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STUDY AND ANALYSIS OF MINIMUM QUANTITY LUBRICANT(MQL) USING VARIOUS OILS FOR MACHINING OF MILD STEEL (AISI 1006) IN TURNING OPERATION

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ABSTRACT:- *A wide variety of cutting fluids are commercially available in the market. Although, these cutting fluids are beneficial in the industries, their uses are being questioned nowadays as regards to health and environmental issues. To minimize the adverse environmental effects associated with the use of cutting fluids, the hazardous components from their formulations have to be eliminated or reduced.*
Today to diminish the negative effects associated with cutting fluids, researchers have developed new bio based cutting fluids from various vegetable oils.
In the present study it has been observed that, the manufacturing industries and metal industries using the cutting fluids has become more problematic in terms of workers health and environmental pollution. To obtain safe, environmental and economical benefits of machining, the research has been carrying out to reduce the use of cutting fluid during machining. One of the alternatives to wet machining is Minimum Quantity Lubrication from the point of cost, ecology and human health issues. From Analysis of Means, it is found MQL and high stainless steel tool shown in better performance on reduction of temperature and metal removal rate.
Furthermore, MQL provides environment friendliness (maintaining neat, clean and dry working area, avoiding inconvenience and health hazards due to heat, smoke, fumes, gases, etc. and preventing pollution of the surroundings) and improves the machinability characteristics.
This thesis report presents the effects of minimum quantity lubrication (MQL) by multi vegetable oils based cutting fluids on the turning performance of mild steel as compared to completely wet machining in terms of metal removal rate, temperature, cost, and health.

KEYWORD *- TAGUCHI METHOD, ANOVA, S/N RATIO, MQL , SYNTHETIC OIL & NATURAL OIL*

1.INTRODUCTION-

In traditional manufacturing in the automotive industry the cooling and lubrication from the metal working fluids,MWF, have been essential when speeding up production and increasing productivity. A natural consequence has been that the amount of oil or emulsion mist in the exhaust air have increased in concentration and the liquid particles have at the same time decreased in size. Typical size distributions have continuously decreased and particles below 0.1 microns in size have become very common. The biggest problem is not to collect the liquid particles, it is to drain the agglomerating droplets out of the filter fast enough to eliminate the risk of quick pressure drop increase. This development have over time increased the demands of products used for oil mist and oil smoke elimination. The penetration of smaller particles is higher in a given filter, affecting both the filtration efficiency and the draining properties. The higher concentration also affects the drainage properties due to the need for larger amounts of oil/emulsion drained from the filters To meet these changes, Filtac continuously develop the filter product range, Fibre Drain, with changes in filter geometry, new materials, material combinations and new auxiliary equipment. Filtac is introducing new products on a regular basis to meet the changes in the market demands. The current trend in the metal-cutting industry is to find ways to reduce cutting fluid use; the use of coolants in machining is thought to be undesirable for economical, health, and environmental reasons.

1.1.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 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
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.

Lubricant is supplied by means of a minimum quantity lubrication system (MQL system). Application of a targeted supply of lubricant directly at the point of use lubricates the contact surfaces between tool, work piece and chip The lubricant is either applied from outside as an aerosol using compressed air or it is “shot” at the tool in the form of droplets.
In comparison to conventional flood lubrication, minimum quantity lubrication uses only a few millilitres (ml) of lubrication per hour for the machining process Minimum quantity lubrication today uses such precise metering that the lubricant is nearly completely used up. Typical dosage quantities range from 5 ml to 40 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.
Cutting fluids can be divided into two categories

- **Water-based fluids** -including straight oils and soluble oils,
- **Oil-based fluids** -including synthetics and semi-synthetics**.**

Main functions of cutting fluid are:
- Cooling,
- Lubrication,
- Removing chips and metal fines from the tool/work piece interface,
- Flushing, Prevention of corrosion.

1.2. BLOCK DIAGRAM OF LATHE MACHINE

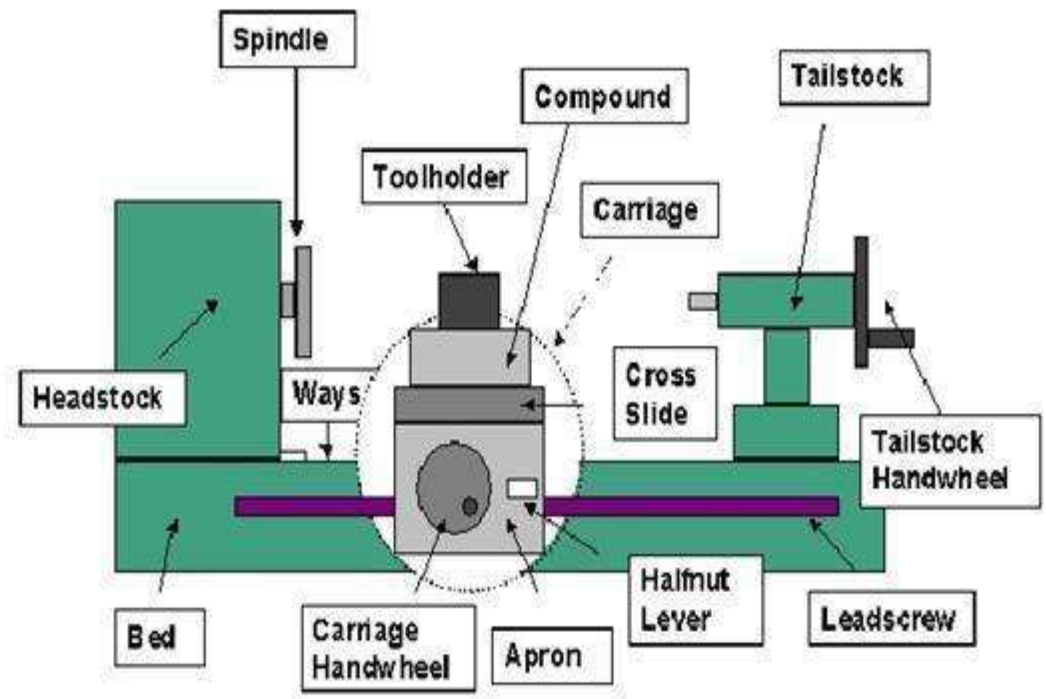


Figure:1.1 Shows block diagram of Lathe Machin

1.3 TYPES OF MQL SYSTEM

There are two basic types of MQL delivery systems
1. External feed
2. Internal feed.

1.3.1 External Feed

The external spray system consists of a coolant tank or reservoir which is connected with tubes fitted with one or more nozzles. The system can be assembled near or on the machine and has independently adjustable air and coolant flow for balancing coolant delivery. It is inexpensive, portable, and suited for almost all machining operations.
The most important areas of application use machine tools with a low level of flexibility and involve sawing, milling, broaching, shaping, drilling and threading processes.

Figure1.2 : Shows External feed via nozzles

1.3.2 Internal Feed

Internal feed MQL systems are available in two configurations; based on the method of creating the air-oil mist. The first is the external mixing or one-channel system. Here, the oil and air are mixed externally, and piped through the spindle and tool to the cutting zone.
Using MQL systems with internal feeds enables precise aerosol supply directly to the contact point through the tool. The lubricant is continually available at the critical points during the entire processing sequence. This makes it possible to drill very deep holes and use very high cutting speeds. Because the medium has to be fed through the machine spindle, converting to this system may be costly.
Common to all MQL systems is the use of vapour or aerosols, consisting of a gaseous and a liquid phase. The MQL systems on the market for internal feed differ in the number of required channels in the rotating chuck and spindles and where the aerosol is generated. Depending on where the vapour is generated, there are two common modes of action.

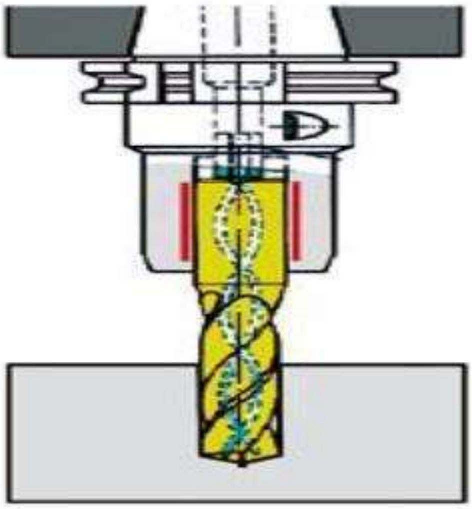


Figure1.3: Shows Internal Lubrication Feed

1.4. MQL SYSTEMS FOR MINIMUM QUANTITY LUBRICATION

The main task of the MQL systems is the targeted supply of an appropriate lubricant to the contact point of the tool (cutting edge). A number of different devices for various requirements are available for this purpose.
For single-purpose machines, e.g. broaching, sawing and shaping, simple, manually controllable
MQL devices with internal and external feeds with different functional modes are normally used.
They are usually systems with pressure tanks and metering pumps.
In the case of external feed, the lubricant is applied by means of spray nozzles around the circumference of the tool. This system is especially suitable for entrance-level implementation for standard processes (turning, milling, drilling).

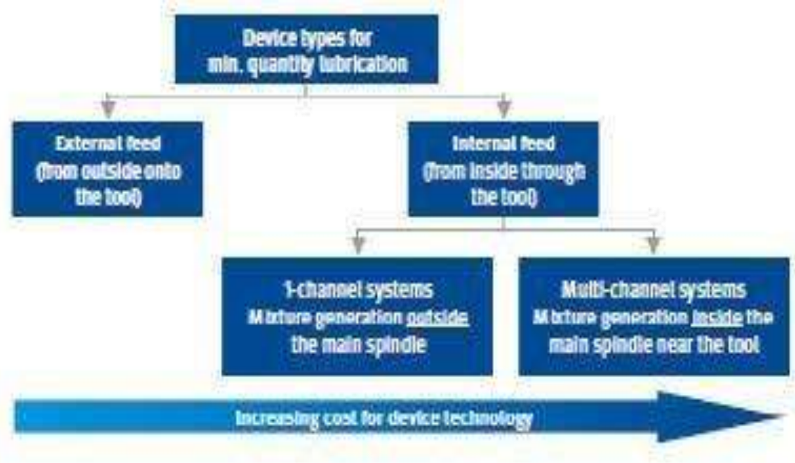


Figure1.4 : Shows Devices types of minimum quantity lubricant system

1.5. ANALYSIS OF TAGUCHI METHOD

Taguchi methods are statistical methods developed by Genichi Taguchi to improve the quality of manufactured goods, and more recently also applied to engineering, biotechnology, marketing and advertising. Professional statisticians have welcomed the goals and improvements brought about by Taguchi methods particularly by Taguchi's development of designs for studying variation, but have criticized the inefficiency of some of Taguchi's proposals.

Taguchi's work includes three principal contributions to statistics

- A specific loss function
- The philosophy of off-line quality control
- Innovations in the design of experiments.

1.5.1 TAGUCHI'S RULE FOR MANUFACTURING

Taguchi realized that the best opportunity to eliminate variation is during the design of a product and its manufacturing process. Consequently, he developed a strategy for quality engineering that can be used in both contexts. The process has three stages:

- Parameter (measure) design
- Tolerance design
- System design

1.5.2 Inefficiencies of Taguchi's designs

Interactions are part of the real world. In Taguchi's arrays, interactions are confounded and difficult to resolve.

Statisticians in response surface methodology (RSM) advocate the "sequential assembly" of designs: In the RSM approach, a screening design is followed by a "follow-up design" that resolves only the confounded interactions judged worth resolution. A second follow-up design may be added (time and resources allowing) to explore possible high-order univariate effects of the remaining variables, as high-order univariate effects are less likely in variables already eliminated for having no linear effect. With the economy of screening designs and the flexibility of follow-up designs, sequential designs have great statistical efficiency. The sequential designs of response surface methodology require far fewer experimental runs than would a sequence of Taguchi's designs

1.6. ANALYSIS OF VARIANCE (ANOVA):

This method was developed by Sir Ronald Fisher in the 1930‟s as a way to interpret the results from agricultural experiments. ANOVA is not a complicated method and has a lot of mathematical beauty associated with it. ANOVA is a statistically based, objective decision-making tool for detecting and differences in average performance of groups of items tested. The decision rather than using pure judgment, takes variation into account.

1.7 TYPES OF ANOVA

There are four types of ANOVA which are as follows.

1.7.1 No-way ANOVA:
Analysisof variance is a mathematical technique which breaks total variation down into accountable source; total variation is decomposed into its appropriate components. No-way ANOVA, the simplest case, breaks total variations down into only two components:

a) The variation of average (or mean) of all the data points relative to zero.
b) The variation of the individual‟s data points around the average (traditionally called experimental error).

1.7.2 One way ANOVA:
One way ANOVA is the next complex ANOVA to conduct. This situation considers the effect of one controlled parameter upon the performance of a product or process, in contrast to no-way ANOVA, where no parameters were controlled.

1.7.3 Two way ANOVA:
Two way ANOVA is the next highest level of ANOVA to review; there are two controlled parameters in this experimental situation.

1.7.4 Three way ANOVA:
One final ANOVA method will be discussed which will demonstrate some mathematical complication in ANOVA. Three ways ANOVA entails three controlled factors in an experiment.

1.8 APPLICATION OF S/N RATIO
The change in the quality characteristics of a product under investigation, in response to a factor introduced in the experiment design is the signal of desired effect. However, when an experiment is conducted, there are numerous external factors not designed into the experiment which influence the outcome. These external factors are called the noise factors and their effect on the outcome of the quality characteristic under test is termed as noise. The signal to noise ratio measures the sensitivity of the quality characteristic being investigated in a controlled manner, to those external influencing factors (noise factors) not under control. The concept of S/N ratio originated in the electrical engineering field. Taguchi effectively applied this concept to establish the optimum condition from the experiments.

The aim of any experiment is always to determine the highest possible S/N ratio for the result. A high value of S/N ratio implies that the signal is much higher than the random effect of the noise factors. Product design or process operation consistent with highest S/N ratio always yields the optimum quality with minimum variance.

From the quality point of view, there are three possible categories of quality characteristics. They are:
1. Smaller is better;
2. Nominal is better;
3. Larger is better.

The S/N ratio is designed to measure the quality characteristics.
The Signal to Noise ratio (S/N ratio) expresses the scatter around a target value. The larger the ratio, the smaller is the scatter. Knowing the S/N ratio of the samples before and after the experiment, Taguchi‟s loss function may be used to estimate the potential cost saving from the improved product.

2. REQUIRED PARAMETERS

Table2.1: Shows required parameters for Machining Operation

Machine tool	Lathe machine 15hp
Work specimen material	Mild steel
Hardness (BHN)	257
Size	ϕ150x 31mm
Cutting tool	HSS (1/2* 4")
Cutting velocity	646, 421, 270 rpm
Feed rate	0.10 mm/rev (constant)
Depth of cut	1.5, 2.0 2.5 mm
Cutting fluid	MQL Condition- food grade vegetable oilOlive oil (1 litre) and Synthetic Oil (Ester) (1 litre)

2.1.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.

Figure2.1: Shows turning by using Natural oil

2.2 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 2.2 : Shows Turning by synthetic oil

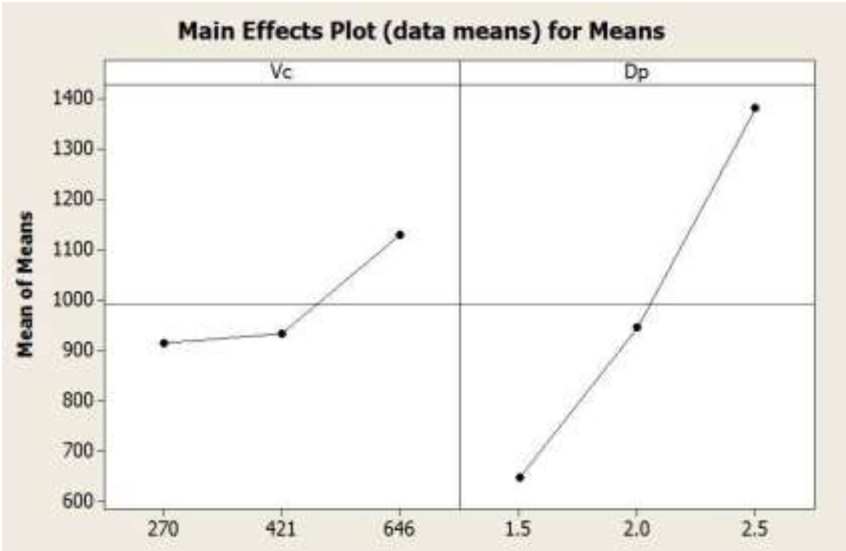
In the above figure shows the turning operation by using the synthetic oil, and the ranges of the cutting velocity (Vc) and feed rate (S0) were selected based on the tool manufacturer"s recommendation and industrial practices. Depth of cut is vary, which would adequately serve the present purpose. Machining 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.

3. RESULTS

3.1 Graph b/w Vc , Dp to MRR and Rank of Natural oil by using Taguchi Method

Table 3.1: 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

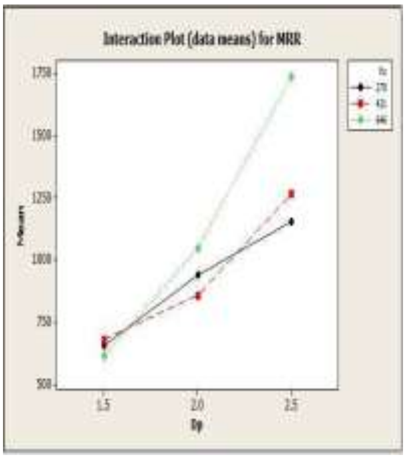


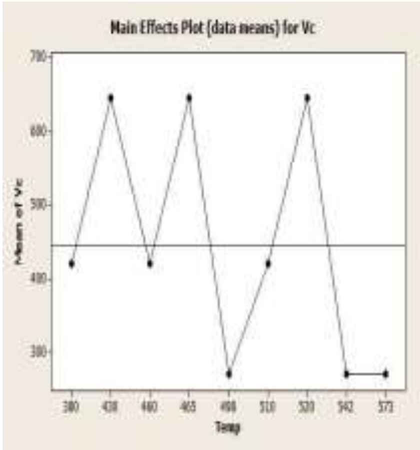
3.2 Analysis of Variance For MRR, Using adjusted SS for Tests to Natural oil

Table 3.2: 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				

3.3Analysis of Variance by Using Natural oil





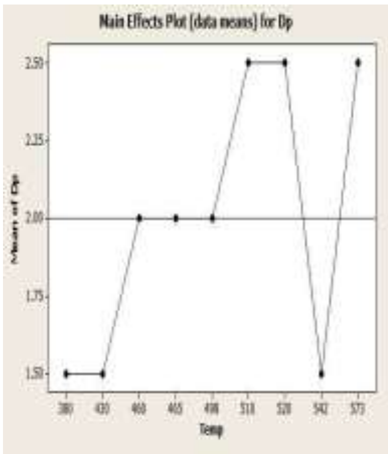
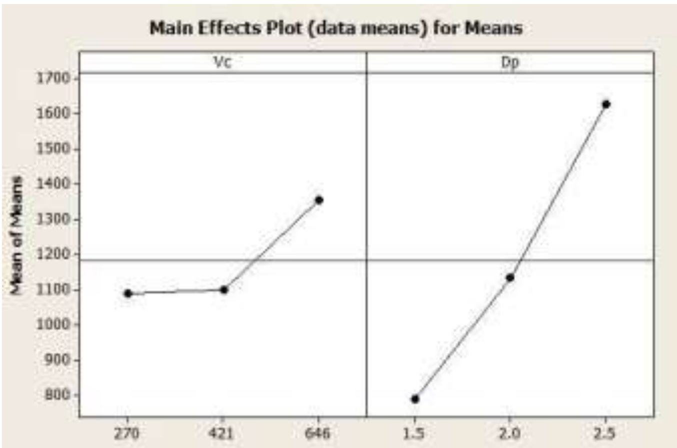


Figure 3.2: Interaction plot for MRR Figure 3.3: Shows graph between V &T Figure 3.4: Shows graph between Dp & T

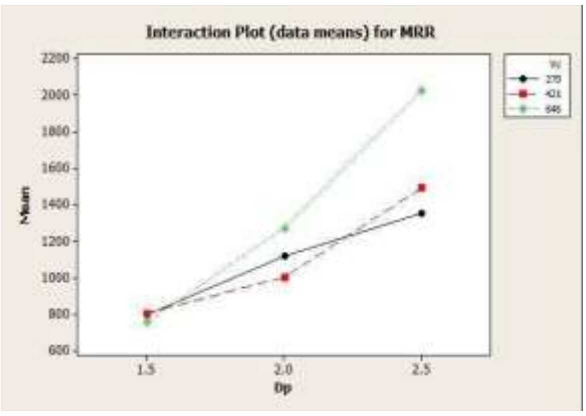
3.4.Graph and Rank of Synthetic oil by using Taguchi Method

Table 3.3: Shows Rank Obtain From Taguchi Method

LEVEL	Vc	Dp
1	60.55	57.92
2	60.54	67.03
3	61.94	64.08
Delta	1.40	6.17
Rank	2.0	1



3.5Analysis of Variance by Using Synthetic oil



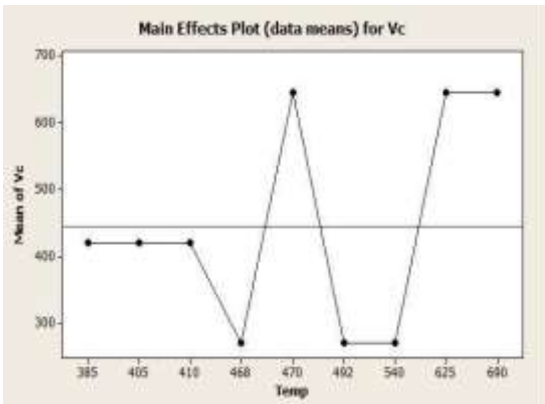
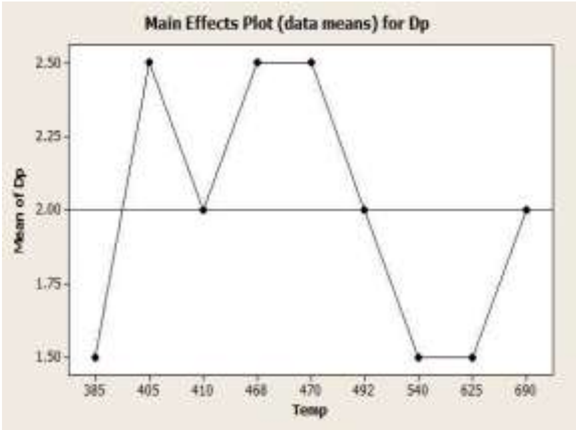


Fig. 3.4:a) Shows Interaction Plot b) graph between Vc & T



c):Shows graph between Dp &T

4.CALCULATIONS

4.1 CALCULATION FOR METAL REMOVAL RATE (MRR)

For calculation of MRR, the specimen is weighed before and after each run using electronic balance having a resolution of 4 cm turning. The weight difference gives the amount of material removed during machining, also the machining time is noted down for each run to calculate MRR. The data of experimentation is entered into MINITAB software and values of mean of MRR and Signal to Noise ratio have been calculated. Material removal rate can be calculated by dividing the work piece weight loss (in grams) to the product of density of the work piece (gm/cc) and the machining time. Using the relation we can get the values of MRR which is shown in Table.

4.2 CALCULATION OF S/N RATIO FOR MRR

The S/N ratio, which condenses the multiple data points within a trial, depends on the type of characteristics being evaluated.MRR is considered as „Larger is better" quality characteristic as the objective is to maximize the machining efficiency by obtaining maximum Material Removal Rate.
For calculation of S/N ratio for material removal rate LARGER IS BETTER condition is opted.

The equation for the calculation of S/N ratio for material removal rate is:

S/NLB= -10*log (Σ (1/yi ²)) ………………. {2}

4.3 CALCULATION OF MEAN S/N RATIO FOR MRR

Mean S/N ratio is calculated by using following formula

nfi= (nf1+nf2+nf3+nf4)/4 ……………….{3}

Where,

nf is mean S/N ratio for factor (f) at the level value (i) of the selected factor, andnf1, nf2, nf3 are S/N ratio for factor (f)at level (u).
The factors which affect the machining parameters show in the table as their respective ranks. Rank of the parameters depends on the value of delta. If the delta value of one parameter is higher than the other that shows first rank. Higher value of S/N ratio of each factor shows the optimal level of the factor. Peak current shows the main effect in the above response table and pulse ON time is less effective as compared to Depth of cut.

5. 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 a 750 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.

6.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.

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