Experimental Investigation of Turning Process in Wet and MQL system on EN 31 Alloy Steel

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ABSTRACT- In mass production generally turning process is sequentially first process so that it is necessary to concentrate on this process for improving surface finish within minimum time and cost. This paper present investigation of turning process parameters on hard EN 31 material, for optimization of surface roughness, material removal rate in wet and MQL system by considering five controllable input variables namely cutting speed, feed rate, depth of cut, nozzle distance and insert nose radius in the presence of wet & MQL system. This experiment present the chip analysis which is related with controllable variables from which its effect on insert wear, quality of product can be easily found out, because of chip formation gives indirectly effect on the insert wear. The design of experiment is carried out by using response surface methodology (RSM). It is clear from analysis that MQL system is better than wet system.

Keywords— CCD, insert wear, Mass production, Minimum quantity lubrication, MRR, RSM, wet system

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INTRODUCTION

The big challenge of the mass production firms is concentrated for achieving high quality products with good dimension ability with high productivity, less wear on the cutting insert, less use of cutting fluid, within less time. Genially machine tool industry made very great progress, but there main drawback is that they not running the machine tools at their optimum operating conditions so that there is loss of man power, material, time, quality along with productivity also. Cutting hardened steel is an interesting topic of today's industrial production and scientific research. Turning process for hard steel is preferable thing compared to grinding process & now days this process is alternative to many finishing processes such as grinding. The main advantage of precision hard turning over grinding include lower production costs, higher productivity, greater flexibility, elimination of grinding fluids, and enhanced work piece quality. In turning process, single-point cutting tool that is nothing but insert can complete the entire machining process in a single fixture, thereby reduced setup times as well as lower costs. Also there are many optionable things to improve the turning process rather than grinding process. In recent there is big problem for all industrialist for achieving high quality products with more productivity within less machining time which affects on surface roughness during turning of hardened steel. As the surface roughness increases then customer demand & quality of product goes on decreasing, so that there should be bridge between quality and productivity. In short there should be such optimum condition on which tool wear rate is minimum, maximum productivity with maximum quality within less time. Generally hard turning requires large quantities of coolants and lubricants. The cost associated with storage and disposal of coolants and lubricants increases the total cost of production considerably. Conventional cutting fluid application fails to penetrate the chip-tool interface and thus cannot remove heat effectively due to which there is loss of surface finish and also loss of tool life. To overcome this problem there are some solutions. Some of these alternatives are dry machining and machining with minimal fluid application. Dry machining is now of great interest as it is reasonable, cleanly process and actually, this system meet with success in the field of environmentally friendly manufacturing. However, they are sometimes less effective when higher machining efficiently, better surface finish quality and serve cutting conditions are required. Minimum fluid application refers to the use of lubricant of only a minute amount typically of flow rate of 50 to 500 ml/hour. The concept of minimum fluid application sometimes referred to as near dry lubrication or micro lubrication.

Surface finish is an essential consumer requirement in all machining processes because of its impact on product performance. The well finished product has significant ability to withstand stresses, temperature, friction and corrosion. Surface roughness is a widely used surface quality indicator in precisely manufactured job. High surface roughness values decrease the fatigue life of machined components. Surface roughness measurement presents an important task in many engineering applications. Productivity of any machine tool as well as any machined surface can be evaluated from the surface quality of job. Highly competitive market requires high quality products at minimum cost. To improve productivity with good quality of the machined parts is the main challenges of metal industry.

Material removal rate is nothing but production term usually measured in cubic inches per minute. To achieve higher productivity it is necessary to increase this rate which will obviously get a part done quicker and therefore possibly for less money even also within less cycle time, but increasing the material removal rate is often accompanied by increases in tool wear, poor surface finishes, poor tolerances, and other problems.

F. Salvatore et al carried out their research on modeling and simulation of tool wear during the cutting process. The main purpose of their work is to present a new approach to predict tool wear progression during cutting operation. In particular, an energy approach, linking the tool wear volume with the energy dissipated by friction is used. In addition, the interaction between residual stresses induced by cutting and the variation of tool geometry due to wear's mechanisms is also investigated by using FEM [1]. Aldo Attanasio et al create analytical models for tool wear prediction during AISI 1045 turning operations. They present comparison between response surface methodology (RSM) and artificial neural networks (ANNs) fitting techniques for tool wear. They used uncoated tungsten carbide inserts and variable cutting parameters. Both flank (VB) and crater wears (KT) of the tool were monitored. The models were validated comparing the calculated tool wear values with the experimental ones, showing that ANNs model provides better approximation than RSM in the prediction of the amount of the tool wear parameters [2]. G.Harinath Gowd et al select optimal machining parameters in CNC turning process of EN-31 using intelligent hybrid decision making tools. The obtained optimal process parameters will be used to automate the process. They conduct experiments as per DOE. Depth of cut, cutting speed and feed is taken as process parameters and the output responses are Fx and Temperature. They found that the speed and the depth of cut have great significance on the force and temperature, whereas the feed has less significance on both the outputs. The developed ANN model can be further integrated with optimization algorithms like GA to optimize the turning parameters [3]. Harsh Y Valera and Sanket N Bhavsar inestigated surface roughness and power consumption in turning operation of EN 31 alloy steel with TiN+Al2O3+TiCN coated tungsten carbide tool under different cutting parameters like spindle speed, depth of cut and feed rate. After the preliminary experimentation, they concluded that spindle speed, feed and depth of cut significantly affect the surface roughness and power consumption [4]. B. Anuja Beatrice et al investigated the effect of minimal cutting fluid application in hard turning of AISI H13 steel for surface roughness prediction using artificial neural network. 20% oil in water as lubricant they have used. They conclude that Minimal cutting fluid application technique promoted green environment in the shop floor, minimized the industrial hazard due to of harmful aerosols and usage of large quantity of cutting fluid [5]. D.V. Lohar et al have evaluated the performance of MQL system during turning on hard AISI 4340 material by using Taguchi method. They have used the feed rate, cutting speed, depth of cut as process parameter for analysis of cutting forces, surface roughness, cutting temperature & tool wear. They have found that cutting force & temperature is less in MQL system Compared to the dry & wet lubrication system. The surface finish is also high in case of MQL system [6]. Y.B. Kumbhar et al investigated tool life and surface roughness optimization of PVD TiAlN/TiN coated carbide inserts in semi hard turning of hardened EN31 alloy steel under dry cutting conditions using Taguchi method. They have concluded that the feed rate was the most influential factor on the surface roughness and tool life [7]. Ravinder Tonk et al have investigated the effects of the parametric variations in turning process of En31 alloy steel. Taguchi's robust design methodology has been used for statistical planning of the experiments. Experiments were conducted on conventional lathe machine in a completely random manner to minimize the effect of noise factors present while turning EN31 under different experimental conditions.The analysis of results shows that input parameter setting of cutting tool as carbide, cutting condition as dry, spindle speed at 230 rpm, feed at 0.25mm/rev and depth of cut at 0.3 mm has given the optimum results for the thrust force and input parameter setting of cutting tool as HSS, cutting fluid as soluble oil, spindle speed at 230 rpm, feed at 0.25 mm/rev and depth of cut at 0.3 mm have been given the optimum results for the feed force when EN31 was turned on lathe [8]. M. A. H. Mithu et al have evaluated the effect of minimum quantity lubrication on turning AISI 9310 alloy steel using vegetable oil based cutting fluid. They have found that chip-tool interface temperature as well as tool wear gets reduced [9]. Nikhil Ranjan Dhar et al evaluated the performance of MQL system on tool wear, surface roughness and dimensional deviation in turning AISI-4340 steel by using cutting speed, feed rate, and depth of cut as controllable variables. They improved the tool life in MQL system [10]. C. R. Barik et al studied the parametric effect & optimization of surface roughness of EN 31 material in dry turning. They concluded that feed rate has more effect on surface roughness [11]. L. B. Abhang et al investigated the effect of MQL during turning of EN 31 alloy steel for analysis of cutting temperature, cutting force, surface roughness. They found that quality of product as well as tool life get improved [12]. C. Ramudu et al have analyzed and optimized the turning process parameters using design of experiments & response surface methodology on EN 24 steel [13]. L. B. Abhang et al have created model and analyzed it for surface roughness in machining EN 31 steel using response surface methodology. They have found that surface roughness increases with increase in feed rate and decreases with increase in cutting velocity [14]. A. Del Prete et al studied & optimized the turning process parameter by using the genetic algorithm & simulated annealing on super-nickel alloy for maximizing the MRR & analysis of thrust force [15]. Ashish Bhateja et al conducted there project work for Optimization of Different Performance Parameters i.e. Surface Roughness, Tool Wear Rate & Material Removal Rate with the Selection of Various Process Parameters Such as Speed Rate, Feed Rate, Specimen Wear , Depth Of Cut in CNC Turning of EN24 Alloy Steel [16]. From the literature review, it is observed that MQL system provide better surface finish. Less research work has been seen for En31 Alloy Steel in CNC turning by the use of MQL system. Also very less work has been reported for investigation of surface roughness, material removal rate & machining time on En 31 material. Investigation of turning process parameter in MQL system & comparison it with wet turning is to be reported to much less. Chip chart is also new concept that has reported for EN 31 material in MQL system and wet system is too much less from which one can easily predict tool life, surface finish.

2. EXPERIMENTAL DETAILS

2.1 Work Piece Material- The work piece material is EN-31 steel in the form of round bars having initial lengths 245mm, 190mm and diameters 61mm, 60mm (sequentially) were used for conducting experiment runs

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in Wet and MQL environments. Components with this material properties are used to make axels, gears, camshafts, driving pinion and link components for transportation and energy products as well as many applications in general mechanical engineering.

Table 1 the chemical composition of EN 31 material:

C	0.9 – 1.2%
Si	0.10-0.35%
Mn	0.3-0.75%
Cr	1-1.6%
Co	0.03%
S	0.05%
P	0.05%

2.2 Cutting Tool- CBN insert CNMG 120408, CNMG 120404, CNMG 120401.2 were selected with tool holder PCLNL 2525R12

2.3 MQL setup- It consists of nozzle, hoses, mixing chamber, pressure regulator valves & compressor. The mixing chamber was connected at the nozzle inlet by very small diameter flexible tube. Mixture of compressed air and blasocut lubricant were injected at 5 bar pressure via Cu alloy nozzle at work piece and insert interface point. MQL block diag. is shown in fig. 1.

Level	Cutting speed (m/ min)	Feed Rate (mm / rev)	Depth of cut (mm)	Nose Radi. (mm)	Nozzle Distance (mm)
Low	100	0.1	0.1	0.4	25
Med.	190	0.25	0.5	0.8	35
High	280	0.4	1.0	1.2	45

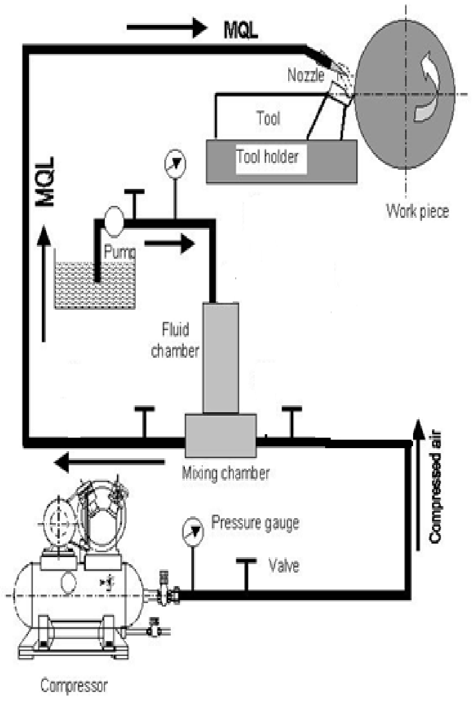

Fig. 1 MQL block diag.

2.4 RESPONSE VARIABLES - Material removal rate, surface roughness, chip morphology.

2.5 Process Parameter Level - In this work, experiments were designed by using Response surface methodology which is a practical, accurate and easy for implementation.

3. RESULT AND DISCUSSION

To calculate material removal rate initial and final weight of work piece was noted using digital weighing machine. Machining time is also recorded. Following equation is used to calculate the response Material Removal Rate (MRR in mm3/min):

$$= \frac{\text{Initial weight(gm)} - \text{Final weight (gm)}}{\text{Density}(\text{gm/mm}^3) * \text{Machining Time(min)}}$$

Roughness measurement has been done using a portable stylus-type profilometer, (Make:- Taylor Hobson, Surtronic 3). The Talysurf instrument (Surtronic 3) is a portable, self-contained instrument for the measurement of surface roughness value, shows the result on a large LCD window. The thicknesses of the chips in every run were repeatedly measured by a digital slide caliper as well as chip color is also noted down. The obtained data shown in following table 2

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Table 2

Sr. No.	C.S.	F.r.	D.O.C.	N.R.	N.D.	MRR *1000	WET		MQL	
							S.R. (µm)	CHIP THICK (mm)	S.R. (µm)	CHIP THICK. (mm)
1	280	0.4	0.1	0.4	45	11.18908	0.88	0.4	0.86	0.37
2	100	0.4	0.1	0.4	25	3.99611	0.71	0.67	0.7	0.66
3	280	0.4	1	0.4	25	110.9103	1.71	0.78	1.64	0.68
4	190	0.25	0.55	1.2	35	25.98231	1.3	0.16	1.24	0.15
5	190	0.25	0.55	1.6	35	25.98082	1.28	0.14	1.27	0.12
6	190	0.25	0.55	0.8	15	25.97918	1.1	0.15	0.9	0.13
7	280	0.1	0.1	1.2	45	2.797127	1.31	0.06	1.3	0.05
8	100	0.4	1	0.4	45	39.58845	1.39	0.95	1.38	0.93
9	100	0.1	1	1.2	45	9.89506	3.42	0.62	3.4	0.6
10	100	0.1	0.1	1.2	25	0.99892	1.18	0.17	1.17	0.15
11	280	0.1	1	1.2	25	27.69924	0.68	0.09	0.6	0.08
12	190	0.55	0.55	0.8	35	57.12167	1.55	0.18	1.5	0.15
13	190	0.002	0.55	0.4	35	0.271914	0.93	0.15	0.82	0.13
14	38.64	0.25	0.55	0.8	35	5.27864	7.7	0.99	7.3	0.95
15	190	0.25	1.3068	0.8	35	68.6554	2.9	0.91	2.7	0.88
16	280	0.4	1	1.2	45	120.25	1.78	0.8	1.68	0.78
17	280	0.1	1	0.4	45	29.266	0.82	0.13	0.78	0.12
18	100	0.4	0.1	1.2	45	4.1149	0.64	0.67	0.54	0.63
19	190	0.25	0.55	0.8	35	26.5982	1.48	0.19	1.32	0.16
20	190	0.25	0.2068	0.8	35	9.89	2.32	0.12	2.02	0.1
21	190	0.25	0.55	0.8	35	25.9	1.38	0.19	1.36	0.16
22	190	0.25	0.55	0.8	35	25.6	1.34	0.19	1.2	0.16
23	190	0.502	0.55	0.4	35	50.61	3.14	0.6	3.1	0.58
24	190	0.25	0.55	0.8	55	24.79	1.55	0.2	1.51	0.19
25	100	0.1	0.1	0.4	45	0.93906	1.29	0.21	1.28	0.19
26	280	0.4	0.1	1.2	25	10.461	0.76	0.28	0.68	0.25
27	100	0.4	1	1.2	25	36.7425	1.31	0.9	1.3	0.88
28	100	0.1	1	0.4	25	8.91	3.29	0.63	3.27	0.6
29	280	0.1	0.1	0.4	25	2.4538	1.32	0.06	1.2	0.05
30	341.4	0.25	0.55	0.8	35	40.7024	5.7	0.13	5.6	0.11
31	190	0.25	0.55	0.8	35	22.2455	1.6	0.19	1.4	0.16
32	190	0.25	0.55	0.8	35	25.90254	1.6	0.19	1.4	0.16

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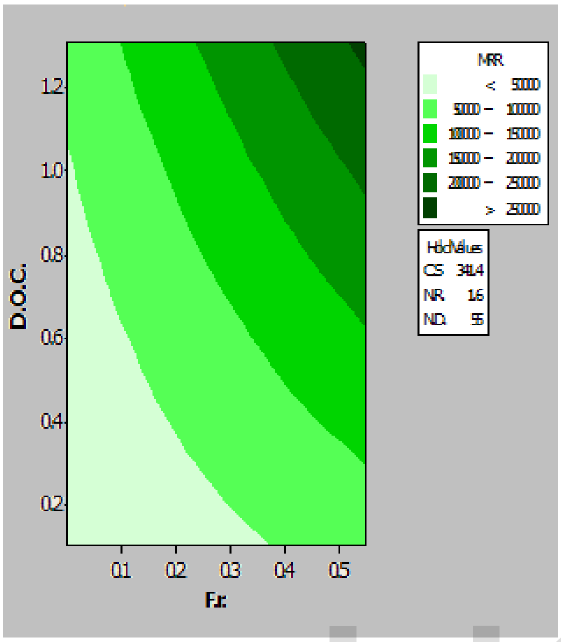
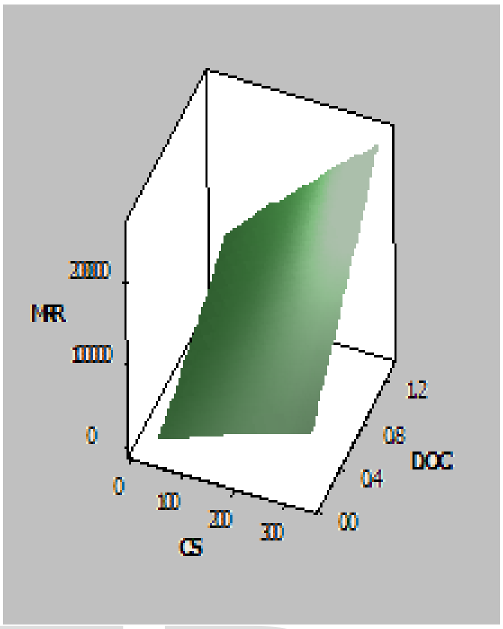
The effect of different process parameters on responses are shown in following graph.





Plot 1 - Contour Plot MRR vs. D.O.C., F.R.

Plot 2 - Surface Plot MRR vs. C.S., D.O.C.

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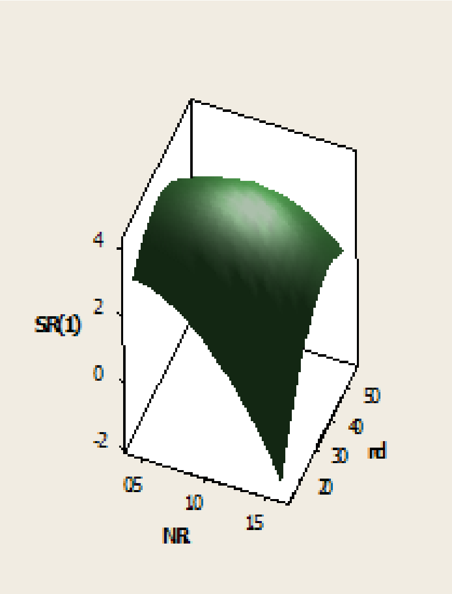

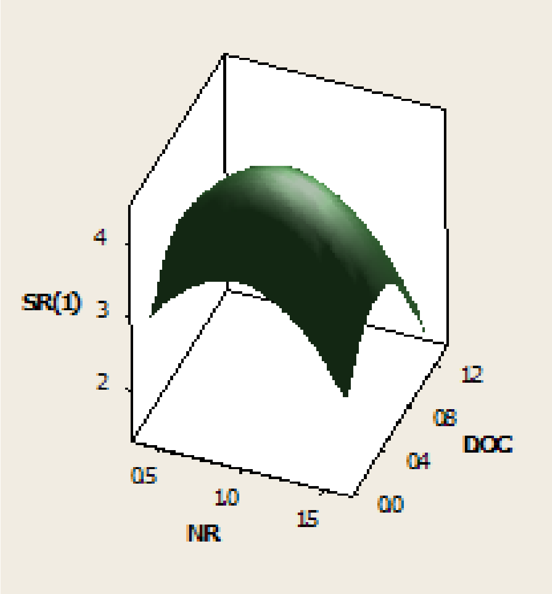

Plot 3 - Surface Plot of SR vs N.R., N.D.

Plot 4 - Surface Plot of SR vs N.R., D.O.C.

Long ribbon type chip in case no.(24)

Half turn golden chip in MQL System in case no. (24)

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Above picture clearly reveals that there is change in color of chip in MQL environment. Effect of different process parameter on MRR and S.R. can be clearly understood from the above mentioned surface plot. From plot 3 & 4, at maximum nose radios and at minimum nozzle distance, minimum d.o.c. S.R. decreases. From plot 1 & 2 MRR can be increased by increasing feed rate, depth of cut and cutting speed. The surface finish obtained during MQL environment is better than wet environment turning. During MQL environment, lubricant is correctly placed at the contact of the insert and the work piece. Hence the chips are easily removed and give better surface finish. By studding chip morphology basic metal cutting process can be easily understand. The comparison of chip produced is one of the major parameters influencing productivity in metal cutting industry. A lower chip thickness indicates better lubrication at the chip-insert interface and formation of chips of thinner sections i.e. if the chip thickness decreases, the process efficiency goes up which also improve work-piece quality. It clearly reveals that increase in chip thickness with the increase in the feed rate and also the decrease in chip thickness with the increase in cutting speed. MQL reduces cutting temperature and reduces adhesion between the tool and chip as result of which reducing chip thickness. MQL with optimum nozzle distance provide maximum momentum, whereas at larger nozzle distance momentum gets loss. By implementing MQL chip breaking can also be achieved.

4. CONCLUSION

From the analysis of surface roughness, material removal rate and chip morphology in wet and MQL system it is clear that MQL system is better than wet system as follows.

1) MQL system reduces near about maximum 16.66% chip thickness which is helpful for reducing the surface roughness and also for reducing the tool wear.

2) MQL system improves the surface finish by maximum 18.18% with better dimensionability.

3) From the investigation it is clear that increase in feed rate increases the surface roughness, increase in cutting speed decreases the surface roughness this is because due to higher cutting temperature made the material ahead of tool softer and plastic. Also increase in insert nose radios there is decrease in surface roughness.

4) As MQL system required less coolant due to which cutting tools and the work-piece will remain clean which also save the recycling cost of lubricant oil.

5) MQL system enable improvement in MRR (Productivity) by allowing higher feed rate and higher cutting speed.

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