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# INFLUENCE OF CUTTING FLUID ON TOOL WEAR AND TOOL LIFE DURING TURNING

**Nilesh C. Ghuge[1] and Dr.Ashish M. Mahalle[2]**
[1,2]*Laxminarayan Institute of Technology, Nagpur, RTMN University, Nagpur, India*

**Abstract-** Role of the small manufacturing units is very significant in the growth of industry. It is observed that 60% to 70% proprietor of small-scale industries are unacquainted to the demerits of the mineral-based cutting fluid. Some are unwilling to use recently developed techniques due to financial limitations. Large numbers of operators are uneducated. They have very little information about cutting fluid and their impact on the health. In India large amount of mineral-based cutting fluids are used in both large scale, medium scale industry. Most of the operator working on machine is continuously exposed to poisonous cutting fluid. They are suffering from skin disease, respiratory disease like bronchitis and asthma, throat cancer, lung cancer etc. It is must to create awareness about shortcoming of mineral-based cutting fluid. It is essential to devise simple low cost system that will eradicate the use of mineral cutting fluid. Minimum quantity lubrication system with vegetable oil is suggested as an option for the dry and flood cutting. This paper focuses on the comparative study of the different cutting fluid based on the tool wear and tool life. Result showed MQL with vegetable oil system gave improved performance as that of mineral-based oil without affecting the ecological system.

**Keyword** –tool life, tool wear, MQL, vegetable oil

## I. INTRODUCTION

Machining process is an integral part of any engineering industry. During machining temperature of the cutting tool and workpiece increases. This high temperature results into increased tool wear and reduced tool life. Cutting tool replacement and maintenance cost is high. To reduce the undesirable effect of the heat, friction, cutting fluids are used. Cutting fluids reduces temperature and helps in chip removal. In industry, cutting fluids with mineral oil base are used. The cost associated with the cutting fluids was up to 17% of the total production cost [1].In addition, mineral-based cutting fluids are creating threat to the atmosphere. Due to elevated heat, poor surface quality, cost, ecological concern and government regulations enormous efforts are made to reduce the petroleum based cutting fluids. Dry cutting (no cutting fluid) is one of the alternatives but increased wear rate, elevated temperature is major concern. Dry cutting is not proved as best alternative to flood cutting. Minimum Quantity Lubrication is emerged as substitute for dry machining and flood cutting. The cutting fluid improves tool life and increases the productivity of the production system. Despite of its share in industry growth, mineral oil based cutting fluids may raise several ecological troubles [2].Increased use of cutting fluids results into environmental degradation like soil pollution, water contamination, disposal and dumping problems. Recycling cost of the waste cutting fluid is high. It requires separate setup for waste disposal and management. Most significant issue is health of the operator. The operator may suffer from dermatological, respiratory disease that may lead to cancer. The mineral-based cutting fluids are not renewable sources. Thus mineral oil based cutting fluids are accountable for disturbing the natural system balance. This disturbance has long-term effect on humanity and next generation. [3]For every business enterprises, it is essential to abide by the terms of ISO-9000 Quality management standards, ISO-14000 standards, occupational health and safety assessment series. Environmental issues are now discussed at international levels and it is obligatory for each nation to maintain the pollution level below certain limit. To sustain the natural balance of ecosystem, all nations are imposing strict restrictions for the use of mineral oil based cutting fluids.

Different regulatory bodies like NIOSH, OSHA, EPA and CPCB set a limit for exposure level of the metal working fluid [4].

The minimization of cutting fluids lead to saving of lubricant cost. Reduced quantity of cutting fluid lessens the exposure level of the cutting fluid. Conventional flood lubrication system uses cutting fluid at the rate of one-liter to ten-liter per min.MQL uses very small amount of cutting fluid (50 ml to 500ml per hour).MQL consist of mixture of high-pressure air and cutting fluid applied directly into the interface of cutting tool and work piece [5].

Using MQL, cutting fluid quantity is decreased significantly but it cannot completely eliminate the mineral-based cutting fluid. Conversely, the health hazard, environment problems resulted into stern legislation to regulate the usage of the mineral oil based cutting fluids.

Vegetable oils are plant based agricultural product. They can be cultivated, genetically customized, renewable, biodegradable and nontoxic. Vegetable oils are, thus considered as viable alternative to mineral-based cutting fluids [6].

This papers focuses on comparing performance of vegetable oils as cutting fluids in comparison with petroleum based cutting oil in terms of tool wear.

## II. EXPERIMENTAL METHODOLOGY

### 2.1 Design of Experiment

Design of experiment is a used to select and optimize the effective parameter to reduce the experimentation cost. Full factorial design and response surface methodology was used for the analysis of the process. In this work, three levels i.e. $3^3$ full factorial design is selected for investigation. Minitab 17 is used for analysis work.

### 2.2 Selection of Workpiece Material, Tool and Working Environment.

Cylindrical bar of AISI 4130 (diameter 60 mm and length of 12 cm) is used as work piece material. AISI 4130 is widely used for valve bodies, pumps, fitting, welding tubing and structural application. AISI 4130 contains 0.3% carbon, 0.52% Mn, 0.24 %Si, 1.06% Cr along with sulphur, phosphorous and nitrogen. Uncoated carbide tipped brazed tools with is used for investigation. Turning was carried out on medium duty lathe machine at different cutting speeds, feeds and cutting depths under dry, flood and MQL conditions.

### 2.3 Selection of Cutting Fluid

Soyabean oil, sunflower coconut oil and groundnut oil are comparatively cheap, easily available. The properties of this oil are similar to the commercially available cutting fluids. Blasocut-4000 is a water miscible, mineral-based cutting fluid. It is used in medium, small-scale industry in large quantity; therefore, it is selected to compare against vegetable oil.

### 2.4 Experimentation

Experimental set up consist of medium duty lathe machine and MQL system. MQL system consists of air compressor, oil tank, flow control valve and nozzle as shown in figure 1. Metzer's Toolmaker's microscope was used for measurement of tool wear. Machine has to be interrupted after each five minutes and tool, wear is measured. Tool life was determined, taking a 0.4 mm flank wear as tool life criterion. Tool wear was measured with respect to time at cutting speed 34.27 m/min, 53m/min and 79.73 m/min at constant feed of 0.45 mm/rev. Depth of cut was taken as 1.5 mm.

Figure 1 Experiment setup

## III. MATHEMATICAL MODELING

Regression analysis is used to develop mathematical models to predict the results when combinations of machining parameters interact under various conditions. Analysis of variance (ANOVA) test is carried out to test the hypothesis as well as to check the adequacy of the model.

### 3.1Tool Wear Modeling

Tool wear models are developed using response surface methodology. These models are tested for adequacy using ANOVA.

Regression equations for Tool Wear –Dry Cutting

$VB_{Dry}$=0.07453+0.00476 t + 0.000006 t*t… …eq (1)

Regression equations for Tool Wear –flood Cutting

$VB_{Flood}$= 0.07169 + 0.002150 t + 0.000036 t*t ... eq (2)

Regression equations for Tool Wear –MQL-Blasocut Cutting

$VB_{Blasocut}$=0.0354 + 0.00395 t + 0.000019 t*t ...eq(3)

Regression equations for Tool Wear –MQL-Soyabean Cutting

$VB_{Soyabean}$ = 0.06998 + 0.000402 t + 0.000034 t*t… … eq (4)

Regression equations for Tool Wear –MQL-Sunflower Cutting

$VB_{Sunflower}$= 0.05686 + 0.002605 t + 0.000010 t*t… … eq (5)

Regression equations for Tool Wear –MQL-Coconut Cutting

$VB_{coconut}$= 0.0363 + 0.004579 t - 0.000004 t*t… …eq (6)

Regression equations for Tool Wear –MQL-Groundnut Cutting

$VB_{groundnut}$ = 0.04809 + 0.003483 t + 0.000006 t*t… …eq (7)

The correlation coefficient $R^2$,Adj.$R^2$ Pre.$R^2$, P value F-Value of tool wear model for all the cutting processes with different cutting fluid, are shown in table 1..R-R2 values for all the process are approaching toward 100%, which indicate that the regression equations developed for tool wear are statistically significant. The adjusted $R^2$ value measures the variation of mean and predicted $R^2$ value measure how well the model predict the response. This value should be within 0.20 of each other. Table 1 also shows that all adjusted $R^2$ and Predicted $R^2$ are in good agreement. The regression equations truly represent the wear of the cutting tool.

Table 1. $R^2$, Adj.$R^2$, Pre.$R^2$, F and P values for Tool Wear

| Factor | Dry Cutting | Flood Cutting | Blaso Cut | Soyabean Oil | Sun flower Oil | Coconut Oil | Ground nut Oil |
|---|---|---|---|---|---|---|---|
| $R^2$ (%) | 99.78 | 99.39 | 97.58 | 99.08 | 98.10 | 97.60 | 98.95 |
| Adj.$R^2$ (%) | 99.68 | 99.30 | 97.20 | 98.94 | 98.73 | 97.23 | 98.79 |
| Pre.$R^2$ (%) | 99.42 | 99.07 | 95.69 | 98.54 | 98.43 | 96.33 | 98.39 |
| P value | 0.00 | 0.000 | 0.000 | 0.0000 | 0.000 | 0.000 | 0.000 |
| F-Value | 2358.37 | 1064.38 | 261.9 | 703.3 | 584.97 | 264.2 | 612.29 |

## IV. RESULTS AND DISCUSSION

Turning of AISI 4130 was performed using carbide tipped cutting tool in different working environment like dry, flood and MQL. MQL cutting was performed with five types of cutting fluid; one is mineral-based (Blasocut-4000) and four vegetable oil (sunflower oil, groundnut oil, coconut oil and soyabean oil).

The tool wear was measured by varying cutting speeds Using tool wear graphs, tool life was determined, taking a 0.4 mm flank wear as tool life criterion. The tool wear increases as machining time increases as shown in figure 2. Tool wear for dry cutting is highest. In MQL, the mixture of air and cutting fluid in the form high speed jet of the cutting fluid decreases temperature, cutting forces, flushes away the chips, which results into decrease in tool wear

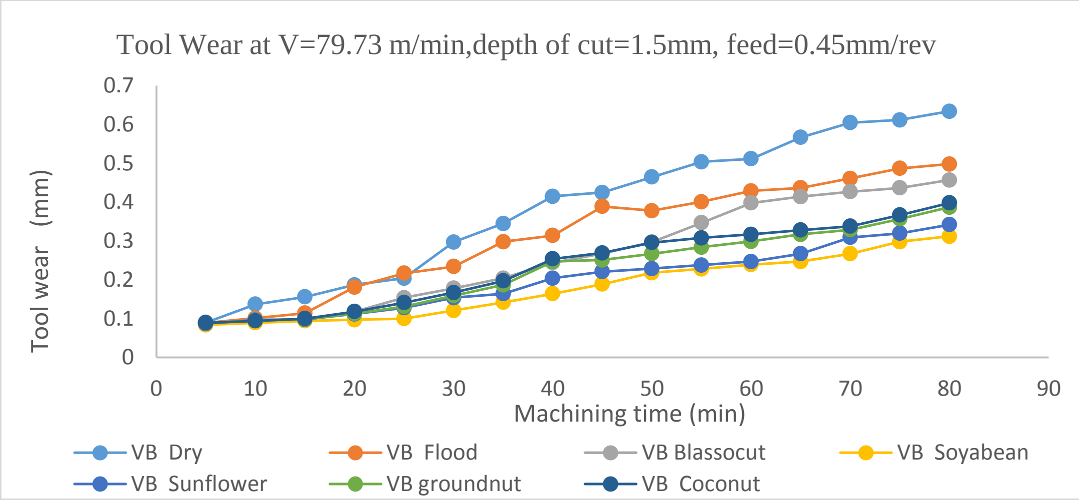


Figure 2 Variation in tool wear (V=0.79.73m/min,f=0.45 mm/rev,dp=1.5 mm).

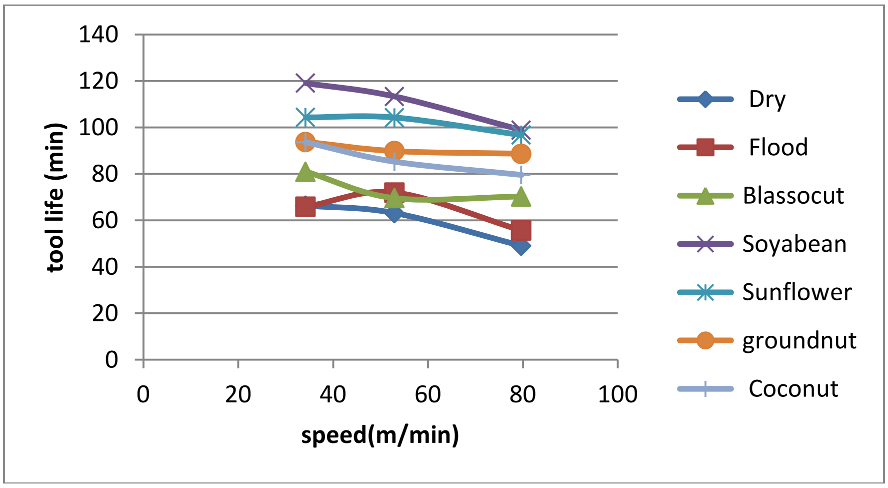


Figure 3. Variation of tool life at different cutting speed

Soyabean oil shows less tool wear as compared to other oils.. For velocity 34.27m/min and 53 m/min, similar graphs are observed. Tool life is calculated from tool wear graphs considering 0.4 as life criteria. Higher cutting speed lead to higher flank wear therefore tool life decreases as speed increases as shown in figure 3 Maximum tool life is obtained by using soyabean oil whereas minimum tool life at dry cutting operations.

## V. CONCLUSION

Based on the results of the experiments and analysis carried out the following conclusions are drawn

- There is significant decrease in tool wear in case of MQL. It is observed that MQL shows average 10% and 18% decrease in tool wear as compared to flood and dry cutting respectively.
- It is observed that MQL shows average 12% and 20% improvement in tool life as compared to flood and dry cutting respectively.
- MQL technique is substitute for dry and flood cutting not only in terms of performance but also in terms of it is cost effectiveness and environment friendliness
- Tool wear for soyabean oil is less than other cutting fluids. Soyabean shows average 5%, 6%,13% and 16% reduction in tool wear as compared to groundnut oil,sunflower,blassocut and coconut oil respectively.
- Soyabean oil shows average 7%,17%, 21% and 33% improvement in tool life as compared to sunflower,groundnutoil,coconut oil and Blasocut oil respectively.

 

- Mathematical models are developed to validate the experimental data. ANOVA test carried out to check the adequacy of the model. Mathematical models developed for all parameters are accurate and acceptable.
- Performance of the vegetable oil is superior to mineral-based oils. The quantity used in MQL is very minute. Saving in cutting fluid reduces the cost. Thus, combined MQL and vegetable oil system proves to be more economical, harmless, environment friendly without affecting the performance.

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