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EXPERIMENTAL ANALYSIS OF MINIMUM QUANTITY LUBRICATION BY THE USE OF ANOVA SOFTWARE

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***Abstract*— In this experimental study, an attempt is made to obtain optimum cutting parameters for turning of mild steel on the basis of surface roughness and surface temperature. Optimization of cutting parameters is very important to obtain a good machining quality of surface and to inhibit the increase of temperature. Minimum Quantity Lubrication (MQL) has been introduced to avoid excessive use of cutting fluid. The parameters considered here are cutting speed, feed and depth of cut. Optimal cutting parameters for each performance measure were obtained employing Taguchi experimental method. To study the performance characteristics in turning operation Analysis of Variance (ANOVA) was employed. It is found that cutting speed and feed has significant effect on both surface roughness and temperature.**

***Index Terms*— Analysis of Variance, Cutting parameters, Minimum Quantity Lubrication, Optimum, Taguchi, Turning.**

I. INTRODUCTION

Minimum Quantity Lubrication (MQL) goes by many names. It has been referred to as “Minimal Quantity Lubrication”, “Near-Dry Machining” or “NDM”, “Micro-Lubrication” or “Microlubrification”, “Micro-Dosing”, and sometimes even gets incorrectly referred to as “mist coolant.” Minimum Quantity Lubrication (MQL) is an alternative to the use of traditional metal working fluids (MWFs) in machining. You may have heard MQL referred to as “Near-Dry

The historical, widespread use of coolants as MWF‟s has overshadowed MQL and kept it as a marginal technology [A. D. Jayal et.al, 2009]. Sadly, not many machinists know or truly understand the concepts behind MQL and therefore never get to enjoy its many benefits. In an industry where production efficiency is crucial, the unknowns of a „new‟ technology pose the potential threat of complications and downtime [03] [A. Devillez et.al, 2007]. The fear of the unknown may be the greatest challenge to MQL, and the fact that a large percentage of metalworking equipment comes already equipped with flood coolant systems is surely no help either [04] [B. K. A. Ngoi et.al, 2000].

The concept of MQL is fundamentally different than that of flood coolant and this can be a large stumbling block to machinists who are new to MQL. The use of flood coolant is incredibly basic. As long as relatively clean coolant „floods‟ the interface of the cutting tool and work piece, the heat generated by machining operations is kept at bay [06] [C. Mao et.al, 2014]. This process works (another reason it is widely accepted!), but has some significant consequences. One of the main downsides to the use of coolant is that it adds extra equipment into the equation. Equipment to recirculate, filter, test, and treat coolant to keep it viable is required [05] [C. M. Douglas et.al, 2001]. Contamination from bacteria, tramp oil, and swarf are major concerns as the disposal of spent coolant. Spent coolant is typically classified as toxic waste and its disposal is regulated. Users of flood coolant must factor the cost of its disposal into their machining costs [09] [C. Mao et.al, 2012]. Another consequence of coolant is that it‟s messy. Despite containment methods, coolant invariably winds up covering more than just the cutting tool and work. Machines, floors, and finished parts are often left wet from coolant, causing potential slip hazards and often requiring part cleaning before secondary operations can take place. Repeated exposure to many coolants can have real consequences for the humans involved as well [07] [C. Mao et.al, 2013].

Some coolants have been shown to cause dermatitis and to be carcinogenic with long-term exposure to coolant vapour. Studies have shown that the cumulative cost of coolants/MWFs can equal as high as 15% of the total cost to produce a part [08] [C. Mao et.al, 2013].

The cost and negative effects of flood coolant set the stage beautifully for MQL. When presented with an alternative which saves money, eliminates the mess, disposal, and negative aspects of coolant, you‟d think that machinists everywhere would be scrambling to implement this new technology wouldn‟t you? In fact, MQL technology has gained much wider acceptance in

European machining due to stricter environmental regulation. In the U.S., MQL still faces an uphill battle to win the „hearts and minds‟ of machinists. This website attempts to promote MQL knowledge and awareness in the industry and

will hopefully become a forum for the discussion of this emergent technology [10] [C. Mao et.al, 2013].

A. THE FUNCTIONAL PRINCIPLE OF MQL

The enormous reduction in the quantity of lubricant compared to the circulated quantities of conventional metalworking fluid systems is the key feature of MQL. In contrast to conventional flood lubrication, minimum quantity lubrication uses only a few millilitres (ml) of lubrication per hour for the machining process [Minitab Statistical Software Features, 2011].

Minimum quantity lubrication today uses such precise metering that the lubricant is nearly completely used up. Typical dosage quantities range from 5 ml to 50 ml per process hour (tool cutting time).

The extreme reduction in lubricant quantities results in nearly dry work pieces and chips. Losses due to evaporation and wastage, which may be considerable with emulsion lubrication (depending on the work piece being processed), are inconsequential with MQL. This greatly reduces health hazards due to emissions of metalworking fluids on the skin and in the breathed-in air of employees at their workplaces [N. Fazli et.al, 2007].

The cost-inflating factors of conventional flood lubrication are done away with when MQL is used. This results in:

- Reduction of metalworking fluid quantities in use
- Decrease in the work required for monitoring and metalworking fluid maintenance
- No need to prepare and dispose of used metalworking fluids
- Decrease in the work required for cleaning the processed pieces
- Easy recycling of the nearly dry chips due to less oil soiling.

II. LITERATURE REVIEW

The concept of minimum quantity lubrication (MQL) was suggested a decade ago as a mean for addressing the issues of environmental intrusiveness and occupational hazard associated with airborne cutting fluid particles on the shop floor. The minimization of cutting fluid leads to economic benefits by saving lubricant costs.

Nourredine Boubekri et al. (2015) study the Minimum Quantity Lubrication (MQL) in Machining: Benefits and Drawbacks and concluded the MQL has been shown to work well in short term tests over a range of processes. Long term capability and robustness remain still unanswered tough MQL applications have indicated favorable cost reduction due to the reduced cost of managing the cutting fluids .Theses issues may be sorted out when more extensive MQL experience is accumulated from large-scale production applications. More material specific issues may require additional testing.

Mohd. Faizan Hasan et al. (2014) from the the Study and Analysis of Natural Oil Based Cutting Fluids Using MQL System for Alloy Steel suggest the Surface finishes also improved mainly due to reduction of wear and damage at the tooltip by the application of MQL.

D.V. Lohar et al. (2014) from the Performance Evaluation of Minimum Quantity Lubrication (MQL) using CBN Tool during Hard Turning of AISI 4340 and its Comparison with Dry and Wet Turning suggest the cutting force in hard turning of hardened AISI 4340 is less as compared to dry and wet turning. There is 40% decrease in cutting forces during MQL. While for wet flood condition it was about 26% more than MQL and 19% less than dry condition.

Dhar et al. (2006) employed MQL machining technique in turning AISI 4340 steel with uncoated carbide tool (SNMM120408).During experimentation, process parameters such as cutting velocity, feed rate and depth of cut were kept constant at 110m/min, 0.16mm/rev and 1.5mm respectively .Water soluble cutting fluid was supplied at flow rate of 60 ml/h and mixed with compressed air prior to being impinged on the cutting zone at a high speed.

Itoigawa et al. (2005), however, found that in actual conditions with high machining load, existence of this kind of boundary film was uncertain. The review of the literature suggests that the concept of MQL presents itself as a possible solution for machining in achieving slow tool wears while maintaining the cutting forces/power at reasonable levels, if the MQL parameters can be strategically tuned. The main objective of the present work was to experimentally investigate the roles of minimum quantity lubrication by vegetable oil based cutting fluid on chip–tool interface temperature, chip colour and shape, chip reduction coefficient, tool wear and surface roughness in turning alloy steel (AISI 9310) by the industrially used uncoated carbide tool (SNMG 120408 TTS) at different cutting velocities and feeds combinations as compared to wet and dry machining.

Krahenbuhl (2005), From performance, cost, health, safety and environment points of view, therefore, considered vegetable oils as viable alternative to petroleum based metalworking cutting fluids. Significant progress has been made in dry and semi dry machining recently and MQL machining in particular has been accepted as a successful semidry application due to its environmentally friendly characteristics. Some good results have also been obtained using this technique.

Stabler et al. (2003) suggested the types of fluids not applicable for the minimum quantity lubrication were water mixed cooling lubricants and their concentrates, lubricants with organic chlorine or zinc containing additives, lubricants that have to be marked according to the degree on hazardous materials, and products basing on mineral base oils in the cooling lubricant 3 ppm(parts permillion) benzpyrene.

III. EXPERIMENTAL WORK

Work piece, cutting tool, machine for turning, vegetable based cutting fluid, selection of cutting parameters and machining conditions can be selected for the experimentation. To record the input and output parameters suitable orthogonal array can be used. For the analysis and to study response

variables taguchi methods, Signal to noise ratio and Annova can be used. Following steps can be followed for experimentation.

Figure3.1: Shows turning by using Natural oil

DESIGN OF EXPERIMENT

Experiments were conducted on plain turning a 31 mm diameter and 150 mm long rod of mild steel which are commonly used in a powerful and rigid lathe (15hp) at different cutting velocities and feeds under dry and MQL by vegetable oil conditions. These experimental investigations were conducted with a view to explore the role of MQL on the machinability characteristics of that work material mainly in terms of cutting temperature, material removal rate. The ranges of the cutting velocity (Vc) and Depth of cut (Dp) were selected based on the tool manufacturer‟s recommendation and industrial practices. Feed rate was kept to vary only, which would adequately serve the present purpose. Machining ferrous metals by carbides is a major activity in the machining industries. Again, the cutting temperature increases further with the increase in strength and hardness of the steels for more specific energy requirement. Keeping these facts in view, the commonly used mild steel was considered in this experimental research.

Figure 3.2 : Shows Turning by synthetic oil

In the above figure shows the turning operation by using the synthetic oil, and the ranges of the cutting velocity (Vc) and feed rate (S0) were selected based on the tool manufacturer‟s recommendation and industrial practices. Depth of cut is vary, which would adequately serve the present purpose. Machining ferrous metals by carbides is a major activity in the machining industries. Machining of steels involves more heat generation for their ductility and production of metal removal rate having more intimate and wide tool contact. Again, the cutting temperature increases further with the increase in strength and hardness of the steels for more specific energy requirement. Keeping these facts in view, the commonly used mild steel AISI 1006 was considered in this experimental research.

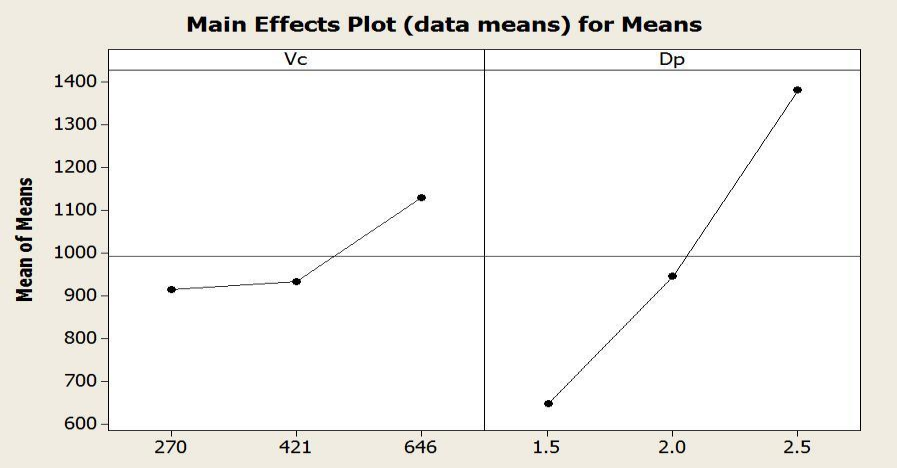
REQUIRED PARAMETERS

Machine tool	Lathe machine (15 hp)
Work specimen material	Mild Steel (C=0.42-0.20%, Fe=98.0 99.26%, Mn = 0.06-0.09%, P=0.04%, S=0.05%)
Hardness (BHN)	257
Size	ϕ150x 31mm
Cutting tool	HSS (1/2* 4")
Cutting velocity, V_c	646, 421, 270 rpm
Feed rate , S_o	0.10 mm/rev (constant)
Depth of cut „"D_p	1.5, 2.0 2.5 mm
Cutting fluid	MQL Condition- food grade vegetable oil: Olive oil (1 litre) and Synthetic oil(Ester)(1litre)

Graph and Rank of Natural oil by using Taguchi Method

Table 3.2: Shows Rank Obtain From Taguchi Method

LEVEL	Cutting Velocity	Depth of cut
1	58.99	56.23
2	59.11	59.49
3	60.30	62.68
Delta	1.31	6.46
Rank	2	1



-Figure3.3: Shows Graph b/w V_c , D_p to MRR

Analysis of Variance For MRR, Using adjusted SS for Tests to Natural oil

Table 3.3: Shows Analysis of Variance For MRR

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Vc	2	85707	85707	42854	1.38	0.351
Dp	2	820691	820691	410345	13.18	0.017
Error	4	124548	124548	31137		
Total	8	1030946				

Analysis of Variance by Using Natural oil

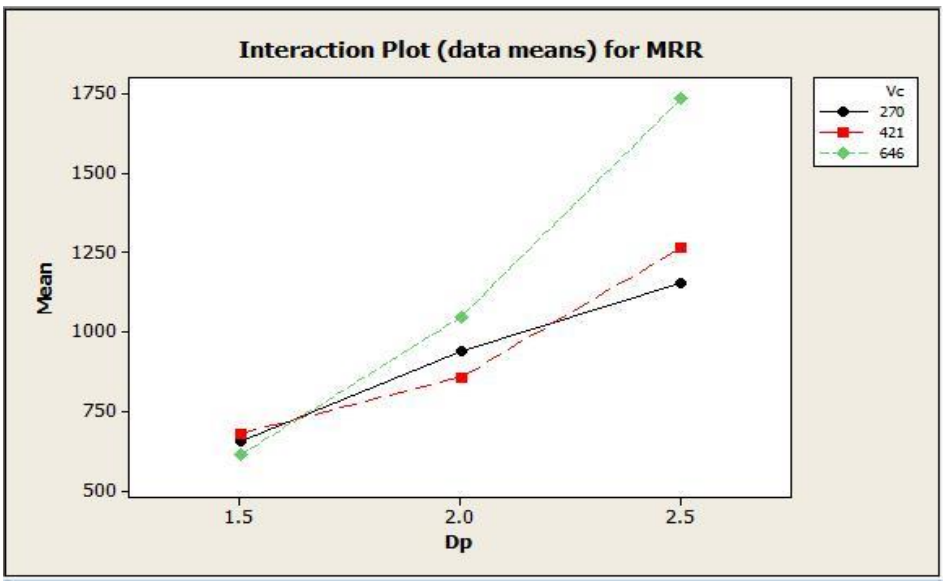


Figure 3.4: Shows Interaction plot for MRR

Graph between cutting velocity and temperature

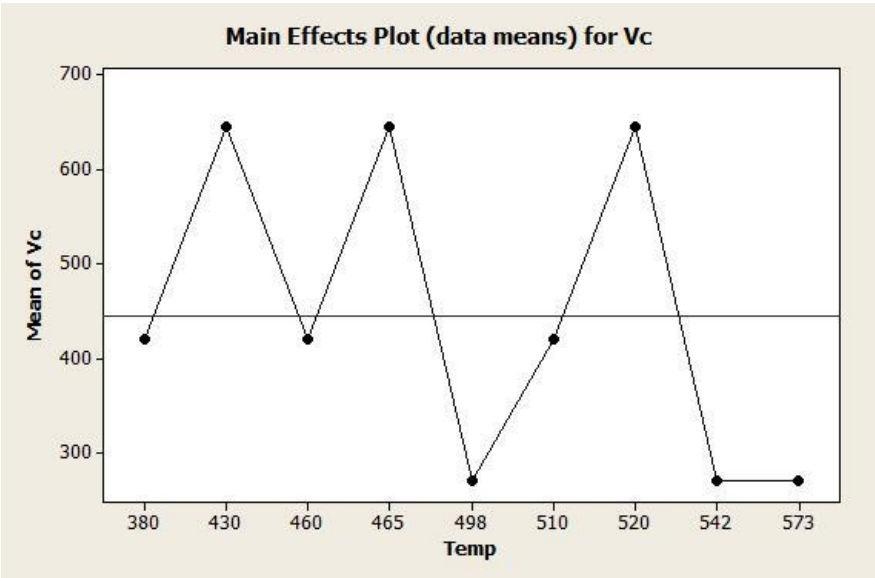


Figure 3.5: Shows graph between Vc & T

Graph between depth of cut and temperature

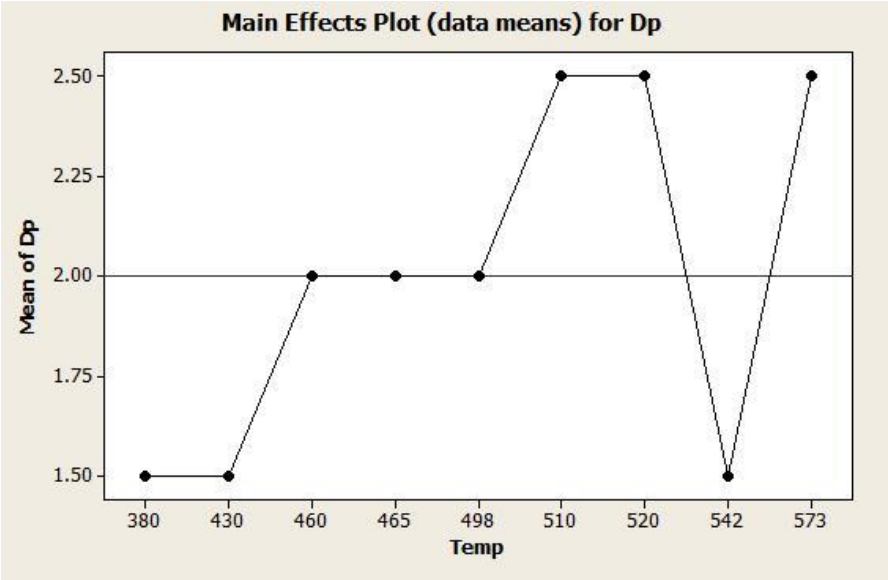


Figure 3.6: Shows graph between D_p & T

IV. RESULT AND DISCUSSION

Cutting velocity and Depth of cut are the two parameters which are used as controlling parameters. Their effect of Material removal rate is discussed:

- If we talk about cutting velocity, at level 1 and 2 the MRR is below overall mean value and in a broad way MRR is very low at level 1. But as we increase the level of cutting velocity, the MRR tends to increase and at level 3 we get higher value of MRR because during Lathe machining process the material removal rate is a function of cutting velocity and depth of cut.
- When Depth of cut increases, the MRR also increases. From the above plot it is clear that with increase in depth of cut the value of material removal rate increases.
- When the cutting velocity decreases the temperature will also decreases. But in case of cutting velocity increases the temperature will rise suddenly and down suddenly by the using of natural oil.
- When Depth of cut increases, the temperature also increases. From the above plot it is clear that with increase in depth of cut the value of material removal rate and temperature increases by the using of natural oil.
- When the cutting velocity increases the temperature will also increases. But in case of cutting velocity decreases the temperature will rise suddenly and after the nine orthogonal array its repeat the all various temperature by using the synthetic oil.
- When Depth of cut increases, the temperature also increases. From the above plot it is clear that with increase in depth of cut the value of material removal rate and temperature increases by the using of synthetic oil.
- There is a750 ml natural oil used in the whole nine experiments but in the synthetic oil case there is 250 ml oil is used in total nine experiments.

V. CONCLUSION

This experimental study described the optimization of conventional machining parameters in Lathe machine of Mild steel using L9 orthogonal array of Taguchi method. Factors like cutting velocity (Vc) and depth of cut (Dp) and their interactions have been found to play significant role in Lathe operation for maximization of MRR.

Based on above work following conclusions are made:

- The Material Removal Rate (MRR) increases with increase in Cutting velocity and depth of cut and the most influential factor was the depth of cut.
- The confirmation experiments are revealed that Taguchi‟s robust design methodology is successfully verified with the optimum process parameters. The predicted model is adequate at 95% confidence level with confirmation experiment chosen for optimum quality characteristics.
- Synthetic oil is much better than natural oil because the machining time of this process is less over the natural oil.
- Synthetic oil is also better than natural oil because of cost comparison the synthetic oil is cheap over the natural oil.

- Surface finishes also improved mainly due to reduction of temperature and damage at the tooltip by the application of MQL.
- Analysis shows that turning with MQL is a good alternative for conventional lubrication. It is important for cost of machining and for ecology as well.
- It is observed that the cutting temperature in turning of AISI 1006 is less as compared to natural wet and synthetic wet turning. It gives decreases in cutting temperature. The MQL shows lower range of temperature which helps to improve tool life.

VI. FUTURE SCOPE

In practice, demanding production processes (HSC machining) for large-scale mass production have been implemented using process-reliable MQL. For this to be the case it is important that the elements are optimally adjusted to each other. A key objective for the user is to keep the MQL process "easy" to use and initiate. The selected NC program contains all information (optimal interface parameters, lubricant quantity and feed, tool etc.) for the smooth running of the process.

- A standard for defining the relevant programs and processes is currently being worked out by a steering committee of industrial companies. This steering committee is composed of experts from companies which have already implemented minimum quantity lubrication in their own production or which, as suppliers, have many years of production system experience in using this technology. The objective of the standardization is to adapt all commonly used MQL systems to the production process through defined configurations.
- Future research will be performed in area of low cost technologies, high productive and hybrid machining processes.
- The process of metal working fluids mist particles generation and their physical characteristics are yet to be determined for a whole class of machining processes and machining conditions.

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