Experimental investigation of machining parameters in MQL turning of hardened steel by generalized pattern search coupled with RSM technique

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ABSTRACT

Manufacturing companies facing more problems to increase productivity with good surface finish in the less amount of cutting fluid. Minimum Quantity Lubrication (MQL) plays a vital role to increase the productivity by use of minimal fluid. In all machined part, surface finish is one of the most important parameter that decide the quality of the part.Control of tool tip temperature in cutting tool is also considered as the key factor to reduce the tool wear and increase surface finish of the work piece. Minimum quantity lubrication using castor oil lowers the tool tip temperature and improves the surface finish of the AISI D2 steel. In this paper it aims to identify the optimal value of minimized surface roughness value and tool tip temperature of the material during machining.Variation of surface roughness and tool tip temperature of the machined surface with spindle speed feed and depth of cut by involving three different machining conditions such as dry, MQL (10 ml/hr) and MQL(15 ml/hr) are studied.Coupled approach of response surface methodology with generalized pattern search method gives the predicted optimal values of the surface roughness and tool tip tempaerature in the steel.This paper compares the optimized values from Response surface methodology (RSM) and Generalized pattern search (GPS) method. Confirmation result shows thatthe output values of surface roughness and tool tiptemperature values are good agreement with the values compared with RSMand GPS.

Key words : AISID2 steel, machining, surface roughness, tool tip temperature, response surface methodology, pattern search method.

NOMENCLATURE

MQL	Minimum quantity lubrication
mm	Millimeter
ml/hr	Milliliters per hour
doc	Depth of cut
rev	Revolution
µm	Micrometer
s	Speed
f	Feed
min	Minute
GPS	Generalized pattern search algorithm
RSM	Response surface methodology
SR	Surface roughness
Temp	Temperature
rpm	revolution per minute

1. INTRODUCTION

Heat generation in machining leads to several problemsinconventional machining process like turning, drilling, milling and shaping operation. To avoid the effect of temperature in machining process flood machining process was employed. But in flood machining process, more amount of cutting fluid was used,at the same time the chemical additives present in cutting fluid create health problem to operators and makes more pollutants to the environment, water and soil contamination during disposal of cutting fluids after machining processes. To achieve the clean and eco friendly machining environment and reduce the cost of cutting fluid, minimum quantity lubrication machining has been considered as the alternative machining process. In Minimum quantity lubrication, air and less amount of oil mixed together and then supplied with maximum velocity towards the point of contact between cutting tool and work piece simply it makes atomization process of oil with air towards the cutting zone in order to reduce the amount of heat and improves sustainability on the machined work piece.

Senevirathne et al. [1] Involves two different work pieces of AISI P20 and D20 were machined by using coated carbide tools. The output parameter of surface roughness was noted at every 5^0Ctemperature rise in aerosol. The aerosol temperature plays aessential role to fix the surface finish in the work piece. Surface finish of the P20 steel is better compared with D20 steel. P. Vamsi Krishna et al. [2] uses Nano boric acid suspension in SAE 40 and castor oil as cutting fluid in MQLmachining of AISI 1040 steel. It was noted that special attachment of provision for thermocouple in tool holder was used to record the tool workpiece interface temperature. Different combination and variable proportion of boric acid suspended in SAE oil and castor oil was used to examine the tool tip temperature by varying the cutting speed and feed rate. Flank wear and surface roughness were considered as the output parameters. It was clearly stated that 0.5 % of nano boric acid suspension in SAE oil gives better result of optimal output parameter compared with castoroil.Heat transfer coefficient was slightly increased with increasing the percentage of nano particles suspended with base oil.ChengyongWang et al. [3] develop a new method to reduce the tool cost and increase the durability of cutting tool while machining compacted graphite cast iron. Three different machining conditions such as external oil on water, cryogenic air with oil on water, internal oils on water were used. Comparative analysis of cutting temperature, flank wear and surface roughness for different machining condition were analyzed. Better surface finish and higher tool wear resistance on PVD TiAlN- based coated tools was attained by external oil on water spray rake to flank face combined with internal oil on water method. It was observed that the tool wear rate is gradually decreased while using cryogenically air mixed with oil on water condition.

ArunachalamSenbagmSetraBalan et al, [4] employed MQL method in grinding operation in two ways such as simulation and experimental method. Computational fluid dynamics simulation method was employed to simulate the model and evaluating the parameters related to spray quality towards tool-work pieceinterface. Discrete phase model was used and it specifies droplet size, air pressure and mesh type for simulation. In the experimental part droplet size analyzer measure the droplet size and droplet size plays a major role to predict surface finish in grinding. He finally finish off 6 to 16.3 nanometer droplet size gives effective lubrication and betterment of surface finish, at the same time it also lowers the grinding force.

L.B. Abhang et al. [5]implemented grey relational analysis to validate the optimum parameters such as surface roughness and chip thickness.Nose radius was considered as one of the input parameters to decide the optimal value of output parameters. Graphite, MoS2 and boric acid powder of each 10% contribute with the base oil was taken as SAE40 used in MQL setup. 24 experiments were planned and conducted as per the design matrix. Related output responses such as surface roughness (SR) and chip thickness were recorded. From the experiment values the optimal value of output response was identified. It was observed that confirmation results indicate percentage of deviation between the results of confirmation to the predicted value lesser than 30%. Dry, MQL (0.45 ml/min), MQL (0.90ml/min), MQL (3.25ml/min)four conditions are preferred to validate the minimum average surface roughness value. A.Çakır,S. Et al. [6] selected AA7075 and AA2024 aluminum alloys to check the surface quality in machining condition. Better surface finish was occurred in AA2024 compared with AA7075 under the same input condition.

Q.L. An et al [7] designed cold water mist jet setupto investigate the effects of cold jet in evaluating cutting temperature and flank wear of the work piece. Special attachment of thermocouple was designed specially to measure the interface temperature in between tool and work piece. It was identified that the short spiral chip formation tends to decrease the interruption in between tool and work piece. Eco friendly machining environment was effectively attempted in this MQL technique. Results show better improvement in surface finishfor the machined part using MQL. Rao,R.V et al [8]was implemented multi objective Jaya algorithm to identifythe best optimal parameters of material removal rate and dross formation rate. Design expert software was used to formulate central composite design matrix for experiments. Pareto front applied to point out the optimal values of material removal rate and dross formation rate using multi objective Jaya algorithm. In micro electro discharge machining parameters Multi Objective Jaya Algorithm (MOJA) technique was execute to predict the best values of Material removal rate (MRR), Tool wear rate (TWR), Dross formation rate (DFR).SatishChinchanikar et al [9]uses Magnetron sputtering coated carbide toolas a cutting tool to examine the cutting tool life. The experiments were conducted by the use of three different cutting inserts such as AlTiNmulti-layerTiAlN and AlTiCrN. Calotest known as thickness tester was used to measure the coating thickness of the cutting tool.It was clearly that AlTiCrN coated tools influences key role to fix on cutting tool life in MQL machining. Different wear mechanism of cutting tools was clearly discussed. Scanning Electron Microscope (SEM) test shows the clear cut view of wear developed in cutting tool. It was view thatthe tool life of AlNiCrN carbide tool has improved 20-25% more than the other cutting tools.

Due to environmental impact, soil damage by using mineral oil, Nilesh C et al. [10] attempted to found an alternative source used as a cutting fluid and finally soyabeanand blasocut 4000 were used as a cutting fluid in the machining of AISI 4130 cylindrical bar. Assessment study between soyabean and blasocut mineral oil in reducing cutting forces, soya bean reduces 10% cutting forces compared with blasocut 4000 mineral oil.K. Giasinet al [11] has compared the values of thrust force torque and surface roughness in the three machining conditions such as dry, cryogenic, and minimum quantity lubrication machining. GLARE laminates mainly used in making of aerospace structures has been taken for research. It was reported that the surface finish was massively improved 44% in MQL and cryogenic compared with dry condition in drilling operation. Due to excellent properties of titanium alloy, it was used in many applications like biomedical, chemical, medical, and marine.Munish Kumar Gupta et al [12] proposed response surface methodology technique to create design matrix for conducting number of experiments.Cutting speed ranging from 200 to 300m/min, feed ranging from 0.1 to 0.2 mm/rev, nozzle positioned to the work piece in three different angles such as 60^0, 75^0 and 90^0. It was observed that feed rate act as a more significant factor deciding surface roughness value. The error percentage in between optimum value to the confirmation result value gives good agreement below 10% deviation.

R.K.Suresh et al [13] estimated the machining performance of AISID3 tool steel using Deng's method and weighted aggregate sum product assessment method(WASPAS). These two methods are mainly concentrated to evaluate the optimal parameters of surface roughness, material removal rate, interface temperature, specific energy, and flank wear. Finally it wasconcluded that WASPAS method gives the optimal value compared with Deng's method.Steven Y. Liang et al [14] clearly indicate the flow chart of residual stress prediction model in MQL machining. In this method TC4 alloy steel used as a work piece and the residual stress was analyzed. Finally it was observed that residual stress was gradually increased with increase in depth of cut. It was clearly stated the relationship between lubrication condition and residual stress. Owing to low machinability in high temperature alloy increases high manufacturing cost.U. Karaguzelet al [15] decides to introduce the new technique to reduce the manufacturing cost of machining high temperature alloy. Multi task machine was employed to adapt MQL technique in machining operation. Flank wear dramatically increases with increase in cutting time. Results confirmed that tool life is increased 40 times compared with other conventional machining process. Turn-milling with MQL technique reduces tool wear in machining of Ti6Al4V, waspaloyand inconel718 alloy.DavorinKramar et al [16] utilizes fuzzy expert model to predict the surface roughness in high pressure jet assisted turning. Genetic Algorithm (GA) based fuzzy expert was applied to predict surface roughness of the workpiece from the experimental data.95.5% accuracy surface roughness prediction model was achieved using bioinspired algorithm. Feed plays a critical role in choose the optimal value of surface roughness. Lesser values of nozzle diameter, jet pressure and distance between the impact point of the jet and the cutting edge improves better surface finish in the machined part.Sanjeev Kumar et al [17] examine the surface roughness value of AISI 4340 steel using minimum quantity lubrication and it was noted that the surface roughness was massively improved by using a cutting tool with nose radius of 0.8mm. Maximum cutting speed and minimum feed rate improves surface finish of the part. Surface quality was improved from 7% to 10% in MQL machining compared with flood lubrication.TadeuszLeppert [16] conducted the machining operation in three different cutting environments such as dry, MQL and emulsion condition in machining of C45 steel. It was evident that a higher feed rate reduces the cutting force in dry and MQL machining conditions.

2. EXPERIMENTAL PROCEDURE

Experiments were conducted by turning of AISI D2 steel with a length of 100 mm and diameter of 50 mm in the conventional all geared lathe was used in this study. In this investigation the control factors were speed, feed, and depth of cut were taken. Special designed attachment of minimum quantity set up was attached to lathe to create minimum quantity lubrication marching process. Infrared thermometer is used to record tool tip temperature during dry, MQL(10ml/hr), and MQL (15ml/hr) machining conditions. Injector is placed in MQL setup is maintained at a distance between tool chip interface to the tip of the nozzle is 35mm. Infrared thermometer is placed in tool holder which was focused towards tool chip interface point to record average tool tip temperature at every pass in turning. The control factors were speed, feed, and depth of cutting for the stated machining conditions. The turning tests were carried out in AISID2 steel for the purpose of experimental investigation of machining parameters. The chemical composition of AISID2 steel is given in Table1.

Table 1: Chemical composition of AISI D2 Steel

Carbon	Silicon	Manganese	Chromium	Molybdenum	Vanadium	Iron
1.5-1.7 %	0.1-0.35%	0.25-0.5%	11-13%	0.8 Max	0.8 Max	Balance

2.1Control parameters and tool material

Turning experiments has been worked out using cubic boron nitride (CBN) cutting inserts in three different environment conditions such as dry machining, minimum quantity lubrication (10ml/hr), and minimum quantity lubrication (15ml/hr).control factors are needed to effective investigation of machining parameters for this research. Control factors and their levels are given in Table 2.

Table 2.Control factors and their levels for machining

Control factors	Level
Feed rate (mm/rev)	0.15, 0.20, 0.25
Spindle speed (rpm)	121,182,270
Depth of cut(mm)	0.5,1.0,1.5
Machining condition	Dry machining , Minimum quantity lubrication (10 ml/hr), Minimum quantity lubrication(15 ml/hr)

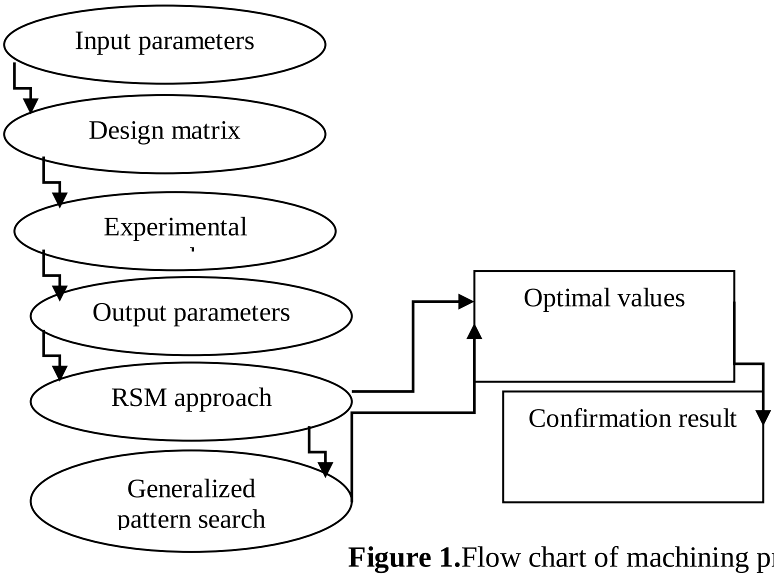

Figure 1. Flow chart of machining process

Flow chart of machining process represented in Figure1 indicates the procedures or steps needed for this investigation. Minimum quantity lubrication setup was shown in Figure2.The aim of this research is to minimize the tool tip temperature and surface roughness of the AISID2 steel. The control factors are selected with the help of referred journals. Mineral based oil used in flood machining effects hazard problems to human and environmental pollution to earth.To avoid this, minimum quantity lubrication was introduced to utilize minimum amount of cutting fluid in machining. In this research cutting fluid used as castor oil mixed with air and by using injector, Airand oil mixed together by means of atomization process and the injector was adjusted directed towards tool chip interface point to reduce tool tip temperature. Regulating valve used in injector was used to regulate the oil in 10 ml/hour and 15 ml/hr during machining process. Infrared thermometer shown in Figure4 indicates the way to measure the tool tip temperature, that the infrared ray emitted by infrared thermometer was focus to the point on cutting zone between tool and work piece. In every pass tool tip temperature were noted for the corresponding control factors value represented in design matrix developed by design expert software. Design matrix table was developed by central composite design in response surface methodology. Totally 20 runs were conducted for this machining process and all the output parameters were noted. Surface roughness of the work piece is measured by using surf tester shown in Figure 3. Along 3 points in the circumference of the work piece, surface roughness value was measured and average value is noted, tool tip temperature was also noted by using infrared thermometer it was clearly indicated in Figure 4. The experiments were conducted using the control variables formulated by design of experiments by using design expert software.The corresponding values are recorded in the Table3.

Figure.2 Experimental setup for MQL machining

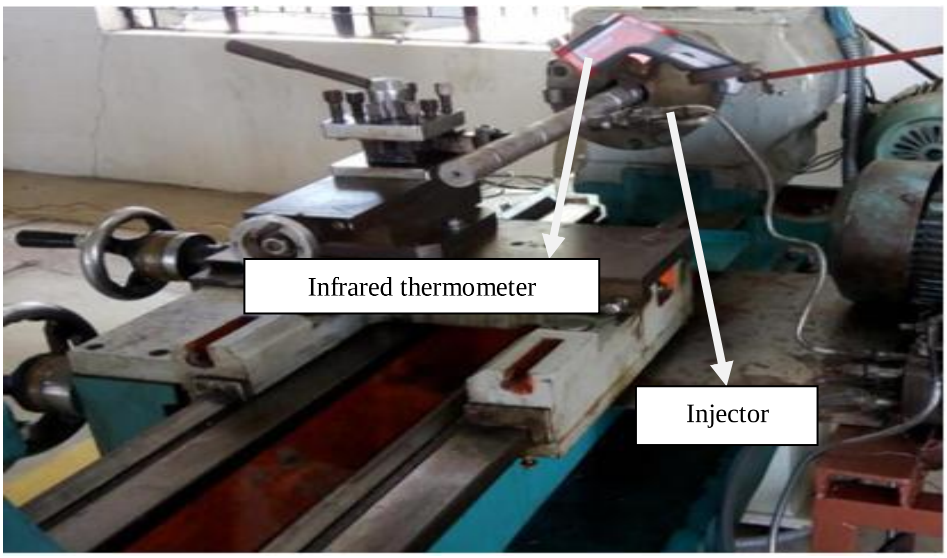

Figure 3.Surface roughness measurement

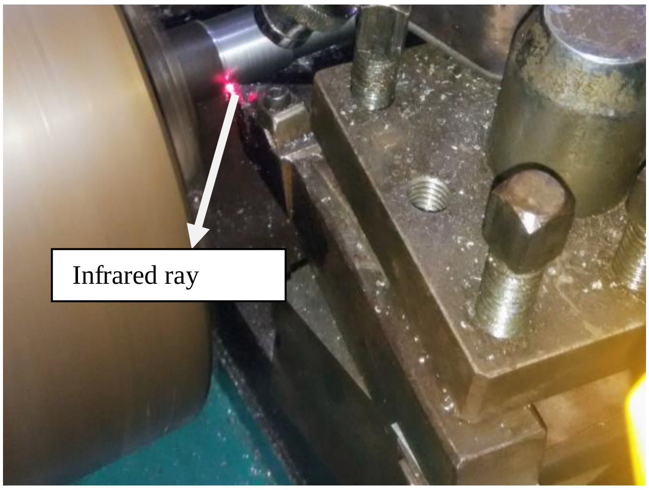

Figure 4. Temperature measurement

.**Table 3.**Design matrix along with measured values of tool tip temperature and surface roughness

Runs	Speed (rpm)	Feed (mm per rev)	Depth of cut (mm)	Temp (^{0}C)	SR(µm)	Temp (^{0}C)	SR (µm)	Temp (^{0}C)	SR (µm)
				Dry	Dry	MQL (10ml/hr)	MQL (10ml/hr)	MQL (15ml/hr)	MQL (15ml/hr)
1	121	0.15	0.5	47.8	3.64	35.8	3.16	41.2	3.92
2	121	0.25	0.5	47.2	3.74	47.5	3.17	44.8	3.7
3	121	0.15	1.5	63.6	4.41	36.2	3.85	42.1	4.1
4	121	0.2	1	51.9	3.9	43.7	3.39	42.6	3.99
5	121	0.25	1.5	63.2	4.22	47.3	3.87	45.1	4.22
6	195	0.2	1	53.3	3.76	43.2	3.17	40	3.56
7	195	0.2	1	53.2	3.7	42.4	3.2	40.1	3.51
8	195	0.2	1.5	64.7	4.2	43.1	3.82	40.5	3.84
9	195	0.15	1	53.8	3.69	36.8	3.21	39	3.61
10	195	0.2	1	53.5	3.72	42.6	3.34	40.3	3.61
11	195	0.2	1	53.1	3.75	42.5	3.24	40.6	3.53
12	195	0.2	0.5	48.7	3.49	42.5	2.92	42.6	3.32
13	195	0.25	1	53.6	3.73	48.1	3.23	42.2	3.4
14	195	0.2	1	53.5	3.71	43	3.22	40.4	3.56
15	195	0.2	1	54.1	3.7	42.7	3.16	40.4	3.54
16	270	0.15	0.5	54	3.14	37.9	2.68	35	2.71
17	270	0.25	1.5	67.1	3.95	49.3	3.4	38.2	3.43
18	270	0.15	1.5	65.1	3.89	37.6	3.37	35.7	3.26
19	270	0.25	0.5	50.9	3.17	49.1	2.7	38	2.57
20	270	0.2	1	55.2	3.4	43.5	2.8	37	2.7

Table 4.R-squared values of different machining condition

Machining condition	Dry Machining		MQL (10 ml/hr)		MQL (15ml/hr)	
Response values	Tool tip temperature	Surface roughness	Tool tip temperature	Surface roughness	Tool tip temperature	Surface roughness
R-Squared	0.993	0.992	0.992	0.979	0.971	0.980
Adj R-Squared	0.987	0.985	0.986	0.960	0.945	0.962
Pred R-Squared	0.888	0.865	0.947	0.904	0.800	0.855

3. Results and discussion

Analysis of variance(ANOVA) approach was helpful to study the importance of control factors and individual interaction between the input factors on surface roughness and tool tip temperature.In thisANOVA method significance level was chosen as 95% and confidence level to be 5%.Design expert software was used to perform ANOVA test. Regression model show that R-squared, Adj.R-squared, Pred R- squared values are very closer to1 is represented in Table 4.It was observed from the values which imply all model are adequate. Table 5 shows the regression equations (1) to (6) for the output responses for roughness and tool tip temperature for three machining conditions. These quadratic equations are developed by design expert software.

Table 5.Regression equations

Temp (Dry) = 57.88268+0.021477* S-90.95660* f-13.70625* doc-3.60341E-005*S * f-.016131*S * doc+26.00000* f * doc+4.77945E-005* S^2+150.90909* f^2+13.30909*doc^2 (1)

SR (Dry) = 3.75 - (8.18E-004*S+1.3*f-0.26*doc+5.36E-03*S*f+1.07E-003*S*doc-1.5*f*doc-1.143E-005*S^2-2*f^2+0.52*doc^2) (2)

Temp(MQL10ml/hr) =12.47-0.031*S+199*f+2.19*doc-6.75E-003*S*f-6.82E-004*S*doc+1.79E-014*f+10E-005*S^2-217*f^2-0.96*doc^2 (3)

SR (MQL 10ml/hr) = 3.24+(3.08E-003*S-0.96*f-0.59*doc+2.35E-003*S*f+2.96E-005*S*doc-0.05*f*doc-1.78E-005*S^2+1.818*f^2+0.66*doc^2) (4)

Temp (MQL 15ml/hr) = 33.2+0.036*S+72.45*f-4.8*doc-0.03*S*f-6.24E-004*S*doc-6*f*doc-1.82E-004*S^2-72.7*f^2+3.07*doc^2 (5)

SR (MQL 15ml/hr) = 5.22+(1.29E-003*S-6.3*f-1.46*doc+1.38E-003*S*f+2.68E-003*S*doc+3.7*f*doc-2.86E-005*S^2+5.09*f^2+0.35*doc^2) (6)

3.1 Effect of surface finish and tool tip temperature

The Figure.5 shows the clear-cut view of the effect of surface roughness and tool tip temperature in different three machining conditions. Surface finish is the most important character which decides the quality of the machined work piece. Investigation of surface quality parameters are necessary to decide the product to be used in real time applications, moreover contribution of surface quality considering wear resistance, corrosion resistance and tribological behavior were considered as most influencing factors in functionality of the product. The Figure.5 clearly shows that the surface quality after machining and tool tip temperature during machining with the different machining conditions. It was observed indirectly, that the depth of cut plays an important role in boost the tool tip temperature. Minimum spindle speed and depth of cut in dry machining decrease the tool interface temperature compared with other combined factors in this kind of machining.

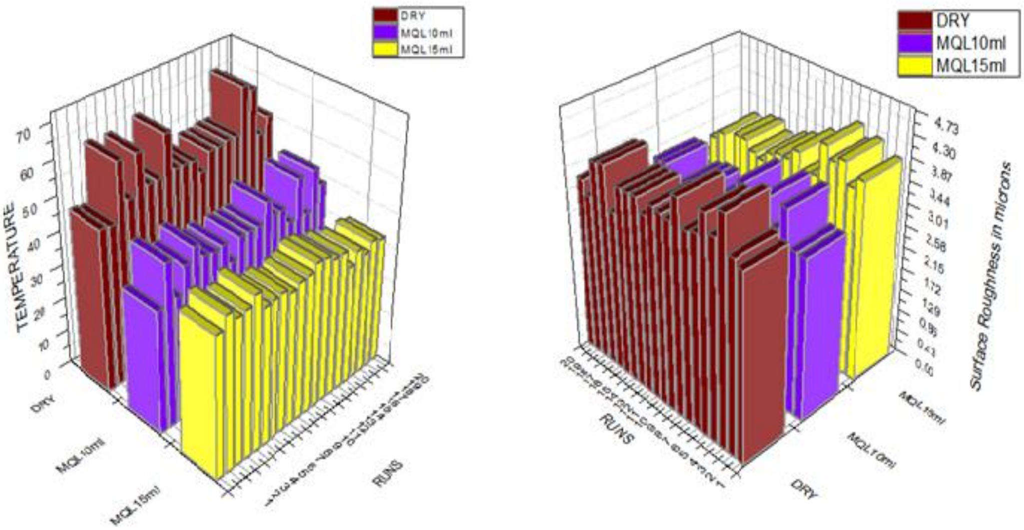

Figure.5 Tool tip temperature and surface roughness comparison under dry, MQL (10ml/hr), and MQL (15ml/hr) conditions.

Comparing dry machining with minimum quantity lubrication machining which injects 10 ml per hour by using injector with high pressure,lessen 27 percentage of tool tip temperature. It was identified that same control factors gives minimum temperature in dry machining and minimum quantity lubrication machining condition. In the minimum quantity lubrication machining delivers 15 ml per hour, greater tool temperature was attained at minimum speed and maximum depth of cut. Temperature instability was identified in Figure.5 for all machining condition, but it was found very negligible in MQL 15ml per hour compared with other machining conditions. Advanced research on surface roughness confirms that it was judged as the most effective parameter, because the quality of product was mainly depends upon the surface texture of the part. Atomization process of lubricant in MQL machining creates cooling effect in machining zone and it effects to reduce the tool tip temperature. Minimumfeed and low depth of cut improves the surface finish of the work piece, at the same time minimum spindle speed and maximum depth of cut generate worst machined surface. Analyzing the effect of surface parameters in minimum quantity lubrication with 10 ml/hour machining, low speed and utmost depth of cut effects more chatter on the work piece. It implies the diminishment of surface finish. It was studied that the better surface finish was attained at MQL with 10ml per hour machining.

3.2Desirability approach based optimization

Response surface methodology is one of the techniques which use the combination of mathematical and statistical method for modeling and optimizing the output response variables such as surface roughness and tool tip temperature. Minimization condition was set as a goal for the output variables of surface roughness and tool tip temperature for the stated three machining conditions. A set of 20 optimal solutions were derived for the specific constraints for surface roughness and tool tip temperature using design expert software. Response variables having higher desirable value is selected as optimal condition for the machining conditions. Figure.7 indicates the desirability graph having maximum value of 0.903 which is very closer to 1. From the desirability graph it was observed that the value is gradually decreased with increase in feed and decrement in speed. Minimum desirable value was identified in the speed of 121 and the feed of 0.25 mm per revolution. The ramp diagram was represented in Figure.6 and the purpose of ramp diagram is to indicate the desirable response variables. The point on each ramp replicates the factor setting or response prediction for the individual response value. The dot on each ramp diagram represents the value which satisfies the objective function

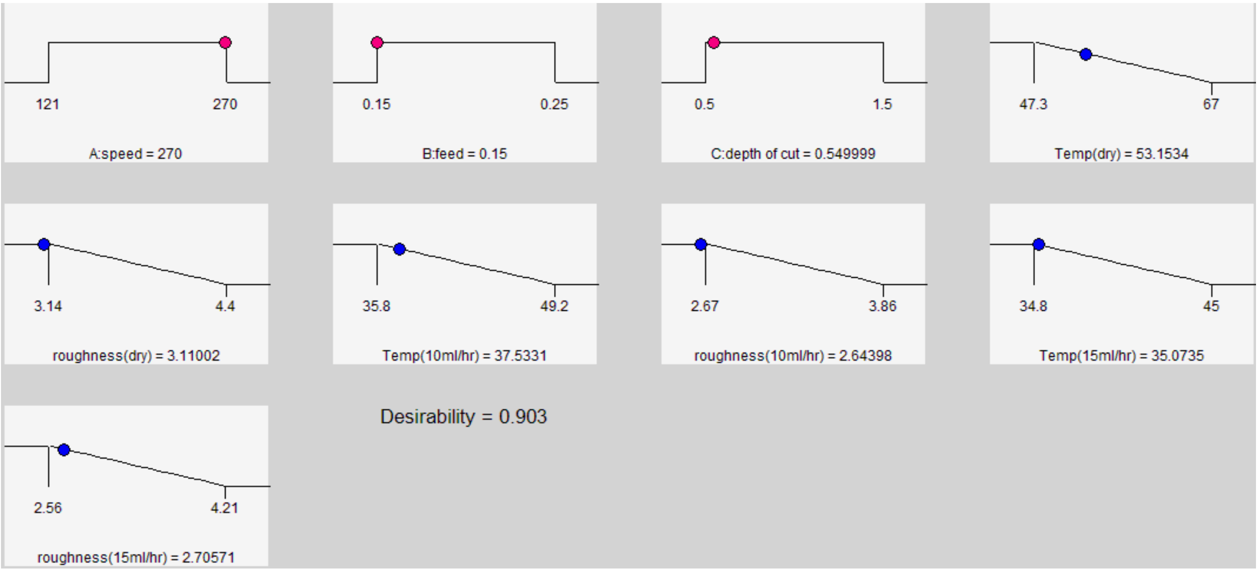

Figure6. Ramp diagram

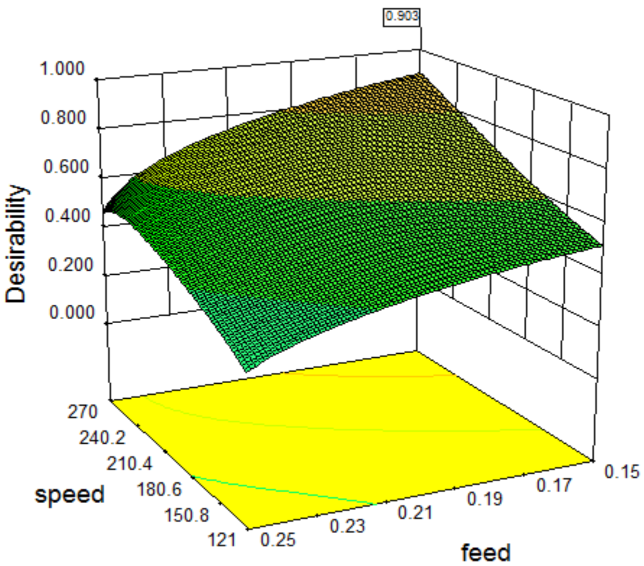

Figure 7.Result of overall desirability function.

3.3 Pattern search algorithm

It is known as direct search algorithm which iteratively searches a point which satisfies the objective function. Generalized pattern search algorithm searches a collection of optimal points based on the function towards looking for the improvement over the incumbent solution. Purpose of this study is to get the optimal input variables with response factors. The Minimum objective function of surface roughness and tool tip temperature in three different machining conditions subjected to constraints given in equation (7). Minimization function of surface roughness and tool tip temperature was optimized by using GPS algorithm generated by MATLAB software. Optimizationtool box available in this software is used to identify the optimal parameters for the multiple regression model developed by design expert software. Poll method of maximal basis 2N was used in GPS algorithm. Initial Mesh size expansion and contraction factors values were set in the pattern search tool box for finding most optimal solution. Objective function used in GPS algorithm was already generated by using design expert software. Minimum values of spindle speed, feed, depth of cut taken as lower bound and larger values of spindle speed, feed, depth of cut was taken as upper bound values in optimization tool box. Poll method was employed in pattern search algorithm to compute optimal values of surface roughness and tool tip temperature in three machining conditions. Optimal values of desired outputs were refined with increasing the number of iterations. Figure. 8 shows the optimal parameters of surface roughness and tool tip temperature in Dry, MQL (10ml/hr), MQL (15ml/hr) machining conditions using GPS algorithm.

$121 \leq \text{speed} \geq 270$; $0.15 \leq$ feed ≥ 0.25 ; $0.5 \leq$ depth of cut ≥ 1.5 ----------------------- (7)

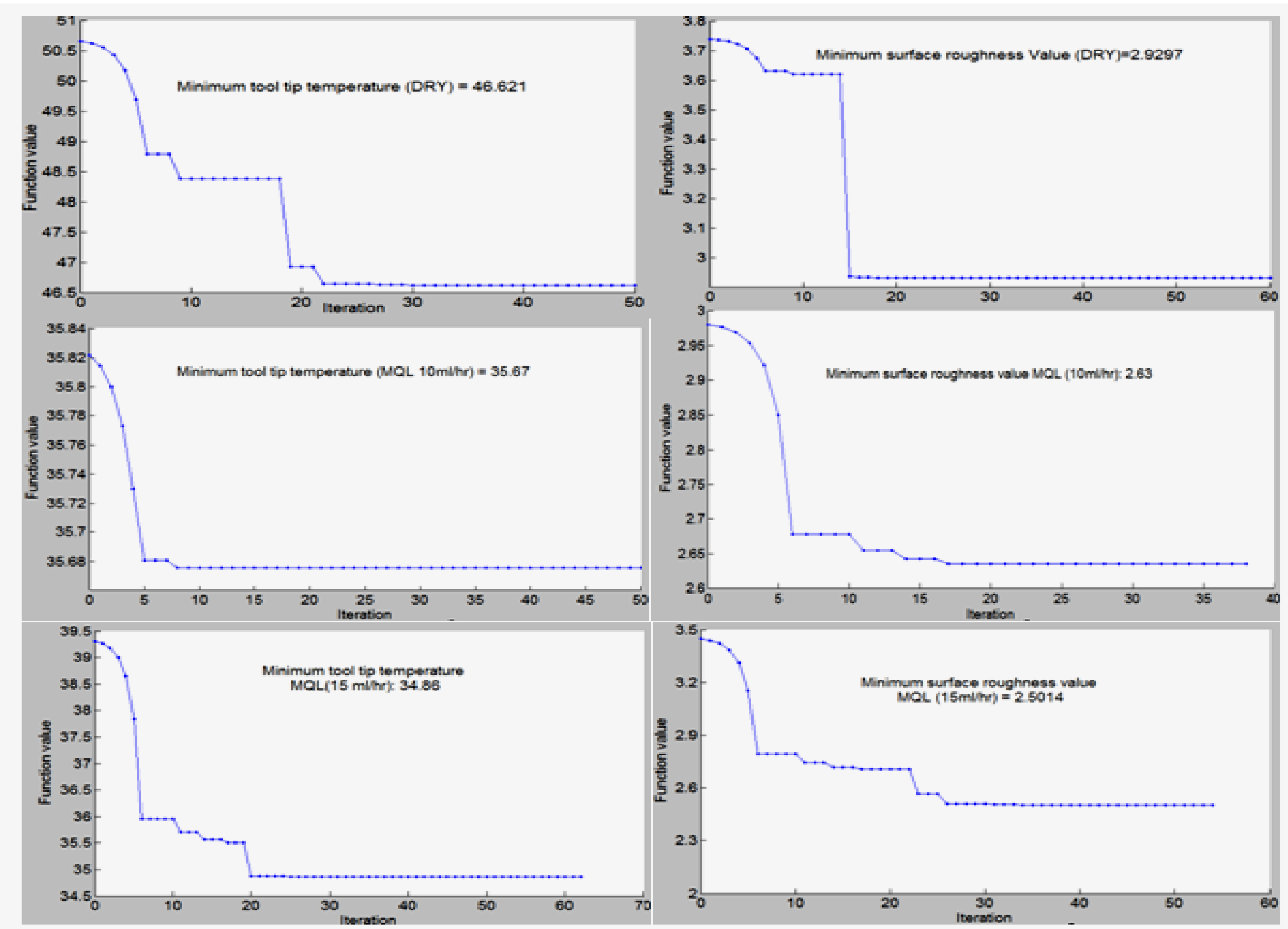

Figure 8.Optimal values of surface roughness and tool tip temperature

Table 6. Comparative values of Tool tip temperature and surface roughness by using RSM and GPS

Desirability	Responses	RSM	Actual (or) Confirmation test	GPS
90.3%	Tool tip temperature(dry) in ^{0}c	53.13	54	46.62
	Surface roughness (dry) in µm	3.1	3.1	2.92
	Tool tip temperature (MQL 10ml/hr) in ^{0}c	37.5	37	35.67
	Surface roughness (MQL 10ml/hr) in µm	2.64	2.67	2.63
	Tool tip temperature (MQL 15ml/hr) in ^{0}c	35.07	34.8	34.86
	Surface roughness (MQL 15ml/hr) in µm	2.70	2.7	2.5

The confirmation tests were conducted by using optimal values obtained from GPS and RSM related to input variables and the output values are noted as an actual values represented in the Table 6.It was observed that the values of actual values compared with RSM and GPS gives minimum error deviation.

4 Conclusion

In this study generalized pattern search method and response surface methodology techniques are implemented to predict the optimal values of control factors. Surface roughness and tool tip temperature were considered as the response output parameters. MQL method by using castor oil minimizes the tool tip temperature in the cutting zone and improves the surface finish of AISID2 steel with CBN cutting tool, compared with dry machining. In MQL method surface finish of the AISID2 steel was highly improved due to the reduction of tool tip temperature. Spindle speed and depth of cut plays a crucial role to desire the surface quality of AISID2 steel. Summary of attained results concluded as follows

- Tool tip temperature of the cutting tool is aggressively decreased in MQL method because atomization process of oil and air reduces the cutting zone temperature during machining.
- Predicted results from the RSM and GPS method compared with the confirmation results shows that good agreement between the output values of surface roughness and tool tip temperature.
- Comparing dry machining with MQL (10 ml/hr) surface roughness of the material is highly improved 14% and 18% in MQL (15ml/hr).
- Tool tip temperature was significantly reduced up to 26% in MQL machining compared with dry machining.

Finally the results reveal that GPS and RSM optimization techniques was very efficient to found the optimal values of input parameters which severely reduces cutting zone temperature and improves surface roughness value of the material.

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