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MADM FOR SELECTION OF VEGETABLE BASED CUTTING FLUIDS BY SAW METHOD AND WPM METHOD

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ABSTRACT

MADM is based on the performance of new developed environmental friendly vegetable based cutting fluids (refined sunflower and canola oils) including different percentage of extreme pressure (EP) additives and two commercial fluids (semi-synthetic and mineral cutting fluids) in turning process of AISI304L. MADM gives the best-optimized results in the overall working conditions considering different attributes surface roughness, cutting force, feed force, flank wear, and nose wear. The best optimum results obtained by SAW METHOD AND WPM METHOD.

1. INTRODUCTION

Much heat is generated in metal cutting operations due to plastic deformations of work material, friction at the tool-chip, and friction between the clearance face of the tool and the work piece. The heat generation increases the temperature of both the work piece and tool point, resulting in decrease in hardness, and hence tool life. The machined surface will also be less smooth, and the possibility of built-up edge increases. Moreover, use of a cutting fluid during a machining operation very essential. The major factors that govern the selection of cutting fluids are: (i) the machining process, (ii) cutting tool material, and (iii) work piece material. Other factors, such as compatibility with the machine tool, performance requirements, operator interaction, environment friendliness, and economy must also be looked into. Nowadays, ever increasing environmental problems are becoming a serious threat to the survival and development of society. After the publishing of ISO 9000 quality management standards, the ISO 1400 environmental management system standards, and the OHASIS 18001 occupational health and safety assessment series, one of our greatest strategic challenges is to apply the three series integrated in to a management system and enterprises, not only from an engineering but also from a business and marketing perspective. The manufacturing industry is one of the main roots of environmental pollution. Therefore we have to minimize the environmental impact of manufacturing industry. As, cutting fluid are widely used in industrial machining operations, and because of their negative effects on health, safety, environment, legislation, and public environmental concerns now have great impact on their development. Dry machining and minimum quantity lubrication (MQL) machining have been successfully applied in some kinds of machining processes. However, in others, such as grinding, it is very difficult to obtain good results without the help of cutting fluids, because of high amount of heat generated during grinding. As for MQL machining, although progress is being made, we have a long way to go before this problem is solved in application workshops. Therefore research on the composition, supply techniques, selections, cleaning and maintenance of cutting fluid is still active at present [1]. For the environmental safety, industrial environment, worker safety, less wear and tear of tool and work material I have used MADM techniques for the best selection of cutting fluid among different vegetable-based cutting fluid with extreme pressure during turning of AISI304L.

2. LITERATURE

The selection of cutting fluids is more an art, than a science, because there is almost no standardized method available for this purpose. Numerous methods have been proposed in the past, yet very few of these gave reasonably satisfactory results. Different metal cutting operations have been used to evaluate cutting fluids. Nagpal and Sharma [2] presented the results of a series of short-and long-run cylindrical turning tests for the evaluation of most common, commercially available metal cutting fluids, namely, water soluble, straight mineral, chlorinated and sulfo-chlorinated oils. Peters and Aerens [3] made an attempt to evaluate grinding fluids based on grinding charts obtained in cylindrical plunge grinding. The authors considered performance parameters, roughness, tangential force, normal force, grinding ratio, specific energy, metal removal rate, tool life, and cost for grinding ratio, specific energy, metal removal rate, tool life, and cost for grinding conditions in the middle of the practical usable range. From the comparison, it appeared that the large variety of grinding fluids offered by the market was not justified commercially or technologically. The use of oils led to a significantly lower cost price, and an increased surface quality in external as well as internal grinding, especially when high wheel speed was used. De Chiffre[4] studied a series of hold-making operations in order to evaluate different types of cutting fluids. After measuring performance parameters such as number of holes to failure, cutting force, and surface finish, the author concluded that the effectiveness of a coolant greatly depended up on the machining process and on the performance measures. Sutcliffe *et al.*[5] used the creation of catastrophic drill failure, or maximum of 120 holes. Different feeds, speeds, and type of cutting fluids were tested, including a nitrite-free synthetic coolant that performed very well. Rowe [6] performed cutting fluid testing for cylindrical grinding operations, involving the coordination of various chemical and physical properties of the grinding fluids, their physiological actions and their mechanical performance. Rapp [7] discussed the general criteria for the selection of cutting fluids for machine tools, and identified the advantages offered by an appropriate selection of cutting fluids (e.g., cost reduction, higher productivity, better safety, lower rate of rejects, and less frequent sharpening of tools). Belluco and de Chiffre [8] presented the result of cutting fluid testing through subsequent hole making operations. AISI 316L stainless steel specimens were machined with drilling, core drilling, reaming and taping using HSS-E tools. The effect of different lubricants on cutting force and power was investigated in connection with the development of vegetable based cutting oils. De Chiffre *et al*. evaluate the effect of cutting fluid on cutting forces, surface finish, and hole description of the lubricating properties of cutting fluids, while conventional surface roughness evaluation was associated with a large scatter in the data. Eppert *et al*.[9] presented a methodology using the cluster analysis in a hierarchical agglomerative form, for the development of a classification scheme based on physical properties of a wide array of cutting fluids, Bartz [10] described ecological and environmental aspects of cutting fluids, and suggested that all components, base oils and additives, have to be selected very carefully in order to minimize any health problems and any impact to the environment. Rao and Gandhi [11] presented a cutting fluid selection index using digraph and matrix methods, which can serve for the evaluation and selection of cutting fluids. Sun *et al* [12] presented two grade fuzzy synthetic decision making method using AHP for evaluation of grinding fluids. Varadarajan *et al.* [13] investigated hard turning operation with MQL, and made a comparison with dry and wet turning. Tan *et al* .[14] presented a decision making framework model for cutting fluid selection for green manufacturing, together with a case study. Sokovic and Mijanovic [15] studied ecological aspects of cutting fluids, and presented a combined MADM method for the selection of environmentally conscious cutting fluids using the TOPSIS and AHP methods. Dhar [16] studied the effect of minimum quantity lubrication (MQL) on tool wear and surface roughness while machining AISI 4340 steel. In another work, Dhar and Kamruzzaman [17] conducted turning experiments on AISI 4037 steel using cryogenic cooling by liquid nitrogen jets. Haqand Tamizharasan [18] investigated the effects of cooling in hard turning operations. Reddy and Rao [19] studied the effect of solid lubricants on cutting forces and surface quality in end milling. The result indicated that there was a considerable improvement in process performance with solid lubricant-assisted machining. Compared to that of machining with cutting fluids. Obikawa *et al.* [20] investigated high speed grooving operations with minimum quantity lubrication (MQL). It is evident from the above the exiting procedures of cutting fluid selection for a given machining application focus mainly on identifying the cutting fluid matching with a tool, work material, and machining operation. Different metal cutting operations have been used to evaluate cutting fluids, and the performance of a cutting fluid judged by the resulting machining process output variables such as : tool life (i.e., life) of single point tool in turning/boring, drill in drilling, reamer in reaming, tap in tapping, grinding wheel in grinding), cutting forces (i.e., main cutting force and/or thrust in turning/boring, torque and/or thrust in drilling/reaming/tapping, normal force and/or tangential force in grinding), power consumption, cost per unit volume of material removed, surface finish, cutting temperature, dimensional accuracy, etc. The selection procedures suggested by earlier researchers considered either a single machining process output variable, or a number of machining process output variables, and these output variables were examined with respect to cutting fluid properties and characteristics. So far, cutting fluids have been evaluated in terms of their performance with respect to each machining process output variable separately, and then the final decision regarding selection was taken, in a subjective manner, keeping in mind the overall performance. It is clear that there is a need to develop a mathematical tool for cutting fluid selection that is capable of considering the requirements of a given machining application. The objective of a cutting fluid selection procedure is to identify cutting fluid properties, and obtain the most appropriate combination of cutting fluid properties, in conjunction with the real requirement of a machining application. Thus, efforts need to be extended to determine attributes that influence cutting fluid selection for a given machining application, using a logical approach, to eliminate unsuitable cutting fluids and to select an appropriate cutting fluid to strengthen the existing cutting fluid selection procedure. A few researchers, such as Rowe [21], Sun *et al.* [22], Rao and Gandhi [23], Tan *et al.* [24] and Rao [25], have presented some mathematical models for cutting fluid selection.

Most of the researchers used different type of technique which are discussed above in the literature section, but they did not use the techniques like SAW and WPM so, this area of work is left that's why I applied both the techniques simultaneously and compare the theoretical and experimental results solved by SAW and WPM. The SAW and WPM method gives the best alternative under different attributes, like the one problem solved in this paper the attributes are: surface roughness, cutting force, feed force, flank wear and nose wear.

3. METHODOLOGY

Multiple criterion decision making (MCDM) refers to making decisions in the presence of multiple, usually conflicting criteria. The problems of MCDM can be broadly classified into two categories: multiple attribute decision making (MADM) and multiple objective decision making (MODM), depending on whether the problem is a selection problem or a design problem. MODM methods have decision variable values that are determined in a continuous or integer domain, with either an infinitive or a large number of choices, the best of which should satisfy the decision maker's constraints and preference priorities. MADM methods, on the other hand, are generally discrete, with a limited number of predetermined alternatives. MADM is an approach employed to solve problems involving selection from among a finite number of alternatives. AN MADM method specifies how attribute information is to be processed in order to arrive at a choice. MADM methods require both inter- and intra-attribute comparisons, and involve appropriate explicit trade-offs.

Each decision table (also called decision matrix) in MADM methods has four main parts, namely: (a) alternatives, (b) attributes, (c) weight or relative importance of each attribute, and (d) measures of performance of alternatives with respect to the attributes. The decision table is shown in Table 1. The decision table shows alternatives, A_i (for I = 1,2,…….,N) , attributes, B_j(for j = 1,2,…….., M), weights of attributes, w_j(for j = 1,2,……., M) and the measures of performance of alternatives, m_{ij}(for i= 1,2,….., N; j=1,2,…..,M). Given the decision table information and a decision-making method, the task of the decision maker is to find the best alternative and/or to rank the entire set of alternatives. It may be added here that all the elements in the decision table must be normalized to the same units, so that all possible attributes in the decision problem can be considered [26].

3.1 MADM

Table 1 decision table in MADM methods

3.1.1 Simple Additive Weighting (SAW) Method

This is also called the weighted sum method (Fishburn, 1967) and is the simplest and still the widest used MADM method. Here, each attribute is given a weight, and the sum of all weights must be 1. Each alternative is assessed with regard to every attribute. The overall or composite performance score of an alternative is given by Equation. (1)

$$P_i = \sum_{j=1}^{M} W_j \; m_{ij}$$

Previously, it was argued that SAW should be used only when the decision attributes can be expressed in identical units of measure (e.g., only dollars, only pounds, only seconds, etc.). However, if all the elements of the decision table are normalized than SAW can be used for any type and any number attributes. In the case, Equation (1) will take the following form:

$$P_i = \sum_{j=1}^{M} W_j \; (m_{ij})normal$$

Where (m_{ij})normal represents the normalized value of m_{ij}, and pi is the overall or composite score of the alternatives Ai. The alternatives with the highest value of pi are considered as the best alternatives.

The attributes can be beneficial or non-beneficial. When objectives values of the attributes are available, normalized values are calculated by (m_{ij})K/(m_{ij})L, where (m_{ij})K is the measure of the attributes for the K-th alternative, and (m_{ij})L is the measure of the attributes for the L-th alternatives that has the highest measure of the attributes out of all alternatives considered. This ratio is valid for beneficial attributes only. A beneficial attribute (e.g., profit) means its higher measure are more desirable for the given decision – making problem. By contrast, non-beneficial attribute (e.g., cost) is that for which the lower measures are desirable, and the normalized values are calculated by (m_{ij})L/(m_{ij})K.[26].

3.1.2 WEIGHTED PRODUCT METHOD (WPM)

In this method, the overall or composite performance score of alternatives score of alternatives is given by Equation (3).

$$P_i = \prod_{j=1}^{M} [(m_{ij})normal]^{wj}$$

The normalized values are calculated as explained above. Each normalized value of an alternative with respect to an attribute, i.e., (m_{ij}) normal, is raised to the power of the relative weight of the corresponding attribute. The alternative with the highest Pi value is considered the best alternatives [26].

3.2 Properties of cutting fluid and work piece material

AISI 304L containing a significant amount of chrome and nickel along with lesser amount of carbon is more ductile and less thermally conductive than other carbon steels or alloyed steel. Consequently, the high energy needed for machining remains in the cutting region, instead of moving away from the reason with chips [27]. Usage of CFs is vital to move away the heat and increased the tool life. AISI 304L having a vickers hardness of 315 was used as work piece material [28]. The chemical composition of AISI 304L work piece material given in percentages of weight are shown in **Table 2.**

Four of six cutting fluids used were formulated as VBCFS and the rest were commercial CFs. Commercial mineral and semi-synthetic based CFs were used as reference for comparison of the surface roughness, tool life, cutting force and feed forces. Physical properties [29] of CFs are shown in **Table 3**.

SCF-II (8% of EP): sunflower based cutting fluids with 8% of EP additive.
SCF-II (12% of EP): sunflower based cutting fluids with 12% of EP additive.
CCF-II (8% of EP): canola based cutting fluids with 8% of EP additive.
CCF-II (12% of EP): canola based cutting fluids with 12% of EP additive.
CMCF: commercial mineral based cutting fluid.
CSSCF: commercial semi-synthetic cutting fluid.

3.3 Properties wise best cutting fluid by SAW and WPM

3.3.1 SAW METHOD:-All the values in Table 4 are taken from the above Table 3.

3.3.1.1 NORMALISED VALUES OF ATTRIBUTES

Table 5 shows the normalized data of cutting fluid selection attributes.

3.3.1.2 SELECTION INDEX

Table 6 shows the selection index of cutting fluids by the SAW METHOD.

3.3.2 WPM METHOD:-

3.3.2.1 NORMALISED VALUES OF ATTRIBUTES

Table 7 shows the normalized data of cutting fluid selection attributes.

3.3.2.2 SELECTION INDEX

Table 8 shows the selection index of cutting fluids by the WPM METHOD.

3.4 Comparison of RESULTS AND RANKS of saw and wpm are shown in Table 9 and Figure 1, Table 10 and Figure 2.

Table 9 shows comparison of results. Table 10 shows comparison of results. Figure 1 shows comparison of results by SAW and WPM method of Table 9. Figure 2 shows comparison of ranks SAW and WPM method of Table 10.

3.5 Experimental data analysis by saw and wpm

3.5.1 Saw method

Table 11 shows the experimental data i.e. Objective data of cutting fluid selection of attributes.

3.5.1.1 Normalized values of attributes

Table 12 shows the normalized data of cutting fluid selection attributes.

3.5.1.2 Selection index

Table 13 shows the selection index of cutting fluids by the SAW METHOD.

3.5.2 Wpm method

3.5.2.1 Normalized values of attributes

Table 14 shows the normalized data of cutting fluid selection attributes.

3.5.2.2Selection index

Table 15 shows the selection index of cutting fluids by the WPM METHOD.

3.6 Comparison of ranks and results of saw and wpm are shown in Table 16 and Figure 3, Table 17 and Figure 4

Table 16 shows Comparison of results. Table 17 shows Comparison of ranks. Figure 3 shows comparison of results of saw and wpm method of Table 16. Figure 4 shows comparison of ranks by saw and wpm method of Table 17.

4. RESULT AND CONCLUSION

4.1 Comparison of optimized results by saw and wpm methods based on theoretical and experimental data shown in Table 18 or Figure5.

Table 18 shows comparison of both the results i.e. theoretical and experimental data analysis by SAW and WPM method. Figure 5 shows comparison of both the results i.e. theoretical and experimental data analysis by SAW and WPM method of Table 18.

4.2 Comparison of optimized ranks by saw and wpm methods based on theoretical and experimental data shown in Table 19 or Figure.6.

Table 19 shows comparison of both the ranks i.e. theoretical and experimental data analysis by SAW and WPM method. Figure 6 shows comparison of both the ranks i.e. theoretical and experimental data analysis by SAW and WPM method of Table 19.

4.3 Conclusion.

1. Objective data analysis based on theoretical data by SAW and WPM method CSSCF is the best cutting fluids.

2. Objective data analysis based on experimental data by SAW and WPM method CCF-II (8% of EP) is the best cutting fluids.

3. When include DRY cutting gives below average results by SAW method and lowest results by WPM method.

4. Over all comparison of all the data we find out CSSCF and CCF-II (8% of EP) are the most feasible cutting fluids for the working condition.

5. REFERENCES

[1] R.V. Rao (2007) Decision Making in the Manufacturing Environment. Cutting tool selection for a given machining application (Page 97-98)

[2] Nagpal BK, Sharma CS (1973) Evolution of four common, commercially available cutting fluids used in flooding. Journal of the Institution of Engineers (India) 23:249-253

[3] Peters J, Aerens R (1976) An objective method for evaluating grinding coolants. CIRP Annals 25:247-250

[4] de Chiffre L (1978) Testing the overall performance of cutting fluids. STLE Transactions 34:244-251

[5] Sutcliffe T, Barber SJ, Dycan W (1979) Coolants laboratory evaluation by drill test technique using high speed drills. STLE Transactions 35:145-152

[6] Rowe GW (1982) Lubricant Testing for grinding operations. Wear 77:73-80

[7] Rapp W (1984) Selection of cooling lubricants. VDI – Z 126:213-220

[8] Belluco, Dechiffre L (2001) Testing of vegetable based cutting fluids by hole making operations. Lubrication Engineering 57:12-16

[9] Eppert JJ, Gunter KL, Sutherland JW (2001) Development of cutting fluid classification system using cluster analysis. Tribology Transactions 44:375-382

[10] Bartz WJ (2001) Ecological and Environmental aspects of cutting fluids. Lubrication Engineering 57:30-16

[11] Rao RV Gandhi OP (2001) Digraph and matrix method for selection, identification and comparison of metal cutting fluids. Proc. IME, Journal of Engineering Tribology 212:307-318

[12] Sun J, Ge P, Zhenchang L (2001) Two-grade fuzzy synthetic decision – making system with use of an analytic hierarchy process for performance evaluation of grinding fluids. Tribology International 34:683-688

[13] Varadarajan AS, Philip PK, Ramamoorthy B (2002) Investigations on hard turning with minimal cutting fluid application (HTMF) and its comparison with dry and wet turning. International Journal of Machine Tool and Manufacture 42:193-200

[14] TanXC, Liu F, Cao HJ, Jhang H (2002) A decision- making frame work model of cutting fluid selection for green manufacturing and a case study. Journal of Material Processing Technology 129:467-470

[15] Sokovic M, Mijanovic K (2001) Ecological aspects of the cutting fluids and its influence on quantifiable parameters of cutting fluid processes. Journal of material processing Technology 109:181-189

[16] Dhar NR, Kamruzzaman M, Ahmed M (2006) Effect of minimum quantity lubrication (MQL) on tool wear and surface roughness in turning AISI-4340 steel. Journal of Materials Processing Technology 172:299-304

[17] Dhar NR Kamruzzaman M, Ahmed M(2006) Cutting temperature tool wear, surface roughness and dimensional deviation in turning AISI-4037 steel under cryogenic condition. International Journal of Machine Tool and Manufacture doi:10.1016/j.ijmachtools. 2006.09.018

[18] Haq AN, Tamizharasan T (2005) investigation of the effects of cooling in hard turning operations. International Journal Advanced Manufacturing Technology 30:808-816

[19] Reddy NSK, Rao PV (2006) Experimental investigation to study the effect of solid lubricants on cutting forces and surface quality in end milling. International Journal of Machine Tools and Manufacture 46:189-198

[20] Obikawa T, Kamata Y, Shinozuka J (2006) High-speed grooving with applying MQL. International Journal of Machine Tools and Manufacture 46:1854-1861

[21] Rowe GW (1982) Lubricant testing for grinding operations. Wear 77:73-80

[22] Sun J, Ge P, Zhenchang L (2001) Two-grade fuzzy synthetic decision-making system with use of an analytic hierarchy process for performance evaluation of grinding fluids. Tribology International 34:683-688

[23] Rao RV Gandhi OP (2001) Digraph and matrix method for selection, identification and comparison of metal cutting fluids. Proc. IME, Journal of Engineering Tribology 212:307-318

[24] TanXC, Liu F, Cao HJ, Jhang H (2002) A decision- making frame work model of cutting fluid selection for green manufacturing and a case study. Journal of Material Processing Technology 129:467-470

[25] Rao RV (2004) Performance evaluation of cutting fluids for green manufacturing using a combined multiple attribute decision making method. International Journal of Environmentally Conscious Design and Manufacturing 12:526-535

[26] R.V. Rao (2007) Decision Making in the Manufacturing Environment. Introduction to multiple attribute decision –making (MADM) methods (Page 27-29)

[27]ciftci I, kasap M, seker U, ostenitikpaslanmazceliklerinislenebilirlikpparametrelerininbelirlenmesiuzerineyapilmisdeneyselcalismalar. ZKU karabukteknikegitimfakultesiteknoloji 1993;3-4:130-41

[28]BarburOzcelik, EmelKuram, M.huseyin, ErhanDemirbas (2011) Experimental investigations of vegetable based cutting fluids with extreme pressure during turning of AISI 304L. Tribology International 44:1864-1871

[29]BarburOzcelik, EmelKuram, M.huseyin, ErhanDemirbas (2011) Experimental investigations of vegetable based cutting fluids with extreme pressure during turning of AISI 304L. Tribology International 44:1864-1871

[30]BarburOzcelik, EmelKuram, M.huseyin, ErhanDemirbas (2011) Experimental investigations of vegetable based cutting fluids with extreme pressure during turning of AISI 304L. Tribology International 44:1864-1871

TABLE 1

Alternatives	Attributes					
	B1	B2	B3	-	-	BM
	(W1)	(W2)	(W3)	(-)	(-)	(WM)
A1	m11	m12	m13	-	-	m1M
A2	m21	m22	m23	-	-	m2M
A3	m31	m32	m33	-	-	m2M
-	-	-	-	-	-	-
-	-	-	-	-	-	-
AN	mN1	mN2	mN3	-	-	mNM

TABLE 2

C	Si	Mn	P	S	Cr	Ni	Mo	Al
0.0250	0.2140	1.9000	0.0200	0.0220	19.2800	8.4600	0.5100	0.0028
Cu	Co	Ti	Nb	V	W	Pb	Mg	B
0.2590	0.0720	0.0039	0.0220	0.0400	0.0170	<0.0030	0.0180	0.0019
Sn	Zn	As	Bi	Ca	Ce	Zr	La	Fe
0.0054	0.0210	0.0095	<0.0020	0.0017	0.0250	0.0070	0.0034	69.1000

TABLE 3

Type of metal cutting fluid	pH (emulsion 8%)	Density(gm/ml) (emulsion 8%)	Viscosity 40°C (mm2/s)	Viscosity 40°C (mm2/s) (emulsion 8%)	Flash point (°C)	Refractive index
SCF-II (8% of EP)	9.20	0.95	99	2.4	221	1.4775
SCF-II (12% of EP)	9.05	0.97	97	2.0	227	1.4793
CCF-II (8% of EP)	9.30	0.99	115	1.8	235	1.4767

CCF-II (12% of EP)	9.00	1.00	109	1.8	245	1.4780
CMCF	9.30	0.99	66	2.2	195	1.4942
CSSCF	9.18	0.99	75	1.7	180	1.4825

TABLE 4

Type of metal cutting fluid	pH (emulsion8%)	Density(gm/ml) (emulsion 8%)	Viscosity 40°C (mm$_2$/s)	Viscosity 40°C (mm$_2$/s) (emulsion 8%)	Flash point (°C)	Refractive index
SCF-II (8% of EP)	9.20	0.95	99	2.4	221	1.4775
SCF-II (12% of EP)	9.05	0.97	97	2.0	227	1.4793
CCF-II (8% of EP)	9.30	0.99	115	1.8	235	1.4767
CCF-II (12% of EP)	9.00	1.00	109	1.8	245	1.4780
CMCF	9.30	0.99	66	2.2	195	1.4942
CSSCF	9.18	0.99	75	1.7	180	1.4825

TABLE 5

Type of metal cutting fluid	pH (emulsion 8%)	Density (g/ml) (emulsion 8%)	Viscosity 40 °c (mm²/s)	Viscosity 40°C(mm²/s) (emulsion 8%)	Flash point (°c)	Refractive index
SCF-II(8% of EP)	0.97826087	1	0.666666667	0.708333333	0.814479638	0.999458545
SCF-II(12% Of EP)	0.994475138	0.979381443	0.680412371	0.85	0.792951542	0.998242412
CCF-II(8% of EP)	0.967741935	0.95959596	0.573913043	0.944444444	0.765957447	1
CCF-II(12% of EP)	1	0.95	0.605504587	0.944444444	0.734693878	0.999120433
CMCF	0.967741935	0.95959596	1	0.772727273	0.923076923	0.988288047
CSSCF	0.980392157	0.95959596	0.88	1	1	0.99608769

TABLE 6

Type of metal cutting fluid	pH (emulsion 8%)	Density (g/ml) (emulsion 8%)	Viscosity 40 °c (mm²/s)	Viscosity 40°c (mm²/s) (emulsion 8%)	Flash point (°c)	Refractive index
SCF-II(8% of EP)	0.220108696	0.22	0.143333333	0.219583333	0.020361991	0.004997293
SCF-II(12% Of EP)	0.223756906	0.215463918	0.14628866	0.2635	0.019823789	0.004991212
CCF-II(8% of EP)	0.217741935	0.211111111	0.123391304	0.292777778	0.019148936	0.005
CCF-II(12% of EP)	0.225	0.209	0.130183486	0.292777778	0.018367347	0.004995602
CMCF	0.217741935	0.211111111	0.215	0.239545455	0.023076923	0.00494144
CSSCF	0.220588235	0.211111111	0.1892	0.31	0.025	0.004980438

TABLE 7

Type of metal cutting fluid	pH (emulsion 8%)	Density (g/ml) (emulsion 8%)	Viscosity 40 °c (mm²/s)	Viscosity 40°c (mm²/s) (emulsion 8%)	Flash point (°c)	Refractive index
SCF-II(8% of EP)	0.999458545	0.999458545	0.999458545	0.999458545	0.999458545	0.999458545
SCF-II(12% Of EP)	0.994475138	0.979381443	0.680412371	0.85	0.792951542	0.998242412
CCF-II(8% of EP)	0.967741935	0.95959596	0.573913043	0.944444444	0.765957447	1
CCF-II(12% of EP)	1	0.95	0.605504587	0.944444444	0.734693878	0.999120433
CMCF	0.967741935	0.95959596	1	0.772727273	0.923076923	0.988288047
CSSCF	0.980392157	0.95959596	0.88	1	1	0.99608769

TABLE 8

Type of metal cutting fluid	pH (emulsion 8%)	Density (g/ml) (emulsion 8%)	Viscosity 40 °c (mm²/s)	Viscosity 40°c (mm²/s) (emulsion 8%)	Flash point (°c)	Refractive index
SCF-II(8% of EP)	0.999878147	0.999880855	0.999883562	0.999832118	0.99998646	0.999997292
SCF-II(12% Of EP)	0.998754236	0.995426989	0.920547119	0.9508672	0.994216957	0.999991204

CCF-II(8% of EP)	0.992649438	0.990967589	0.887466382	0.982436952	0.99335645	1
CCF-II(12% of EP)	1	0.988778907	0.89774966	0.982436952	0.992322093	0.9999956
CMCF	0.992649438	0.990967589	1	0.923183714	0.998000933	0.999941096
CSSCF	0.99555432	0.990967589	0.972890079	1	1	0.9999804

TABLE 9

Type of metal Cutting fluid	saw	Wpm
SCF-II(8% of EP)	0.828384646	0.999458545
SCF-II(12% of EP)	0.873824484	0.865189584
CCF-II(8% of EP)	0.869171065	0.851955806
CCF-II(12% of EP)	0.880324213	0.865386032
CMCF	0.911416864	0.906251735
CSSCF	0.960879785	0.959797632

TABLE 10

Type of metal cutting fluid	saw	Wpm
SCF-II(8% of EP)	6	6
SCF-II(12% of EP)	4	4
CCF-II(8% of EP)	5	5
CCF-II(12% of EP)	3	3
CMCF	2	2
CSSCF	1	1

TABLE 11

Type of metal Cutting fluid	surface roughness (µm)	Cutting force (N)	feed force (N)	flank wear (mm)	nose wear (mm)
SCF-II(8% of EP)	3.47	635.15	439.59	0.1793	0.1505
SCF-II(12% Of EP)	3.93	627.39	423.8	0.1881	0.1682
CCF-II(8% of EP)	3.06	629.26	401.53	0.1527	0.1316
CCF-II(12% of EP)	3.75	668.12	495.04	0.1962	0.1616
CMCF	4.75	663.26	544.86	0.1949	0.2339
CSSCF	4.01	615.05	523.93	0.2436	0.2094
dry cutting	3.3	503.15	271.14	0.54	0.5357

TABLE 12

Type of metal Cutting fluid	surface roughness (µm)	cutting force (N)	feed force (N)	flank wear(mm)	nose wear (mm)
SCF-II(8% of EP)	0.88184438	0.792175077	0.61680202	0.851645287	0.874418605
SCF-II(12% Of EP)	0.778625954	0.801973254	0.63978292	0.811802233	0.782401902
CCF-II(8% of EP)	1	0.799589995	0.6752671	1	1
CCF-II(12% of EP)	0.816	0.753083278	0.54771332	0.778287462	0.814356436
CMCF	0.644210526	0.758601453	0.49763242	0.783478707	0.562633604
CSSCF	0.763092269	0.818063572	0.51751188	0.626847291	0.628462273
dry cutting	0.927272727	1	1	0.282777778	0.245659884

TABLE 13

Type of metal Cutting fluid	surface roughness (µm)	cutting force (N)	feed force (N)	flank wear (mm)	nose wear(mm)
SCF-II(8% of EP)	0.282190202	0.170317642	0.08326827	0.106455661	0.179255814
SCF-II(12% of EP)	0.249160305	0.17242425	0.08637069	0.101475279	0.16039239

CCF-II(8% of EP)	0.32	0.171911849	0.09116106	0.125	0.205
CCF-II(12% of EP)	0.26112	0.161912905	0.0739413	0.097285933	0.166943069
CMCF	0.206147368	0.163099312	0.06718038	0.097934838	0.115339889
CSSCF	0.244189526	0.175883668	0.0698641	0.078355911	0.128834766
dry cutting	0.296727273	0.215	0.135	0.035347222	0.050360276

TABLE 14

Type of metal Cutting fluid	surface roughness (µm)	cutting force (N)	feed force (N)	flank wear (mm)	nose wear (mm)
SCF-II(8% of EP)	0.88184438	0.792175077	0.61680202	0.851645287	0.874418605
SCF-II(12% Of EP)	0.778625954	0.801973254	0.63978292	0.811802233	0.782401902
CCF-II(8% of EP)	1	0.799589995	0.6752671	1	1
CCF-II(12% of EP)	0.816	0.753083278	0.54771332	0.778287462	0.814356436
CMCF	0.644210526	0.758601453	0.49763242	0.783478707	0.562633604
CSSCF	0.763092269	0.818063572	0.51751188	0.626847291	0.628462273
dry cutting	0.927272727	1	1	0.282777778	0.245659884

TABLE 15

Type of metal Cutting fluid	surface roughness (µm)	cutting force (N)	feed force (N)	flank wear (mm)	nose wear (mm)
SCF-II(8% of EP)	0.96056205	0.951144613	0.93684918	0.980126978	0.972864766
SCF-II(12% Of EP)	0.923050029	0.953661775	0.94148717	0.974274375	0.950940029
CCF-II(8% of EP)	1	0.953051744	0.94837305	1	1
CCF-II(12% of EP)	0.937002718	0.940851856	0.92194433	0.969153357	0.958775614
CMCF	0.868738165	0.94232983	0.9100865	0.969959051	0.88878407
CSSCF	0.917116817	0.957743508	0.91491183	0.943289975	0.909174483
dry cutting	0.976127157	1	1	0.853946494	0.749926188

TABLE 16

Type of metal Cutting fluid	saw	Wpm
SCF-II(8% of EP)	0.821487591	0.8161622
SCF-II(12% Of EP)	0.769822918	0.767835931
CCF-II(8% of EP)	0.913072908	0.903848591
CCF-II(12% of EP)	0.761203205	0.755224857
CMCF	0.649701785	0.642279665
CSSCF	0.697127975	0.689200487
dry cutting	0.732434771	0.625108746

TABLE 17

Type of metal Cutting fluid	saw	Wpm
SCF-II(8% of EP)	2	2
SCF-II(12% Of EP)	3	3
CCF-II(8% of EP)	1	1
CCF-II(12% of EP)	4	4
CMCF	7	6
CSSCF	6	5
dry cutting	5	7

TABLE 18

Type of metal Cutting fluid	saw experimental	wpm experimental	saw theoretical	wpm theoretical
SCF-II(8% of EP)	0.821487591	0.8161622	0.828384646	0.999458545

SCF-II(12% Of EP)	0.769822918	0.767835931	0.873824484	0.865189584
CCF-II(8% of EP)	0.913072908	0.903848591	0.869171065	0.851955806
CCF-II(12% of EP)	0.761203205	0.755224857	0.880324213	0.865386032
CMCF	0.649701785	0.642279665	0.911416864	0.906251735
CSSCF	0.697127975	0.689200487	0.960879785	0.959797632
dry cutting	0.732434771	0.625108746	-	-

TABLE 19

Type of metal Cutting fluid	saw experimental	wpm experimental	saw theoretical	wpm theoretical
SCF-II(8% of EP)	2	2	6	6
SCF-II(12% Of EP)	3	3	4	4
CCF-II(8% of EP)	1	1	5	5
CCF-II(12% of EP)	4	4	3	3
CMCF	7	6	2	2
CSSCF	6	5	1	1
dry cutting	5	7	-	-

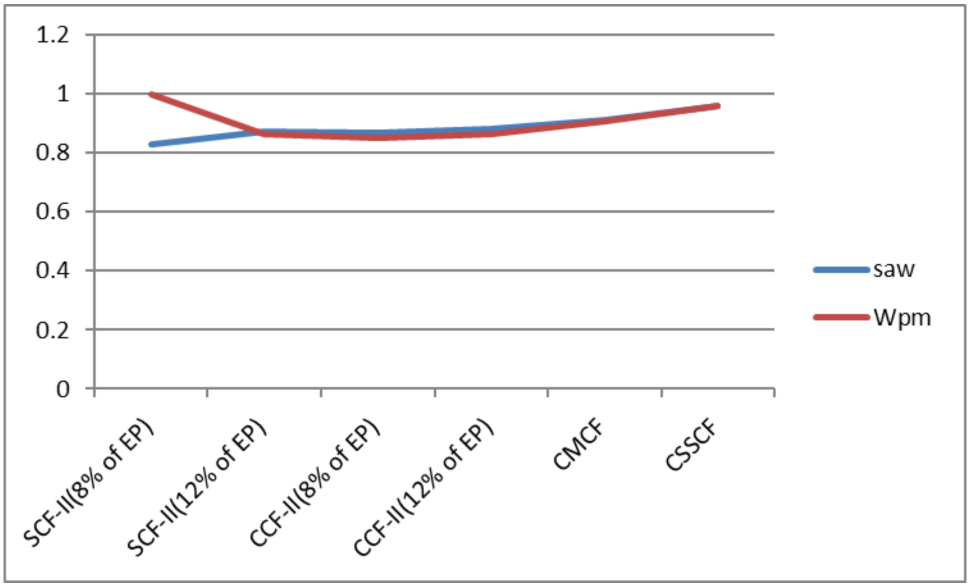
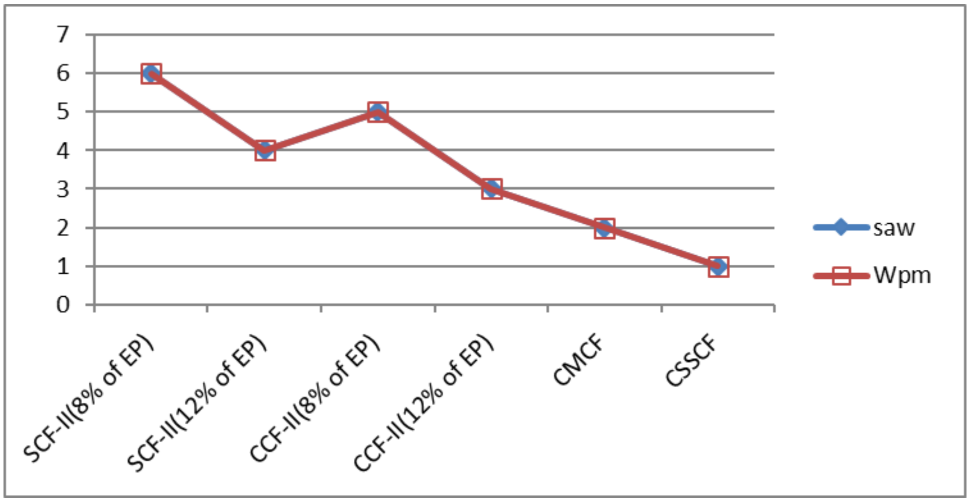


Fig 1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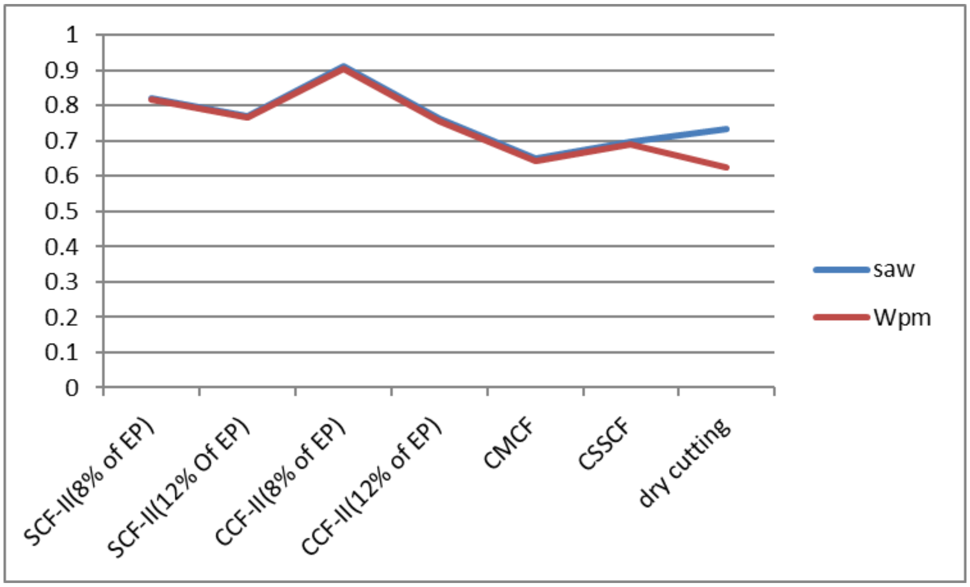
6
5
4
3
2
1
0
SCF-II(8% of EP)
SCF-II(12% of EP)
CCF-II(8% of EP)
CCF-II(12% of EP)
CMCF
CSSCF
saw
Wpm

Fig 2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0.7
0.6
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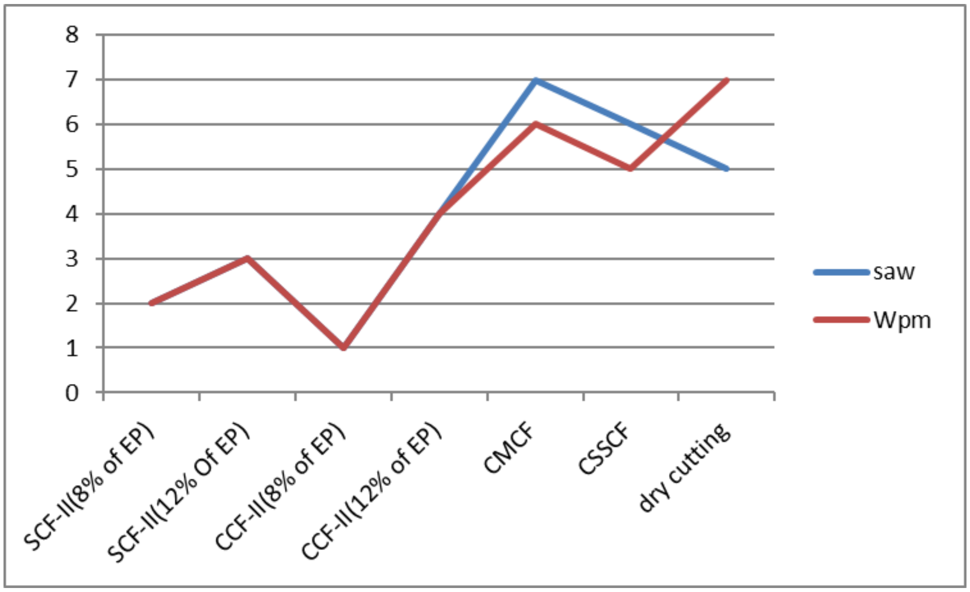
0.4
0.3
0.2
0.1
0
SCF-II(8% of EP)
SCF-II(12% Of EP)
CCF-II(8% of EP)
CCF-II(12% of EP)
CMCF
CSSCF
dry cutting
saw
Wpm

Fig 3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7
6
5
4
3
2
1
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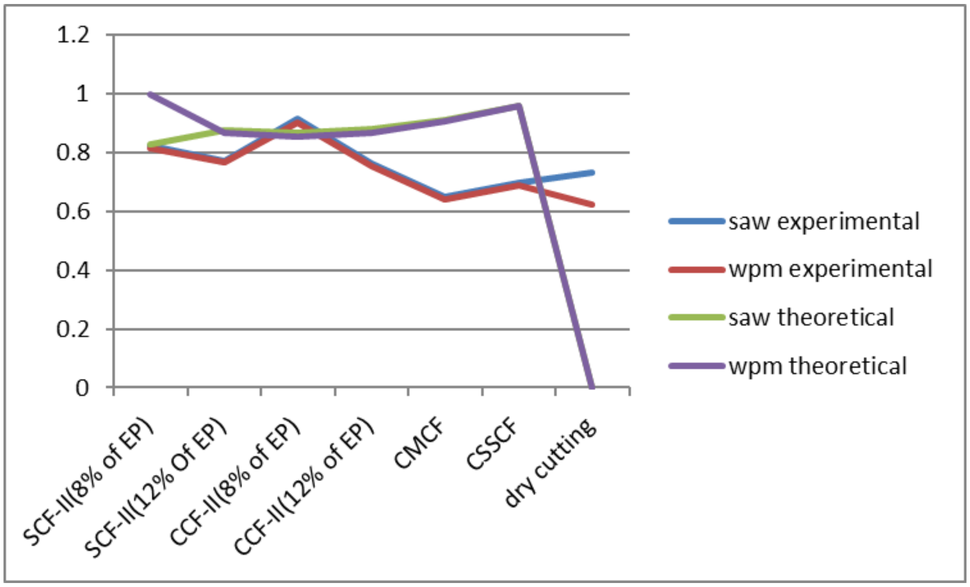
SCF-II(8% of EP)
SCF-II(12% Of EP)
CCF-II(8% of EP)
CCF-II(12% of EP)
CMCF
CSSCF
dry cutting
saw
Wpm

Fig 4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0.6
0.4
0.2
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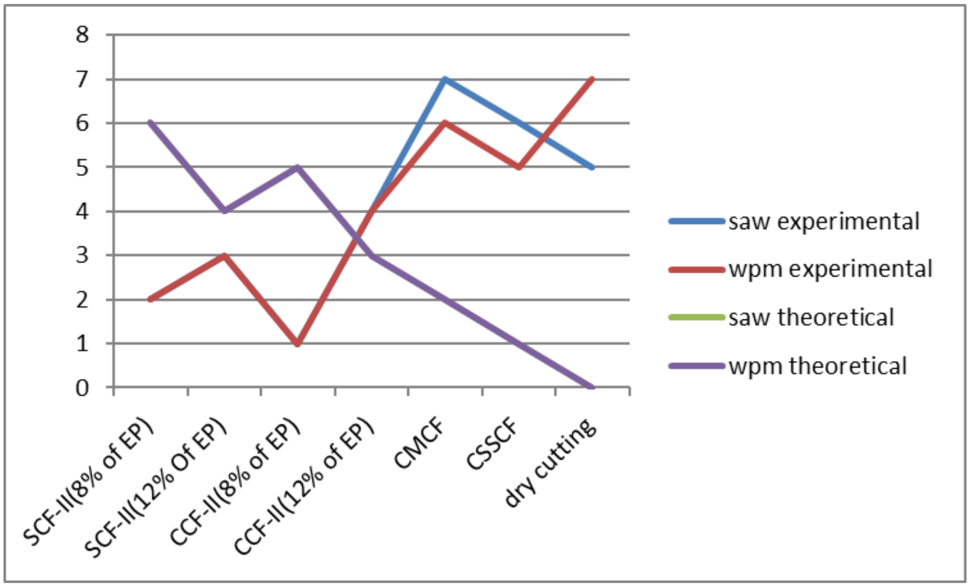
SCF-II(8% of EP)
SCF-II(12% Of EP)
CCF-II(8% of EP)
CCF-II(12% of EP)
CMCF
CSSCF
dry cutting
saw experimental
wpm experimental
saw theoretical
wpm theoretical

Fig 5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7
6
5
4
3
2
1
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SCF-II(8% of EP)
SCF-II(12% Of EP)
CCF-II(8% of EP)
CCF-II(12% of EP)
CMCF
CSSCF
dry cutting
saw experimental
wpm experimental
saw theoretical
wpm theoretical

Fig 6