut, rake angle cutting speed, feed rate and cutting tool life. Therefore various force measurement methods have been developed to measure cutting force. It is known that load-cell, piezoelectric, thermo-electric, photoelectric etc. transducer type dynamometers are used for measuring cutting forces during turning process. There were many experimental studies for direct cutting force measurements besides estimating cutting forces depending on the process parameters. Simple analytic models were also used to show effects of process parameters such as cutting speed and feed rate.

1.1 Cutting Force Measurement

In this there are three cutting forces which are acting on a single point cutting tool shown in figure 1.1.

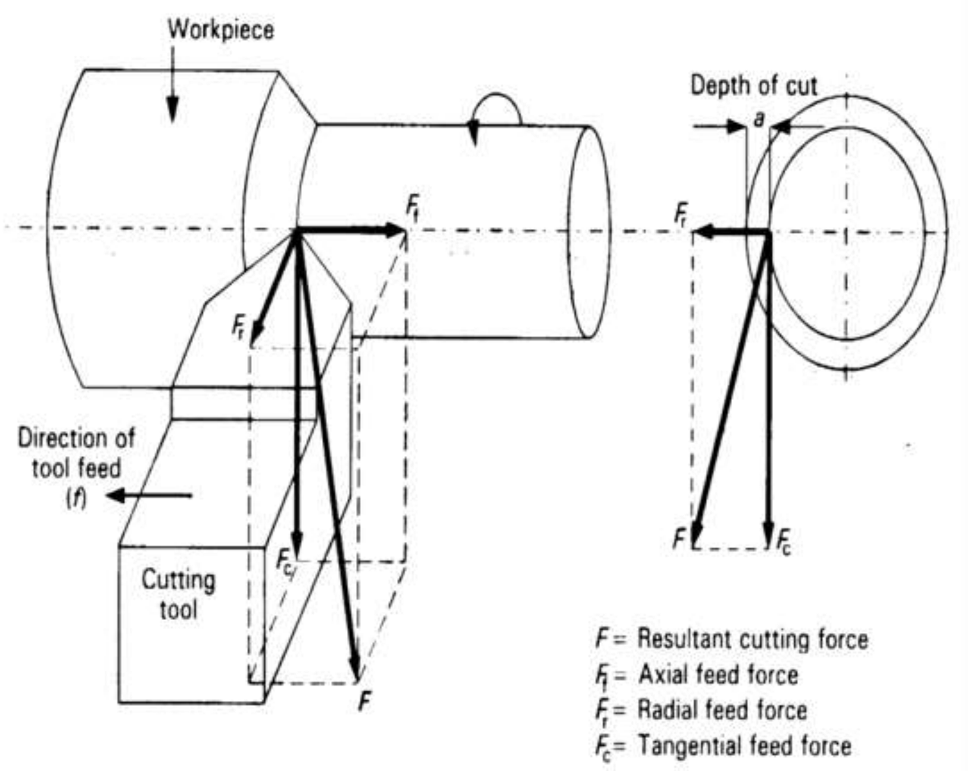

Fig 1: Cutting Forces Acting on Cutting Tool [1]

The Fx is the feed force acting on the X direction, the Fy is cutting force acting on the Y direction and Fz is the radial force acting on the Z direction. The cutting forces were measured using dynamometer shown in Figure 1.5.

1.2 Cutting Fluid [6]

There are different cutting fluids available, which include pastes, oils, gels, aerosols (mists), air, oil-water emulsions or other gases. They may be prepared from plant oils, animal fats, petroleum distillates water, air, or other ingredients.

2. Literature Review

Dwivedi (2002) studied the specific power consumption and cutting forces as a function of depth of cut, rake angle and cutting speed. And concluded that rake angle increases with decreases in cutting forces and the forces will increase with the increase in cutting speed and depth of cut. Ozel et al (2005) experimentally investigated the effect of work piece hardness cutting edge geometry (rake angle), cutting speed and feed rate on surface roughness. This study concluded that the effect of tool geometry, cutting speed and feed rate are statically significant. Prabhu and Ponnusamy (2013) studied the surface roughness of the mild steelwork piece in Turning under various eco-friendly cutting fluids as a coolant. Cylindrical shape job of mild steel is machined by single point cutting tool. The sunflower oil, coconut oil and normal coolant are the fluids take part in operation and in dry condition also machining is done. Mahesh et al (2015) work out a model to analyse the impact of radial rake angle on the end milling cutting tool by taking the different machining parameters: depth of cut(radial), feed rate, spindle speed, axial depth of cut.

3. Methodology

Methodology includes flowchart of the experimental setup. Flowchart is step by step process of the working of the experimental setup which gives a clear understanding of working of the setup. As flowchart gives overall view of the working, detailed explanation of steps.

In this proposed work, the following steps are followed to select the best cutting fluid.

- Compute the various turning process parameters for different cutting fluids.

  Select the best cutting fluid through the application of MCDM method.

- Compare the different MCDM methods.

- Perform the sensitivity analysis for cutting fluid selection.

Method of selection of cutting fluid for various materials is given in Figure 2

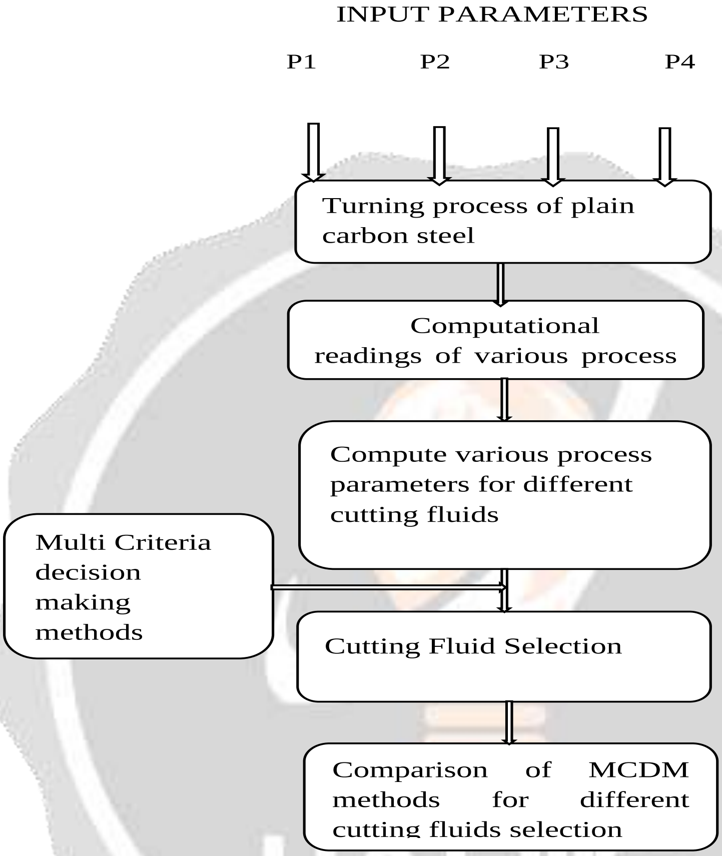

Fig -2: Work Flow Chart

This figure 2 shows the methodology of the work, in which, first the turning process of plain carbon steel is carried out and the computational readings from load cell dynamometer is obtained.

After that we computed the various process parameters for different cutting fluids, after that the multi criterion decision making method for cutting fluid selection is applied and the results are obtained using the AHP and TOPSIS methods for different cutting fluid selection.

3.1 Problem Statement

Based on the above literature review it has been estimated that selection of cutting fluid places an important part during cutting process as it affects the cutting conditions that is depth of cut, surface finish, cutting forces etc. Optimization of process parameters requires the use of optimization algorithms and other numerical optimization techniques to optimize the turning, milling etc. An optimization problem consists of optimizing one or multiple objective functions while satisfying many conflicting constraints. As cutting fluid selection effects many parameters, therefore there is need of developing a optimization method for selecting appropriate cutting fluid during turning process. From the above literature review it can been also estimated that by using the appropriate cutting fluid at the various cutting conditions we can improve the surface roughness and also improve the various process parameters and we can also use the eco-friendly cutting fluids as a coolant.

In this proposed work, the following cases based on the different cutting fluids are considered as suggested in [1]

Case 1:

Table -1: Experimental Results at 220 rpm

Sr.No	Speed (rpm)	Feed (mm/ min)	Depth of Cut (mm)	Coolants Used	F_X(N)	F_Y(N)	F_Z(N)	Surface Rough-ness (µm)
1	220	100	0.1	Sun flower oil	30	220	40	11
2				Coconut oil	20	200	30	18
3				Normal Coolant	33	150	30	13
4				Dry Condition	41	200	50	22

Case 2:

Table -2: Experimental Results at 350 rpm

Sr.No	Speed (rpm)	Feed (mm/ min)	Depth of Cut (mm)	Coolants Used	F_X(N)	F_Y(N)	F_Z(N)	Surface Rough- ness (µm)
1	350	150	0.15	**Sun flower oil**	20	270	20	6
2				**Coconut oil**	50	340	60	13
3				**Normal Coolant**	40	380	50	11
4				**Dry Condition**	80	380	70	27

Case 3:

Table -3: Experimental Results at 560 rpm

Sr.No	Speed (rpm)	Feed (mm/ min)	Depth of Cut (mm)	Coolants Used	F_X(N)	F_Y(N)	F_Z(N)	Surface Rough-ness (µm)
1	560	250	0.2	**Sun flower oil**	110	410	84	3
2				**Coconut oil**	180	120	60	5
3				**Normal Coolant**	80	200	40	3
4				**Dry Condition**	170	340	70	10

3.2 Mathematical Calculation

A. Arithmetic Hierarchy Process [18]

The method of the AHP can be defined as:

The question is break down into a hierarchy of goal, criteria, sub-criteria and alternatives. It is important to note that when comparing elements at each level a decision-maker has just to com-pare with respect to the contribution of the lower-level elements to the upper-level one. Experts can estimate the comparison as equal, marginally strong, strong, very strong, and extremely strong. The comparisons are made for each criterion and changes into quantitative numbers as per Table 4.The pairwise observations of various criteria produced at step 2 are arranged into a square matrix. The diagonal aspects of the matrix are 1. The criterion in the *i*th row is better than criterion in the *j*th column if the value of element (*i*, *j*) is more than 1; otherwise the criterion in the *j*th column is better than that in the *i*th row. The (*j*, *i*) element of the matrix is the reciprocal of the (*i*, *j*) element.

Table -4: Comparison Criterion Matrix

Option	Numerical value(s)
Equal	1
Marginally strong	3
Strong	5
Very strong	7
Extremely strong	9

The corresponding normalised right Eigen-vector of the comparison matrix and principal eigenvalue give the relative importance of the different criteria being compared. The elements of the normalised eigenvector are termed weights with respect to the criteria or sub-criteria and ratings with respect to the alternatives. The consistency of the matrix *is* calculated. Combinations crate by this process are subjective and the AHP provide inconsistency through the amount of redundancy in the approach. If this consistency index fall to reach a required level then answers to comparisons may be again calculated. The consistency index, CI, is calculated as

$CI = (\lambda_{max} - n)/(n - 1)$

Where λ_{max} is the maximum eigenvalue of the judgement matrix. This CI can be compared with that of a random matrix, RI. The ratio derived, CI/RI, is termed the consistency ratio, CR. The value of CR should be less than 0.1. The valuation of each alternative is multiplied by the weights of the criteria and amass to bring local ratings for the sake of each criterion. The AHP provides weight values for each alternative based on the importance of one alternative over another with respect to a common criterion.

B. Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) [16]

Establish the decision matrix, Where i is the criterion index and j is the alternative index (j= 1 . . . n). Then calculate a normalised decision matrix, the normalized values stands for Normalized Decision Matrix which shows the relative performance of produced design alternatives. After that the weighting decision matrix is simply make by multiply each element of each column of the normalized decision matrix by the random weights.

$V = V_{ij} = W_j \times R_{ij}$

Identify the Positive and Negative Ideal Solution

$PIS = A^+ = \{V^+_1, V^+_2 .... V_n^+\}$, Where: $V_j^+ = \{(\max_i (V_{ij}) \text{ if } j \in J) ; (\min_i (V_{ij}) \text{ if } j \in J')\}$

$NIS = A^- = \{V^-_1, V^-_2 .... V_n^-\}$, Where: $V_j^- = \{(\min_i (V_{ij}) \text{ if } j \in J) ; (\max_i (V_{ij}) \text{ if } j \in J')\}$

The positive ideal (A^+) and the negative ideal (A^-) solutions are defined according to the weighted decision matrix via step (4) and (5) below Where, J is associated with the beneficial attributes and J' is associated with the non-beneficial attributes. Evaluate the separation distance of each alternative from the ideal and non- ideal solution.

$S^+ = \sqrt{\sum^n_{j=1}(V_j^+ - V_{ij})^2}$ i=1,…..,m

$S^- = \sqrt{\sum^n_{j=1}(V_j^- - V_{ij})^2}$ i=1,……,m

Where, j = alternative index. i = criterion index

Measure the relative closeness of each location to the ideal solution. For each competitive alternative the relative closeness of the potential location with respect to the ideal solution is computed.

$C_i = S_i^- /(S_i^+ + S_i^-)$, $0 \le C_i \le 1$

Ranking of the preferences in descending order so that relatively better performances to be compared and higher the value of C_i the relative closeness, higher the preference order and hence better the performance of the alternative.

C. Vikor Method [17]

Decide the best f_{i*} and the worst f_i^- values of all criterion functions i = 1,2…..,n. If the ith function represents a benefit then:

$f_{i*} = \max_j f_{ij}$, $f_i^- = \max_j f_{ij}$

Calculate the values S_j and R_j; j = 1,2…..,n., by the equations

$S_j = \sum^n_{j=1} w_i (f_i^* - f_{ij})/(f_i^* - f_{ij})$, $R_j = \max_j [w_i(f_i^* - f_{ij})/(f_i^* - f_{ij})]$

Where w_i are the weights of criteria, expressing their relative importance.

Calculate the values of Qj, j = 1,2…..,J., by the relation

Qj = v (Sj – S*)/(S- – S*) + (1 – v)(Rj – R*)/(R- – R*)

S* = minj Sj, S- = maxj Sj

R* = minj Rj, R- = maxj Rj – R*

And v is imported as weight of strategy of the maximum group utility, here v= 0.5.

Preference ranking, sorted by the values S, R and Q, in decreasing order.

4. Result and Discussion

The following results which are obtained by using AHP and TOPSIS, are discussed below.

This table shows the different weights calculated by AHP for various factors influencing cutting as per the designer/manufacturer.

Table -5: Weights of factors influence cutting

Coolant Used/Factors influence Cutting	Feed Force F_X(N)	Cutting Force F_Y(N)	Radial Force F_Z(N)	Surface Rough-ness(μm)
Weights	0.140	0.20430	0.0492	0.60643

Conclusion of chart 1: This graph shows highest value of relative closeness 0.818 which indicates the C1* as the best and lowest value of relative closeness 0.049 which indicates C4* as the worst cutting fluid at 220 rpm at the criterion weights given in table 5.

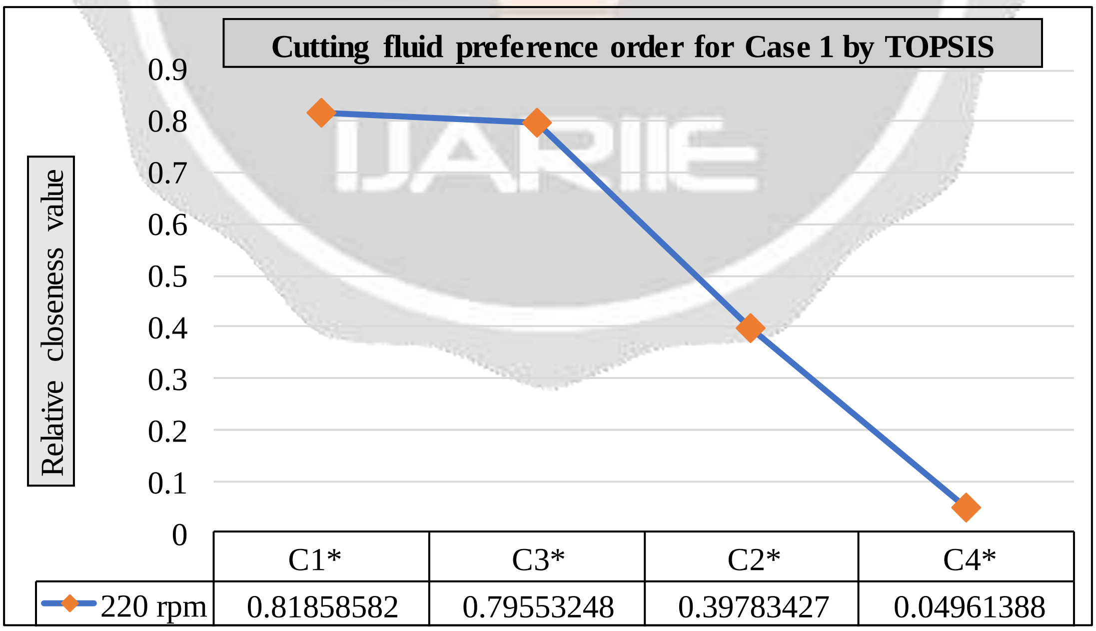

Chart -1: Cutting Fluids V/S Relative Closeness Value

Conclusion of Chart 2: This graph shows lowest value of relative closeness -0.0796 which indicates the Q3 as the best and highest value of relative closeness .550 which indicates Q4 as the worst cutting fluid at 220 rpm at the criterion weights given in table 5.

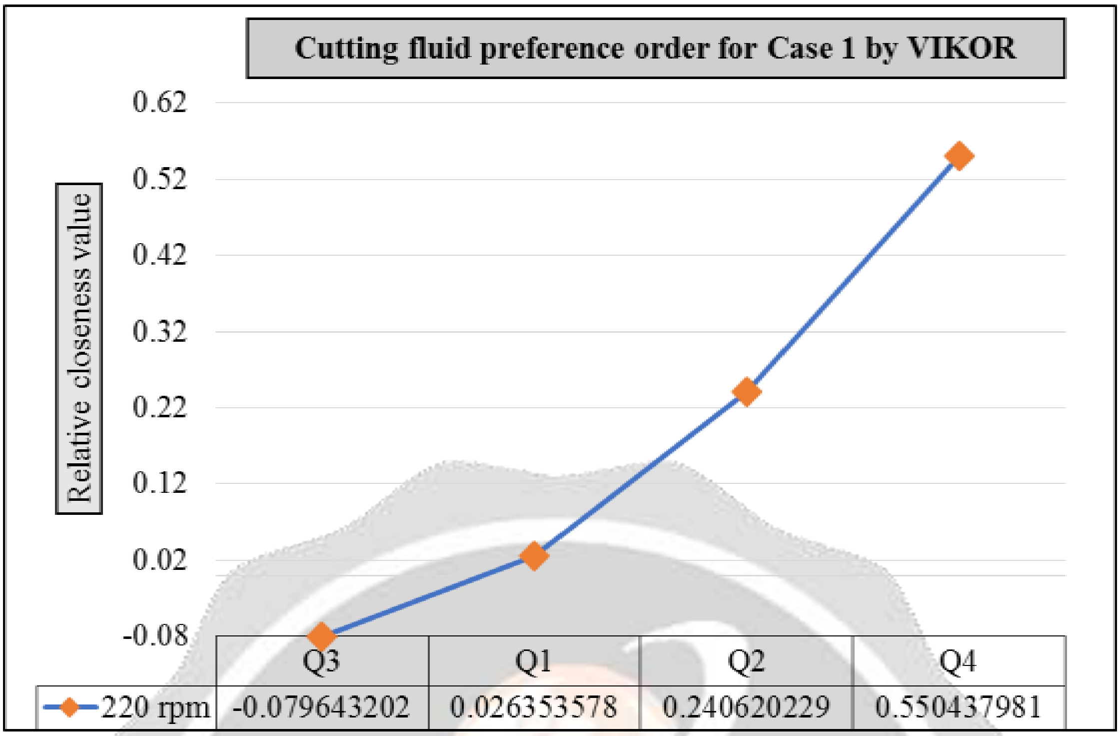

Chart -2: Cutting Fluids V/S Relative Closeness Value

Conclusion of Chart 3: This graph shows highest value of relative closeness 1 which indicates the C1* as the best and lowest value of relative closeness 0 which indicates C4* as the worst cutting fluid at 350 rpm at the criterion weights given in table 5.

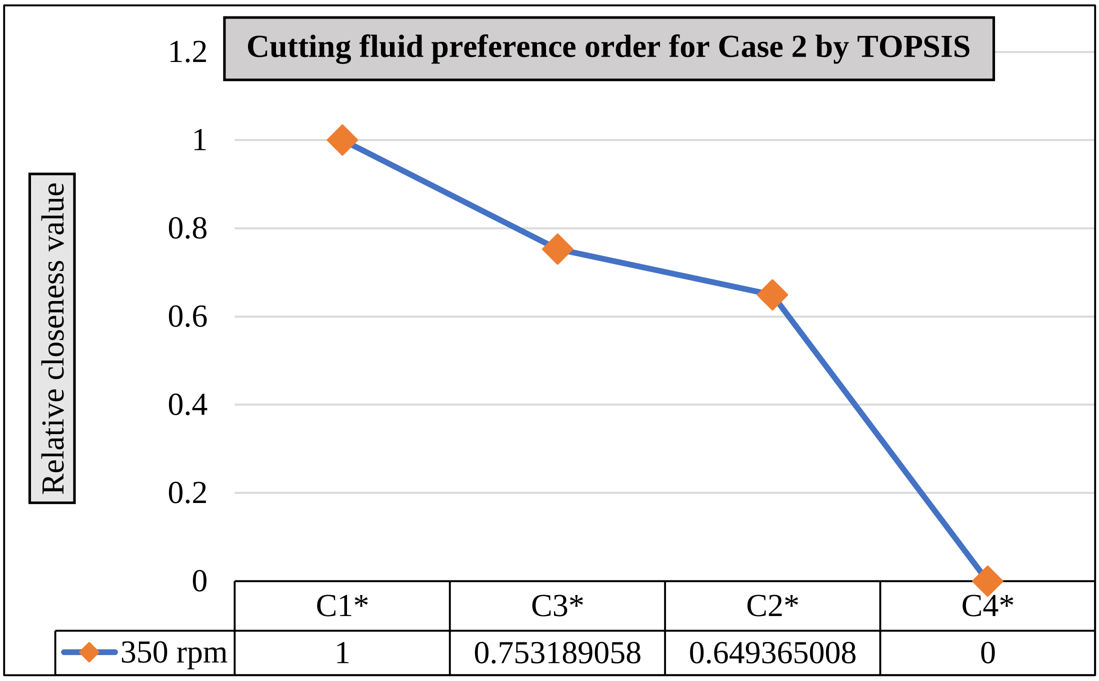

Chart -3: Cutting Fluids V/S Relative Closeness Value

Conclusion of Chart 4: This graph shows lowest value of relative closeness 0 which indicates the Q1 as the best and highest value of relative closeness .803 which indicates Q4 as the worst cutting fluid at 350 rpm at the criterion weights given in table 5.

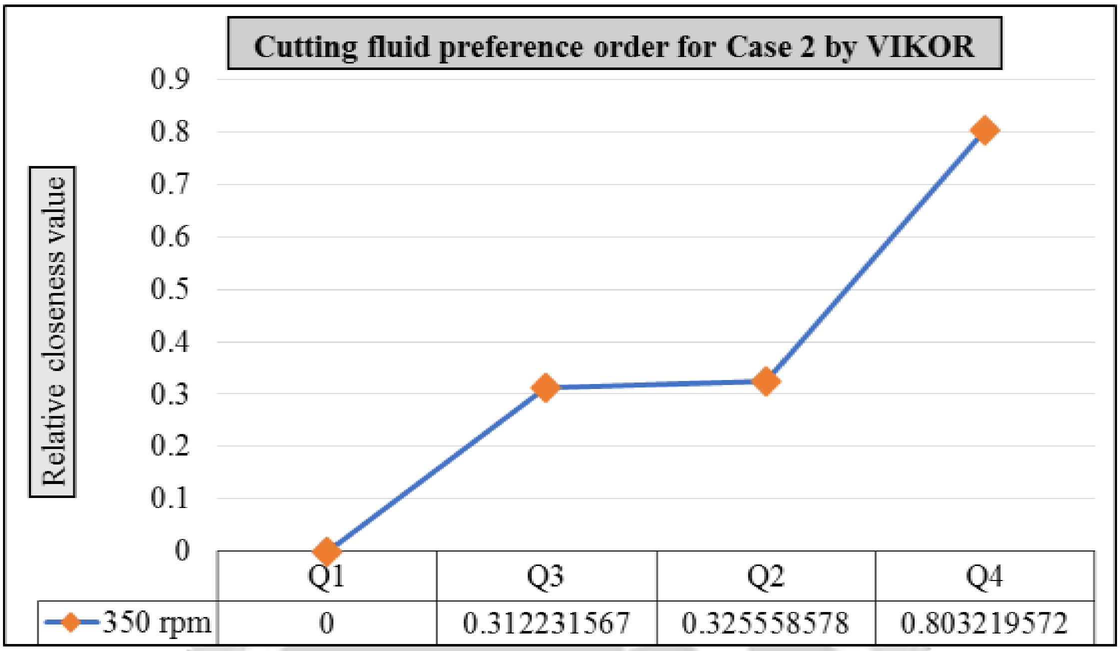

Chart -4: Cutting Fluids V/S Relative Closeness Value

Conclusion of Chart 5: This graph shows highest value of relative closeness 0.913 which indicates the C3* as the best and lowest value of relative closeness 0.072 which indicates C4* as the worst cutting fluid at 560 rpm at the criterion weights given in table 5.

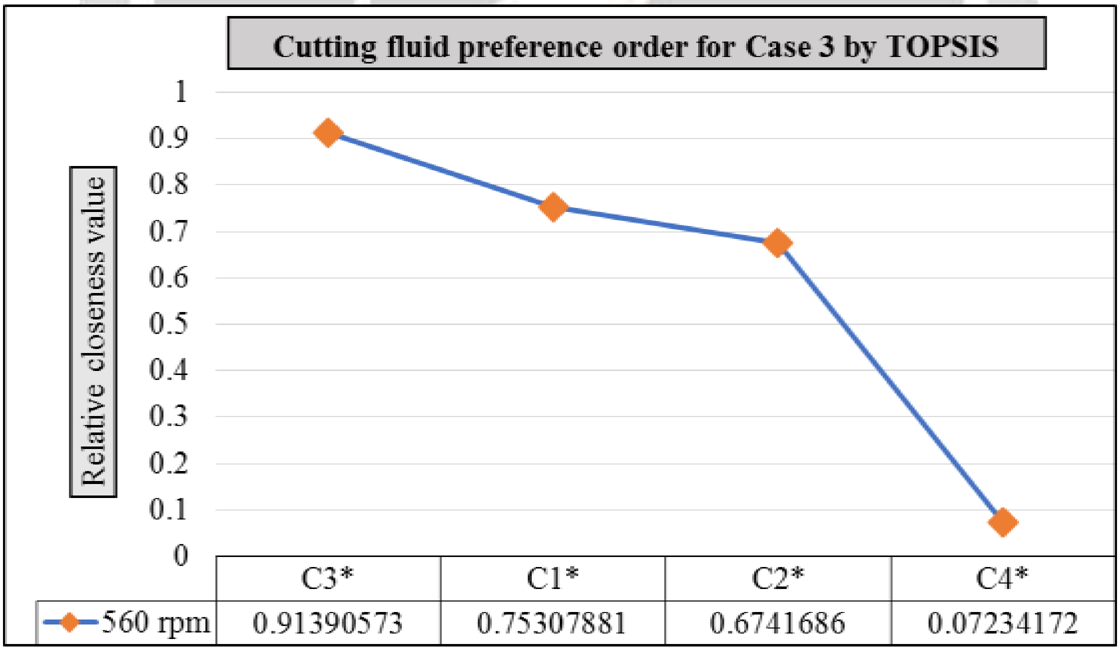

Chart -5: Cutting Fluids V/S Relative Closeness Value

Conclusion of Chart 6: This graph shows lowest value of relative closeness -0.030 which indicates the Q3 as the best and highest value of relative closeness 0.667 which indicates Q4 as the worst cutting fluid at 560 rpm at the criterion weights given in table 5.

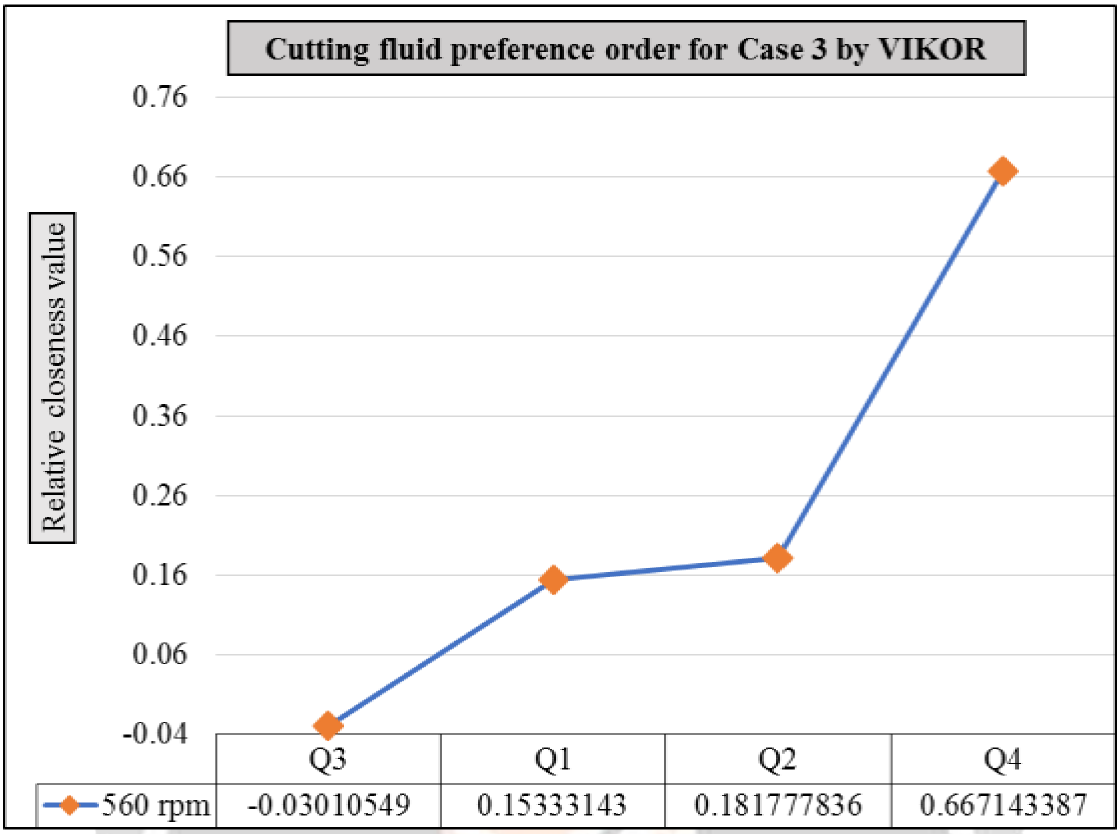

Chart -6: Cutting Fluids V/S Relative Closeness Value

5. CONCLUSIONS

From the above literature review and experiments we can conclude that by investigating and evaluating the thrust force, radial force and surface roughness we developed an optimization model to help the designer/manufacturer during selection of appropriate cutting fluid for turning process. This model improve the surface roughness and improves the process parameters. The best cutting fluid is selected through the application of MCDM method for three different cases at the desired criterion weight.

6. Future Scope

We obtained the value of different forces by varying the cutting fluids. The values of various cutting forces are obtained by using the load cell dynamometer and made to calculate the values of forces at different cutting conditions such as depth of cut, cutting speed and feed rate etc. This load cell dynamometer and experimental setup can be used for the analysis, making and to produce such working parameters which gives the good surface finish, better accuracy and low cost of production.

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