Comparative Study of Different Cooling Conditions In Turning Operation For Sustainability

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Abstract- *The present investigation reports the turning of medium carbon steel on a CNC lathe machine using different cooling conditions i.e. dry, wet and MQL (minimum quantity lubrication.). Measurements of material removal rate, tool tip temperature and surface roughness was carried out in this work. The effect of process parameters such as speed, feed and depth of cut were analyzed under the given cooling conditions.*

Keywords- MQL, turning, surface roughness and MRR.

I. INTRODUCTION

It has been reported that the energy spent on the manufacturing process is nearly 50%, but the energy actually used for machining is approximately 10%. Although the applications of coolants or lubrications can enhance the energy efficiency, they have adverse effects on the conventional flood methods, minimum quantity lubrication (MQL), which refers to a technique that directly sprays extremely small amount of lubricants. MQL has been reported as a technologically and environmentally feasible alternative to flood cooling and proved capable of reducing the cutting energy consumption. Economical and environment friendly machining is the need of industry with all metal cutting operation like turning, drilling, milling, grinding etc. it is well known fact that the cutting operations generate heat which is to be minimized by any means in order to reduce the friction generated at the tool work piece contact for obtaining improved tool life and surface finish Conventional metal cutting operation involves the removal of material in the form of chips from the surface of the work piece[1]. During chip tool contact, friction is generated at the interface due to which large amount of heat is evolved affecting the tool geometry. In order to achieve higher productivity rate in machining it is desirable that the cutting speed should be high but due to higher temperature generation the cutting tool wear out rapidly which poses a limit on the cutting speed. Also the deterioration of the tool profile leads to poor surface finish of the work pieceas well as increase in power consumed by the machineTool [2].

II. MACHINING UNDER DIFFERENT COOLING CONDITIONS

As machining involve plastic deformation of work piece material and also friction between tool chip and tool-work piece interface these both phenomenon needed high amount of energy which further converted into heat. While machining low strength alloys there is less amount of heat generation take place but machining of ferrous and other high strength alloys are associated with larger amount of heat generation. The distribution of temperature is shown in Fig. 2.1. The dissipation of this generated heat is one of the important factors as per good machining requirements [3]. If the generated heat is not dissipated effectively, may cause for reduced tool life, poor surface finish of machined face and thereby reduction in overall performance of the machining process obtained as a result Although high speed machining is desirable condition in most of the cases, the penalty of higher heat generation needs to be minimized.

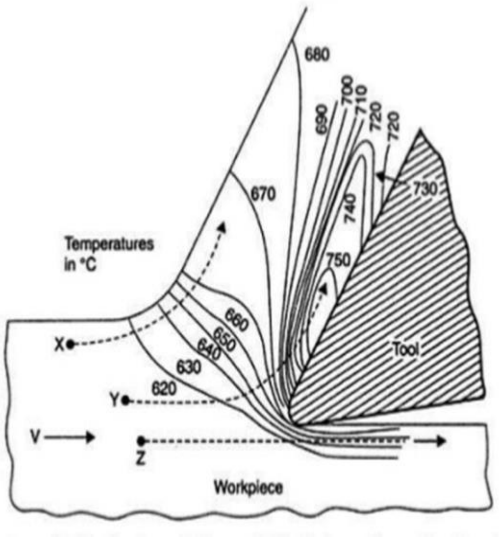


Fig. 2.1 Temperature Distribution in Metal cutting (Boothroyd, 1974)

A. Dry machining

When no cutting fluid is used during machining, it is called dry machining. Dry machining associated with low cutting speeds and easily machinable materials. Usually, dry machining is not appropriate in cases where great surface finish and high precision in dimensional stability are required. This is so because dry machining involves high temperature generation which enhances the chances of formation of built up layer. This built up layer due to its unsteady nature breaks and takes away a portion of tool material due to its high adhesive nature causing tool wear. The broken segments when stick to the machined surface deteriorates the surface finish [4]. Thus, dry machining without any lubricating and cooling enhancement is not preferred in general cases of machining. Fig. 2.2 shows the benefits of dry machining.

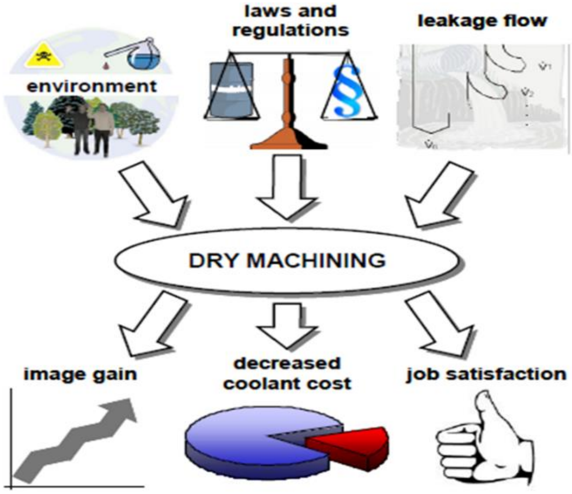


Fig 2.2 – Benefits of dry machining

B. Wet machining

Cutting fluid also known as lubricants and coolants as it fulfills both the desired purpose. It serves the cooling effect to minimize the negative thermal affects and lubricating effect to provide better surface finish. Cutting fluids are used extensively in machining operation to:

- Cool the cutting zone, thus reducing work piece temperature and distortion, and improving tool life.
- Reduce friction and wear, hence improving tool life and surface finish.
- Reduce forces and energy consumptions.
- Wash away chips.
- Protect the newly machined surfaces from environmental attack.

The following are the essential properties, which cutting fluids must possess in order to fulfill their desired function:

- A good cutting fluid is defined with its large specific heat capacity and high thermal conductivity.
- It should have low viscosity in order to easily enter through small gaps.
- It should be non-corrosive, nontoxic and should not react with work piece and tool material.
- It should be ease as per availability and should not be much expensive.
- It should have high flash point to maintain its properties [5].

C. Minimum Quantity Lubrication

Minimum quantity lubrication is one of the mostpreferable techniques now a day as a cutting fluid purpose due to its capability of giving the good results with only small consumption of resources(power, cutting fluid). In this technique of cooling and lubrication a typical flow rate of cutting fluid in the range of 50-500 ml/h is directly applied to the cutting zone. Unlike normal flood cooling this technique is free from fluid disposal problem as it takes very small quantity for machining. Since this technique involves significantly lesser amount of cutting fluid, this technique is also termed as ‘near dry machining’ or ‘micro lubrication’ or ‘spatter lubrication’.

Minimum quantity lubrication technique has several advantages over conventional flood cooling, which can be summarized as below:

- It consumes relatively very less amount of cutting fluid thereby making the process almost clean and dry.
- As per small amount of cutting fluid less vaporization takes place, which is more environmentally friendly and less harmful for the operating worker as per health concern.
- As the process involves high pressure of air, it helps small droplets of aerosol to reach directly over to cutting zone easily.
- The mixture of highly pressurized air and cutting fluid easily flushes the forming chip effectively thereby making the chip handling task much easier.
- The machining processes which concerns with MQL is more productive with increased tool life and better surface finish of work piece [6].

III. EXPERIMENTAL DETAILS

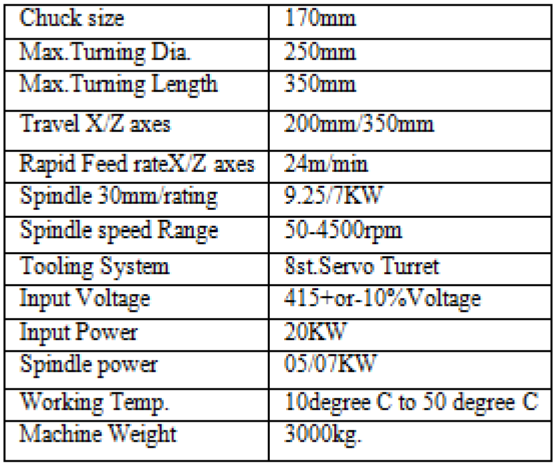
The experimentation is one of the most important aspect in engineering to generate the practical data , to appreciate and visualize complicated concepts behavior of materials, process , to develop new product design ,etc.

accordingly the predefined assumptions, concept, behavior are modified to meet the actual requirement. The participation in the initial stages of experiments in different areas of research leads to justify the experimental treatments whose effects to compare and to defend completed experiment .when experiment are repeated , the effect of experimental treatment varies from trial to trial This introduces a degree of uncertainty into any conclusion.

A. Experimental setup

In this study we have consider 3 factors which affect majorly on quality characteristic such as spindle speed, feed rate & depth of cut. The design of experiment was carried out by response surface methodology using design xpert software. In this technique the main objective is to study the effect of process parameters on response parameters of turning [7]. A Series of experiment was conducted to evaluate the influence of parameters on surface roughness, tool tip temperature and MRR. The experiments were carried out on CNC lathe machine The CNC lathe machine (table 3.1) has the following specifications:

Table 3.1 – technical specifications of CNC lathe



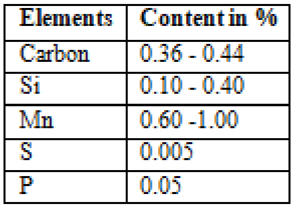
Chuck size	170mm
Max.Turning Dia.	250mm
Max.Turning Length	350mm
Travel X/Z axes	200mm/350mm
Rapid Feed rateX/Z axes	24m/min
Spindle 30mm/rating	9.25/7KW
Spindle speed Range	50-4500rpm
Tooling System	8st.Servo Turret
Input Voltage	415+or-10%Voltage
Input Power	20KW
Spindle power	05/07KW
Working Temp.	10degree C to 50 degree C
Machine Weight	3000kg.

Fig 3.1 – Image showing CNC lathe

B. Work-piece and tool inserts

Material selected is EN 8 medium carbon steel, it is widely used in automotive industry.Work piece Dimensions: diameter = 32 mm length = 60 mm. Chemical composition of EN 8 steel is given in table – 3.2 below:

Table 3.2 – Chemical composition of EN8 steel



Elements	Content in %
Carbon	0.36 - 0.44
Si	0.10 - 0.40
Mn	0.60 -1.00
S	0.005
P	0.05

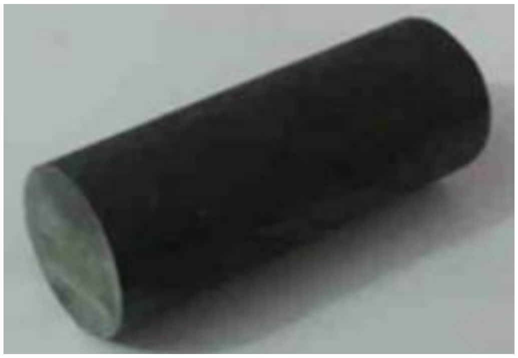


Fig 3.2 – Work piece of EN 8 steel

C. Tool inserts specifications

Tool used in the research is TiN-TiCN-Al2O3 coated carbide TNMG160404 CN1500 manufacturer code manufactured by KORLOY made in Korea. Tool geometry is defined by rake angle 6º, clearance angle 11º, tool cutting edge angle 60º, cutting edge inclination angle 0ºand tool nose radius 0.8 mm used.

Fig 3.3 – Tool holder with inserts

D. FRL unit

An FRL unit is comprised of a filter (F), regulator (R), and a lubricator (L). They are often used as one unit to ensure clean air in a pneumatic system but can also be used individually. Having a proper FRL unit installed in a pneumatic system provides higher reliability of the components downstream, reduced power waste due to over pressurization, and increased component lifetime.FRL unit is used to work as a MQL setup by producing required amount of mist with pressure.

Fig 3.4 – FRL unit

E. Measurement of response parameters

Response parameters such as surface roughness, tool tip temperature and material removal rate are measured using different equipment as follows:

a. MRR Measurement

MRR is the rate at which the material is removed from the work piece. Turning operation takes place between the tool and the work piece during the machining process material is removed The MRR is defined as the ratio of the difference in weight of the work piece before and after machining to the machining time [8].

b. Surface roughness measurement

Roughness measurement has been done using a portable stylus-type profilometer, Mitutoyo (Surftest SJ-210 Series) the surface roughness values like Ra, measured using surface roughness tester with model no. SJ 210 178-561-DA for measurement. The detector with instrument is 0.75 mN type (178-296) with stylus tip radius 2 µm with measuring force 0.75 mN.

c. Tool tip temperature

To measure the temperature we used Maxtech instruments made digital infrared temperature gun thermometer, non-contact laser point type K-input.

F. Coding Of Variables For Dry and Wet Machining

The table.3.3 shows the coding of input variables: Speed, Feed and Depth of cut distance for Low, Medium and High levels.

Table.3.3 –Coding of input variables

Levels	**Low(-1)**	**Medium (0)**	**High (+1)**
Speed (rpm)	2000	2750	3500
Feed (mm/rev)	0.14	0.17	0.2
Depth of cut (mm)	0.6	0.8	1

IV. RESULTS AND DISCUSSIONS

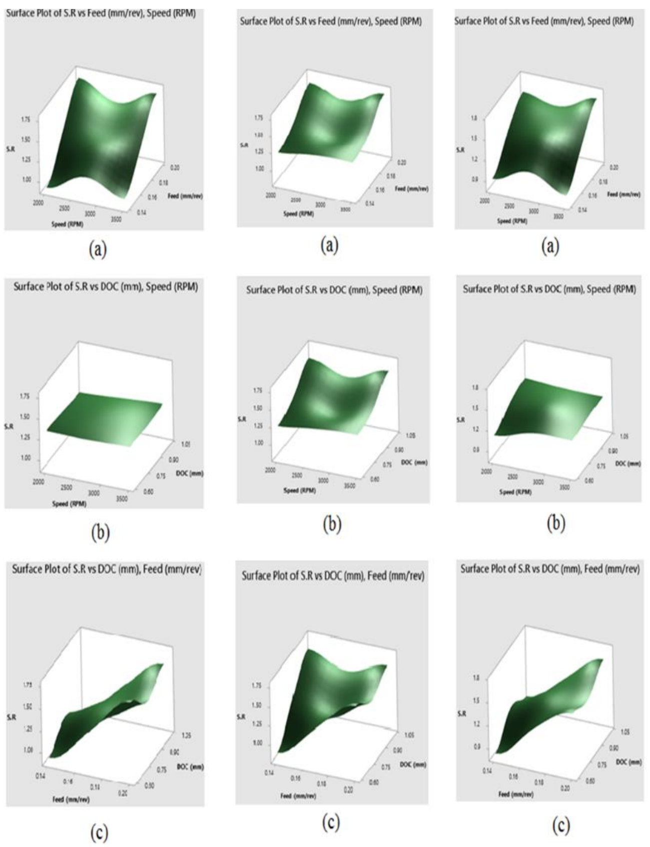
A set of experiment carried out on CNC machine using different speed, feed and depth of cut. Experiments have been performed as per the three level full factorial design and surface roughness, tool tip temperature and material removal rate measured for dry, flood and MQL cooling conditions. Results obtained during Dry Wet and MQL conditions are tabulated. With the use of statistical software, the data is analyzed. The 3D surfaces plots are graphical representations of effect of process parameters on response parameters while other parameters are at the fixed levels. The relationship between the responses and process parameters visualized by the three-dimensional surface plots to see the influence of the parameters.

A. Comparative analysis of machining under different cooling conditions

Comparative study between different cooling conditions has been undertaken to evaluate the performance of different cooling conditions in finish turning of EN8 and compare their effect against responses such as surface roughness, tool tip temperature and material removal rate.

a. Comparison of Surface Roughness under Dry, Wet and MQL condition

Figure 4.1 Shows effect of speed, feed and depth of cut on surface roughness during turning of EN8 steel. Different cooling conditions are compared for surface roughness and showed in figure 4.1.It has been observed from figure that minimum surface roughness is observed during Minimum Quantity Lubrication. Also it has been seen that as feed increases surface roughness is also increased. It can be seen from Fig. 4.1 (a) that there exists a direct relationship between the surface roughness and the feed rate. The change in surface roughness is associated with the increase in feed rate [9]. Minimum quantity lubricant with a non-edible vegetable mahua oil have a beneficial effect in EN8 turning due to its superior cooling capability of the oil. The value of surface roughness is 0.801 µm in MQL condition while in dry and wet conditions values are0.917 µm and 0.825 µm respectively.fig.4.1 (b) shows the effect of depth of cut and speed on surface roughness.it can be seen that surface roughness is near about constant in dry condition 1.326 µm, maximum 1.71 µm in wet condition and minimum in MQL condition 1.037 µm.



(A) (B) (C)

Figure 4.1 - Effect of speed, feed and depth of cut on surface roughness in (A) Dry, (B) Wet and (C) MQL conditions.

b. Comparison of tool tip temperature under Dry, Wet and MQL condition

The tool tip temperature comparison for dry, wet and MQL machining condition is shown in Fig 4.2.It is observed that at higher cutting speeds and depth of cut temperature is maximum. For example, the tool tip temperature increases 8.3% for cutting speed 3500, while the tool tip temperature only increases 2% for cutting speed 2000 rpm. It is found that the tool flank wear has a larger effect on cutting temperature for high cutting speed. The greater the cutting forces the more heat is generated and consequently the higher tool tip temperature [10]. Moreover, the average cutting tool tip temperature increase ,relative to wet machining ,on the tool – chip interface in dry machining is below 10%.the heat taken away from tool tip is relatively insignificant. It is observed that in MQL condition with mahua oil as a cutting fluid tool tip temperature is low as compared to dry machining. Also the minimum temperature is observed in wet condition.

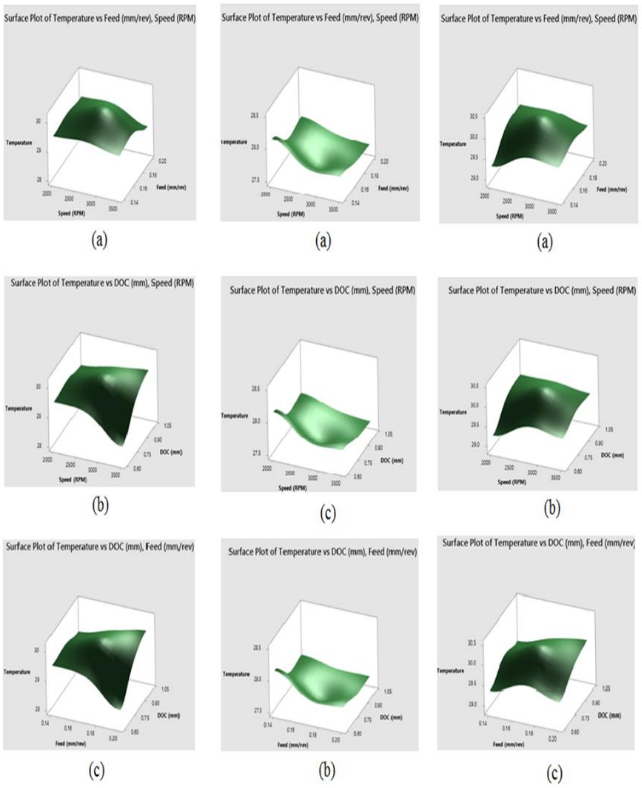


Figure 4.2- Effect of speed, feed and depth of cut on tool tip temperature in (A) Dry, (B) Wet and (C) MQL conditions

c. Comparison of Material removal rate under Dry, Wet and MQL condition

The MRR comparison for dry, wet and MQL machining condition is shown in fig. 4.3.It is observed that at higher depth of cut and higher feed it is higher. For example, the MRR is observed to be 2.88, 2.778 and 3.22 gm/sec for dry, wet and MQL machining condition respectively the cutting speed is found to be least effective. But the MRR does not increases drastically under wet machining compared to dry machining.it has significant value of 3.571 gm/sec under MQL machining condition.

Fig. 4.3 (a) is a 3D surface plot for MRR against speed and feed under dry, wet and MQL conditions. From the plot it is clear that maximum MRR is obtained at higher feed and speed in MQL condition as compare to dry and wet. Fig. 4.3 (b) shows the effect of speed and depth of cut on MRR under different cooling conditions. From the plot it is clear that MRR is slightly more as compare to MQL but MRR is more in MQL as compared to dry. Fig. 4.3 (c) shows the effect of feed and depth of cut on MRR under dry, wet and MQL cooling conditions.it can be seen from the figure that MRR is near about same for wet and MQL conditions. While it is slightly more in case of dry but again there is problem with surface roughness and tool life.

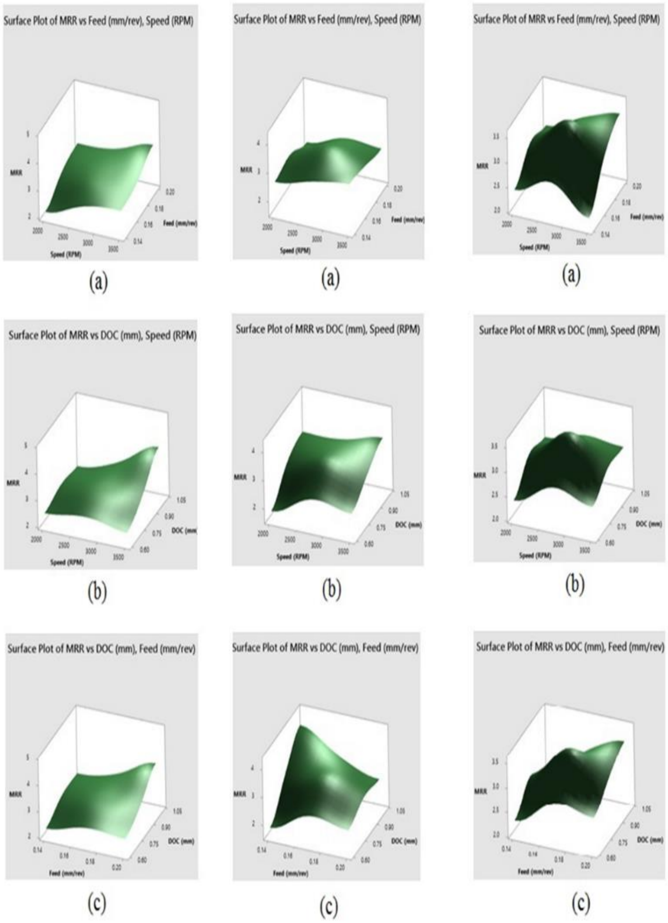


Figure 4.3- Effect of speed, feed and depth of cut on material removal rate in (A) Dry, (B) Wet and (C) MQL conditions

V. CONCLUSION

Based on the results of the experiments carried out, the following conclusions can be drawn:

1. Surface roughness is lower (0.801µm) and MRR is higher (3.5 gm/sec) in MQL technique as compare to Dry and Wet techniques.
2. Tool tip temperature is lower in Wet technique as compare to MQL and Dry. But there is environmental & economy issues related with cutting fluid.
3. When compare MQL and Dry temperature is low in MQL. By considering above results which we get through experiment we can say that the alternate for Dry and Wet technique would be MQL. If we increase the flow rate of Mahua oil in MQL then temperature may also get reduced, in this experiment 0.2830 ml/sec Mahua oil is consumed by increasing the flow rate temperature can be reduced and tool life will increase

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