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Use of Vegetable Oil as Cutting Fluid in Turning of Mild Steel with MQL and Optimization of Cutting Parameter

Bramhane R S[1], Pawar D S[2]

[1]P.G. Student, Department of Mechanical Engineering, Pravara Rural Engineering College Loni, Maharashtra-413204, India

[2]Assistant Professor, Department of Mechanical Engineering, Pravara Rural Engineering College Loni, Maharashtra-413204, India

Abstract: ***Cutting fluids are mainly used in machining process as coolant to reduce the temperature at cutting zone and for the lubrication to avoid the friction between the work piece and tool .The current research involves the performance analysis in turning M.S bar in flood and MQL cutting scenario. Most of the industrial application mineral oil use as cutting fluid. The use of mineral oil is hazards to living condition. Cutting fluid which are used in industry today is toxic and costly unhealthy for worker and environment .damping of cutting oil is most problematic subject to the industry. Denigration of cutting fluid also lead to economical advantage of saving recycling of cutting fluid, corrosion and erosion of work piece. In this project vegetable oil used as cutting fluid and effect on cutting forces, surface roughness and temperature of work piece is analyses with application of minimum quantity lubrication system .flow rate of mql kept 50 ml and flow rate for flood cooling 500 ml. Low budget carbide tipped single point cutting tool is used. Optimize the cutting parameter with help RSM***

Keywords: MQL, cutting performance, turning, and carbide insert, vegetable oil

1. Introduction

The cutting fluid improves the cutting tool life and increases the productivity of the production system. Despite of its share in industry growth, mineral oil based cutting fluids may create several ecological problems. Large amount of cutting fluids are used in the industry. It is reported that, China and Japanese Union alone consumes approximately 45, 00, 00 tones per year of cutting fluids out of which two third needs to be disposed. Waste management of the cutting fluid is very big issue from environmental point of view.[4]Increased use of cutting fluids results into environmental damage like soil pollution, water pollution, disposal and dumping problems. Recycling cost of the waste cutting fluid is high as it requires separate setup and maintenance. Most important factor is health of the operator. The operator may suffer from dermatological, respiratory disease which may lead to cancer. In India, large amount of mineral based cutting fluids are used in both large scale factory, medium scale factory. 65% of the operator working on machine suffering from skin disease, lung cancers. Most of the small scale and medium scale industries are unaware of the disadvantage of the cutting fluids. The use of the mineral oil is conceivable hazardous. The mineral oils which are used as cutting fluids are irreplaceable and exhaustible sources. They are depleting. Gases exerted from theses oils also results into isothermal layer depletion and contribute to increase the average temperature of the earth's atmosphere. Thus mineral oil based cutting fluids are responsible for disturbing the natural system balance. This disturbance has long term effect on mankind and next generation. To protect natural balance, ecosystem, every country now making the strict restrictions for the use of mineral oil based cutting fluids. Depleting nature of petroleum based oils, health associated problems, cost, pollution, government regulations forces industries to develop alternative technologies.

MQL uses very small amount of cutting fluid (50 ml to 500ml per hour) which is very low than conventional flood lubrication system (1liter to 10liter per min).The minimization of cutting fluid leads to saving of the cutting fluid, reduces the machining cycle time hence reduces the chances of the contact of the operator with cutting fluid. MQL consist of mixture of high pressure air and cutting fluid applied directly into the interface of cutting tool and work piece. It works on the principle that droplet of the liquid is atomized by high pressure air flow distributed and moved in the direction of air flow.[11]

2. Literature Review

Vaibhav Khanna [1] (2014) Study the Effect on Surface Properties OF Mild Steel during Dry Turning & Wet Turning on Lathe. In the present experiment investigation on straight turning of mild- steel bar by using HSS tool. The experiment aimed at evaluating the best process environment which could simultaneously satisfy requirements of both quality and as well as productivity with special emphasis on reduction of cutting tool flank wear. Because reduction in flank wear ensures increase in tool life. The predicted optimal setting ensured minimization of surface roughness.

Kedare S. B.[2] (2017) In this research work, the effects of three parameters, namely, cutting speed, feed and depth of cut were studied upon Surface Finish during milling operation. The end milling was performed under the Minimum Quantity Lubrication condition (900ml/hr) using end mill cutter and compared with conventional flooded lubrication (2liter/min). The comparative effectiveness was investigated in terms of surface finish. The surface finish was found to be improved by 27%. The findings of this study show that MQL may be considered to be an economical and environmentally compatible lubrication technique

Kamal kishorjoshi [3] (2018) The current research involves the performance analysis in turning Incoloy 800 in dry, minimum quality lubrication and flooded cutting scenario. Two types of MQL namely MQL1 (150 ml/h) and MQL2 (230 ml/h) have been implemented. Flooded cooling rate has been fixed as 600 ml/h. Grey relational method is used to ameliorate the cutting process restrictions (feed, cutting-speed, and depth of cut), in order to have minimum roughness of surface and tool flank wear. Later analysis of variance (ANOVA) is carried out to analyze the impact of turning variables on responses. The outcomes obtained show that the roughness of surface and tool wear both are minimal under MQL2 is more favorable than MQL1.

S. Ekinovic [4] (2015) Investigated that cutting forces are reduced to 16% by MQL supply during the machining of aluminium bronze .it is due to a decrease of friction between chip and tool interface .they also observed that MQL helps in energy saving due to decrease in cutting forces during machining . Experimental results show the appearance of minimum cutting force during machining with 1.7 l/h of water, and 10 ml/h of the oil. Position of the nozzle does not significantly affect the cutting forces

C.J.Rao [5] (2014) this paper presented a review of Analysis of Tool Life during Turning Operation by Determining Optimal Process Parameters. In this work aluminium is taken as a work material and tungsten carbide as tool material. By varying the different parameters like depth of cut, speed and feed at different conditions the tool life, surface finish, cutting force and other parameters were calculated. The results showed that the tool life is decreasing as the cutting force, MRR and cutting speed increases. The optimum process parameters obtained from MATLAB program will give a reasonable surface finish with better life.

All the studies highlighted the advantages of using MQL in machining processes under different lubricants. However, MQL system using vegetable oil as cutting fluid is still an innovative investigation area that needs to be explored. What are the effect on surface finish, cutting forces, power consumption and temperature with use of vegetable oil as cutting fluid still an innovative investigation area that needs to be explored Low budget uncoated carbide inserts implementation in finishing operation is rarely investigated

3. Problem Statement

The increasing awareness on environmental and health concern of industrial activities and governmental law are forcing industrialists to reduce the use of mineral oil as cutting fluids. Mineral oil are limited and non-renewable in nature, health associated problems for operator who work on that environment , cost, pollution, government regulations forces industries to develop alternative technologies.75% of the operator working on machine suffering from skin disease, lung cancers. Cutting fluids are environmentally unfriendly, costly, and potentially toxic. The recent shift to dry cutting has not completely solved the problem. Dry cutting increases energy costs, increases per part costs, and requires a capital investment that is too large for most machine shops.

Growing demand of productivity, high production is required for that we should use high feed, speed and depth of cut, so we can minimize the machining time and find the combination or relation among the input variable so that we get maximum productivity with minimum cost and time without affecting the product quality

4. Objective

- To compare the flood and MQL lubrication system
- To compare performance of vegetable oil and mineral oil in terms in terms of cutting temperature, surface roughness and cutting forces
- Optimization of turning parameters

5. Proposed Methodology

The experiment methodology and details of the equipment used and Taguchi designed of experiment techniques for performance evaluation of wet turning and minimum quantity lubrication (MQL) turning processes. Present study has been done through the following plan of experiment.

a) Checking and preparing the Centre Lathe ready for performing the machining operation.
b) Cutting MS bars by power saw and performing initial turning operation in Lathe to get desired dimension of the work pieces.
c) Performing straight turning operation on specimens in various cutting environments involving various combinations of cutting parameters like: spindle speed, feed and depth of cut.
d) Measuring cutting forces during turning operation on specimens in various cutting environments involving various combinations of cutting parameters like: spindle speed, feed and depth of cut with the help of lathe tool dynamometer.
e) Measuring surface roughness with the help of a portable stylus-type profilometer.

Selection of Work material

MS material is being widely used for various industrial applications so experiments is been carried out by turning cylindrical MS bars (figure 4.1) with a diameter of 50 mm and length of 15 cm on lathe machine at different cutting speeds, feeds and cutting depths under dry wet and MQL conditions. Mild steel having a wide range of application in forged motor shaft, hydraulic shafts and pump shafts as well machinery parts.

The chemical composition and mechanical properties of MS are given in the table

Grade	C (%)	Mn (%)	Si (%)	P (%)	S (%)	Cr (%)	Ni (%)	N (%)
AISI1018	0.193	0.747	0.238	0.0281	0.0098	1.06	0.017	0.22
Grade	**Yield Strength (Mpa)**		**Tensile strength (Mpa)**		**Elongation (%)**		**Vickers Hardness (HV)**	
AISI1018	370		440		15		131	

Experiment Setup

Experimentation is carried out on conventional lathe as shown in figure having detailed specifications are already provided in the previous chapter. Experimental setup also consists of MQL system which having various components i.e. air compressor, oil tank, air filter regulator, Solenoid valve, Spray lube unit, Air Flow control Valve with Built in Check Valve, Siphon tube with Suction strainer, Oil Control Valve, Coolant Pipe, PU tube, Air Pressure control valve, Magnetic base, Tee Joint, M.S. mounting plate and Nozzle etc.

Figure: Experiment Setup

Experiment is conducted on MS bars and carbide coated single point Cutting tool is used for the experimentation. In order to conduct experimentation successfully all the connection are correctly connected specially lathe tool dynamometer which is used for cutting force measurement is connected to cutting tool through connecting wires and ports provided to the display of dynamometer then lathe tool dynamometer is connected the supply voltage. Insuring initial zero reading on the lathe tool dynamometer experiment is proceed. Experimentation is done for three different cutting conditions namely wet cutting and MQL cutting. Cutting forces (radial cutting force, thrust cutting force) are measured with the help of lathe tool dynamometer and surface roughness values are measured with the help of profilometer surface measuring instrument for dry cutting, wet cutting and MQL cutting separately for the various combinations feed rate, depth of cut and cutting speed. As describe already there are three cutting parameters namely cutting speed in m/min (A), feed rate in mm/rev (B) and depth of cut in mm (C) having three levels are shown in previous table. There are total 27 number of possible combinations in which experiment is conducted and cutting forces and surface roughness are measured for each combination cutting speed, feed rate and depth of cut. Detailed experimental setup is shown in the figure.

6. Experimental Results and Performance Evaluation

A] Wet turning:

In the wet turning Cool 30 cutting fluid is supplied at 2 L/min flow and 2 Mpa pressure. Cutting force and surface roughness are measure for various combination of cutting speed, feed rate and depth of cut according to selected level of cutting parameter for the experiment. There are total 27 combination of speed, feed rate and depth of cut. Cutting forces are measure on dynamometer for each combination on separate workpiece and after the experimentation surface roughness (Ra) is measured for individual workpiece with the help surface roughness measuring instrument. Table 4.2 shows the output values of cutting forces and surface roughness values for given combination input cutting parameters.

B] MQL turning

In the MQL turning with the help of MQL setup Cool 30 and groundnut cutting fluid is supplied at 0.3 L/min flow and 0.0005 Mpa pressure so that fluid is atomized into fine droplets which provides lubricating effect. Cutting force and surface roughness are measure for various combination of speed, feed rate and depth of cut according to selected level of cutting parameter for the experiment. There are total 27 combination of feed rate, depth of cut cutting speed. Cutting forces are measure on dynamometer for each combination on separate workpiece and after the experimentation surface roughness (Ra) is measured for individual worpiece with the help surface roughness measuring instrument. Table 4.3 shows the output values of cutting forces and surface roughness values for given combination input cutting parameters. The minimization of cutting fluids also leads to economical benefits by way of saving lubricant cost, workpiece and tool.

Table 4.1: Experimental results of Fc, Ft and Ra in wet turning (Cool 30)

Total runs	Cutting speed m/min	Feed Rate mm/rev	Depth of Cut (mm)	Cutting force Fc(N)	Temperature	Surface roughness Ra µm
1	50	0.30	0.50	353.26	33.90	2.5
2	50	0.30	1.0	542.61	40.44	2.3
3	50	0.30	1.5	744.65	45.10	2.45
4	50	0.35	0.50	332.60	40.2	2.8
5	50	0.35	1.0	445.43	46.18	2.9
6	50	0.35	1.5	488.65	52.2	3.18
7	50	0.40	0.50	350.01	45.8	3.25
8	50	0.40	1.0	438.60	54.6	3.19
9	50	0.40	1.5	575.40	58.1	3.5
10	60	0.30	0.50	281.65	32.1	1.9
11	60	0.30	1.0	458.38	39.20	2.00
12	60	0.30	1.5	632.98	44.20	2.25
13	60	0.35	0.50	311.10	38.2	2.28
14	60	0.35	1.0	399.14	47.10	2.3
15	60	0.35	1.5	480.88	49.20	2.4
16	60	0.40	0.50	260.12	46.10	2.45
17	60	0.40	1.0	376.25	51.25	2.50
18	60	0.40	1.5	458.10	55.15	2.55
19	70	0.30	0.50	222.20	29.3	1.65
20	70	0.30	1.0	368.42	40.1	1.99
21	70	0.30	1.5	513.15	50.2	2.1
22	70	0.35	0.50	183.08	37.2	2.33
23	70	0.35	1.0	336.30	44.3	2.48
24	70	0.35	1.5	489.72	55.3	2.87
25	70	0.40	0.50	220.10	37.3	2.97
26	70	0.40	1.0	344.31	46.3	2.99
27	70	0.40	1.5	475.85	58.1	3.65

Table 4.2: Experimental results of Fc, Ft and Ra in MQL turning (cool 30)

Total runs	Cutting speed m/min	Feed Rate mm/rev	Depth of Cut (mm)	Cutting force Fc(N)	Temperature	Surface roughness Ra µm
1	50	0.30	0.50	323.26	32.70	2.3
2	50	0.30	1.0	535.49	38.25	2.15
3	50	0.30	1.5	700.72	44.2	2.20
4	50	0.35	0.50	327.88	40.00	2.0
5	50	0.35	1.0	415.10	45.10	2.40
6	50	0.35	1.5	450.63	51.2	2.9
7	50	0.40	0.50	326.32	46.2	3.0
8	50	0.40	1.0	438.10	53.1	2.82
9	50	0.40	1.5	523.98	57.2	3.18
10	60	0.30	0.50	253.15	32.5	1.55
11	60	0.30	1.0	430.10	38.10	1.90
12	60	0.30	1.5	616.45	43	1.95
13	60	0.35	0.50	300.40	36.80	1.88
14	60	0.35	1.0	357.98	46.10	2.0
15	60	0.35	1.5	479.88	48.50	2.10
16	60	0.40	0.50	247.20	45.20	2.20
17	60	0.40	1.0	360.40	50.10	2.25
18	60	0.40	1.5	448.18	54.00	2.22
19	70	0.30	0.50	204.28	28.20	2.18
20	70	0.30	1.0	316.22	40.10	1.92
21	70	0.30	1.5	517.18	49	1.99
22	70	0.35	0.50	181.21	36.40	2.39
23	70	0.35	1.0	319.25	43.50	2.34
24	70	0.35	1.5	467.33	54.10	2.28
25	70	0.40	0.50	210.20	36.35	3.0
26	70	0.40	1.0	327.22	45.65	2.85
27	70	0.40	1.5	422.13	57.38	3.30

7. Result and Discussion

There is significant decrease in temperature for MQL cutting as compared to flood cutting. In MQL, high-pressure air jet mixes with coolant and this mixture is sprayed on the work piece-tool interface. This mixture of high-pressure air and coolant removes heat excellently. Due to high velocity, particle of coolant penetrated easily which results into less temperature for MQL. Temperature is reduced by 2%-5% as compared to the flood cutting. Vegetable oils has more viscosity, which offers better lubrication. When the machining temperature increases, the viscosity of vegetable oil drops more slowly than that of mineral oil. Conversely, as the temperature falls, vegetable oil remains more fluid than mineral oil, facilitating quicker drainage from chips and work pieces. The lubricity of groundnut is not affected at higher temperature.

Cutting forces increase with increasing feed rate and decreases with increase in speed. With increase in cutting speed, frictional forces are decreased, which results in decrease in cutting forces. Increase in depth of cut results into increased tool work contact length, hence frictional force will be more. This is the reason cutting forces are increased at higher depth of cut. As depth of cut increases, there is increase in cutting force

8. Conclusion

From the experimental results and performance analysis of turning process shows that,

- Cutting forces are less in MQL turning as compared to wet turning. There is 5.52 % decrease in cutting forces when cool 30 oil is used. Cutting forces are reduced due to decrease in friction in case of MQL cutting.
- There is 9.047% reduction in cutting forces is observed in MQL when cool 30 mineral oil is compared with ground nut oil (vegetable oil) .
- The cutting temperature was considerably reduced by average 2.013% for the MQL cutting as compared to wet cutting.
- When groundnut oil used in MQL there is 7.48 % reduction in the cutting temperature compared to cool 30 oil used in MQL.
- There is extensive difference in surface roughness produced by flood and MQL cutting conditions. There is an average 8.766% reduction in roughness values for MQL as compared to flood cutting.
- Result shows that surface roughness values are less in case of groundnut oil compared to cool 30 oil .there is an average 10 % reduction in roughness values.
- Mathematical models are developed based on experimental data. ANOVA test carried out to check the adequacy of the model. Mathematical models developed as accurate and acceptable
- Depth of cut has great significant effect on main cutting forces followed by feed rate but cutting speed has no significant effect on main cutting forces in all cutting conditions.
- Temperature is influenced by depth of cut.

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