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Experimental Investigation of End Milling Operation under Optimal Lubricant Use

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Abstract :- In this research project an on-going comparative study will be made for tool wear and surface roughness by varying cutting parameters under dry and Minimum Quantity Lubrication (MQL) environment while machining hardened medium carbon steel (hard machining). The effects of tool materials, oil flow rate and air flow rate on tool performance in MQL cutting are also studied. A mathematical model will also developed to determine the surface roughness in terms of machining time and cutting tool wear function in terms of the four independent variables: the cutting depth (d), the cutting feed (f) and the cutting speed (Vc. The results application of MQL technique will significantly helps to obtain better performance in compare to dry condition.The purpose of cutting fluid in a machining operation is to cool the work piece, reduce friction, and wash away the chips. The cutting fluid contributes significantly toward machining cost and also possesses environmental threats.

Keywords - *Minimum Quantity lubrication, hard materials*

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I. INTRODUCTION

Metal cutting fluids changes the performance of machining operations because of their lubrication, cooling, and chip flushing functions. Typically, in the machining of hardened steel materials, no cutting fluid is applied in the interest of low cutting forces and low environmental impacts. Minimum quantity lubrication (MQL) presents itself as a viable alternative for hard material machining with respect to tool wear, heat dissertation and machined surface quality.

The necessity to machine using less harmful cutting fluids has prompted many researchers to investigate the use of minimum quantity lubrication (MQL). Chalmers(1999) reported that more than 100 million gallons of metalworking fluids are used in the U.S. each year and that 1.2 million employees are exposed to them and to their potential health hazards. The U.S. Occupational Safety and Health Administration (OSHA) (Aronson, 1995) and the U.S. National Institute for Occupational Safety and Health (NIOSH) reported that the permissible exposure level (PEL) for metal working fluid aerosol concentration is 5 mg/m^3 and 0.5 mg/m^3 respectively (U. S. Department of Health and Human Services, 1998). However, the oil mist level in the U.S. automotive parts manufacturing facilities has been estimated to be 20 – 90 mg/m^3 with the use of conventional lubrication by flood coolant (Bennett and Bennett, 1985).

The quality of machined component is evaluated with respect to dimensional accuracy and close tolerances in the time of globalization of manufacturing when working with conventional machining. In metal cutting fluid changes the performance of machining operations in terms of both employee's health and environmental pollution. Hence, use of minimum quantity lubrication system plays an important role in respect of accuracy obtained. Also prevents environmental pollution and hazard to the employee. Use of optimum cutting fluid leads to economical benefits and environmental friendly machining as well.

Minimum quantity lubrication (MQL) is micro lubrication near dry machining, or "spatter" lubrication. It could be considered as the latest method of delivering metalworking fluids to the point of cut, or just the logical continuation of the age old technique of "brushing on" a lubricant where it is needed. This technology recognizes that a little fluid, when properly selected and applied, can make a substantial difference in how effectively a tool performs.

Important Factors For Minimum Quantity Lubrication

Lubricant: The selection of correct oil for minimum quantity lubrication is very important. Lubricant selected for this operation is Mobil cut 102.This is having excellent emulsion stability, Excellent rust protection. This lubricant is water mix cutting fluid suitable for ferrous & non ferrous materials

Application: The second important factor is the precise application of the fluid which makes the MQL implementation successful. The success of the MQL system is depend on the proper application of the Aerosol (oil air mixture) to the tool chip interface i.e. in between the cutting edge and the work piece. If the lubricant is used in excess quantity that goes waste.wheareas with too little lubricant, friction is not reduced and heat builds up in the tool. The goal of MQL is to maintain a thin film of oil that lubricates the cutting interface the application system must pass the fluid continuously. The best application is the system where the air oil mixture is prepared just before the application in tool chip interface. Air flow rate is also very important

Machining system: The proper application system depends on the operation, variations in the material size and shape, and the design of the machine. The system should be such that after machining the chip must go off by gravity.

II. MINIMUM QUANTITY LUBRICATION SYSTEM

The conventional system of applying the coolant is flood coolant system, in which a large quantity of coolant is continuously impinged on the rake face of the tool. This system is very inefficient. First of all, a large quantity of the cutting fluid is required. Second, the cutting fluid is not able to reach the cutting zone due to obstruction from chips. A better method is the application of mist lubrication, in which a mixture of air and cutting called aerosol is produced and supplied in the cutting zone with a high pressure

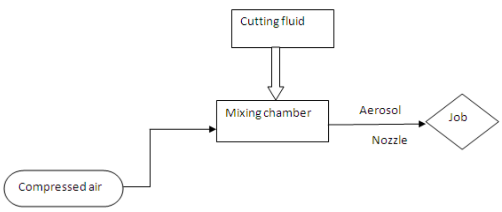

Figure 1. optimal lubricat flow system

The system uses an atomizer. The atomizer is an ejector where the compressed air is used to atomize the cutting oil. By the air in a low-pressure distribution system to the machining zone. As the compressed air flows through the venturi path, the narrow throat around the discharge nozzle creates a venturi effect in the mixing chamber, i.e., a zone where the static pressure is below the atmospheric pressure (often referred to as a partial vacuum). This partial vacuum draws the oil up from the oil reservoir where the oil is maintained under a constant hydraulic head. The air rushing through the mixing chamber atomizes the oil stream into an aerosol of micron-sized particles.When the aerosol impinges through the jet, it produces a spray of gaseous suspension called mist in the machining zone which works as cooling as well as lubricating medium

III. ORIGIN OF THE RESEARCH PROBLEM

The metal industries using the cutting fluid has become more problematic in terms of both employee health and environmental pollution. The current trend in metal working industry is to completely eliminate or drastically reduce the cutting fluid use in most machining operations. But the use of cutting fluid cause economy of tools and it becomes easier to keep tight tolerance and to maintain the work piece surface properties without damages. Also Metal cutting fluid changes the performance of machining operation because of their lubrication, cooling and chip flushing function. The growing demands for high productivity machining need use of high cutting speed and high feed rate. This produce high temperature which not only reduce the tool life but also impairs the product quality. Because of this some alternative has been sought to minimize or even avoid the use of cutting fluid in machining operations. One of the alternatives is MQL. The MQL can able to subsidize the heat generated. The saving in cutting fluid and other related costs would be very significant if micro lubrication (MQL) is adopted.An alternative, machining with MQL is gaining acceptances as a cost saving and environmental friendly option.

IV. OBJECTIVE OF RESEARCH

The purpose of this research is to investigate and optimize the milling operation under the effects of minimum quantity lubrication. Also investigate the effect of various cutting conditions for surface roughness and find out the factors or variables that mostly affect the surface roughness in machining process.

V. LITERATURE REVIEW

The authors summarize the traditional purposes of cutting fluids and also tried to minimize or even eliminate the concerns associated with cutting fluid usage. Several recent and novel approaches have been proposed and are examined [1]. The experimental investigation is done on the role of MQL on cutting temperature, tool wear, surface roughness and dimensional deviation in turning of AISI-4340 steel at industrial speed-feed combinations by uncoated carbide insert[2],[5]. MQL under pulsed jet mode protects the operator's health and reduces the detrimental effects on the environment [3].Feasibility study of the minimum quantity lubrication (MQL) in high-speed end milling of hardened steel by coated carbide tool was undertaken. The encouraging results include significant reduction in tool wear rate, dimensional inaccuracy and surface roughness [4]. MQL technique offer better results than by dry cutting in terms of surface roughness. The total length of travel by super cobalt cutting tool in MQL condition is higher than that in dry cutting. The tool life was increased by 43.75 % by MQL than dry cutting [6].The average chip-tool interface temperature increases with the increases in cutting velocity and feed rate for all three conditions. The chip-tool interface temperature values for MQL are lower than dry and wet conditions [7]. The evolution of the surface finish and tool wear with cutting time has been monitored. Analytical and

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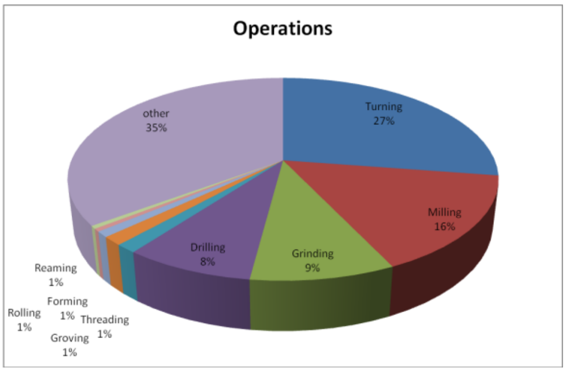
artificial neural network- models, able to predict the surface roughness under different machining conditions, have been proposed[8].Author deals with experimental investigation on the role of MQL on cutting temperature, tool wear in turning of mild steel at industrial speed-feed combinations by H.S.S cutting tool[9].Several grinding fluids, including mineral, vegetable and synthetic esters oil, are compared on the basis of the grinding forces and surface quality properties that would be suitable for MQL grinding applications, to develop a multifunctional fluid having the MQL results such as cooling, lubrication and high ecological and environmental safety performances[10].



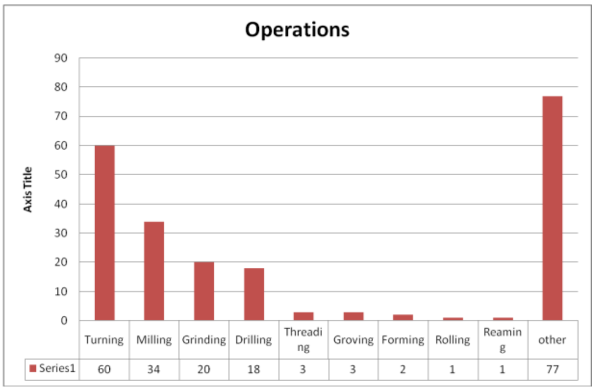


FIGURE 2. MQL APPLICATION TO VARIOUS CUTTING OPERATIONS

DESIGN OF EXPERIMENTS

From the literature review it is seen that most of the work has completed in turning operation with minimum quantity lubrication with a successful results. But still there is a large scope for research for milling operation .Hence the research work is initiated for milling operation. The operation selected is [face milling as it is a most important operation done in industries. The Work piece material is AISI1047 size 90X90X20mm plate with the following chemical composition as given below

TABLE3. CHEMICAL COMPOSITION

C	M	Si	P	Cu	S	Cr	Ni	M	Fe
0.	0.	0.	0.	0.	0.	0.	0.	0.	bala

This material is mostly used in Automotive, naval and building industry. Tool material: coated carbide inserts with TiAlN monolayer. Diameter of the tool is 12mm with 2 flute.Lubricant selected for this operation is Mobil cut 102.This is having excellent emulsion stability, Excellent rust protection. This lubricant is water mix cutting fluid suitable for ferrous & non ferrous materials.

- Input parameters: cutting Speed, feed rate ,depth of cut, tool type
- Output parameters: Surface roughness, MRR, Tool wear, cutting force

Selection of orthogonal array:

Selection of particular orthogonal array from the standard O.A depends on the number of factors, levels of each factor and the total degrees of freedom.

- Number of control factors = 4
- Number of levels for first three control factors = 3
- Number of levels for fourth control factor = 2
- Degree of freedom of each factor= number of level-1
- Degree of freedom of first three factors= 3-1=2
- Degree of freedom of forth factor= 2-1=1
- Total degrees of freedom of factors = sum of Degree of freedom of all factors= (2+2+2+1) =07
- Minimum number of experiments to be conducted =07+1=08

Based on these values and the required minimum number of experiments to be conducted (08), the nearest O.A. fulfilling this condition is L9 .OrthogonalArray:L9

TABLE4. ORTHOGONAL ARRAY L9

Experimental Scheme under MQL for I level of Flow				
Ru	**Cutting**	**Feed**	**Depth of**	**Tool type**
1	20	0.15	0.1	uncoated
2	20	0.63	0.3	Coated(PVD
3	20	0.18	0.5	Caoted(CVD
4	25	0.15	0.3	Caoted(CVD
5	25	0.63	0.5	uncoated
6	25	0.18	0.1	Coated(PVD
7	30	0.15	0.5	Coated(PVD
8	30	0.63	0.1	Caoted(CVD
9	30	0.18	0.3	uncoated

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Experimental Scheme under MQL for II level of				
Ru	**Cutting**	**Feed**	**Dept**	**Tool type**
1	20	0.15	0.1	uncoated
2	20	0.63	0.3	Coated(PVD)
3	20	0.18	0.5	Caoted(CVD
4	25	0.15	0.3	Caoted(CVD
5	25	0.63	0.5	uncoated
6	25	0.18	0.1	Coated(PVD)
7	30	0.15	0.5	Coated(PVD)
8	30	0.63	0.1	Caoted(CVD
9	30	0.18	0.3	uncoated
Experimental Scheme under MQL for III level of				
Ru	**Cutting**	**Feed**	**Dept**	**Tool type**
1	20	0.15	0.1	uncoated
2	20	0.63	0.3	Coated(PVD)
3	20	0.18	0.5	Caoted(CVD
4	25	0.15	0.3	Caoted(CVD
5	25	0.63	0.5	uncoated
6	25	0.18	0.1	Coated(PVD)
7	30	0.15	0.5	Coated(PVD)
8	30	0.63	0.1	Caoted(CVD
9	30	0.18	0.3	uncoated
Experimental Scheme under MQL for IV level of				
Ru	**Cutting**	**Feed**	**Dept**	**Tool type**
1	20	0.15	0.1	uncoated
2	20	0.63	0.3	Coated(PVD)
3	20	0.18	0.5	Caoted(CVD
4	25	0.15	0.3	Caoted(CVD
5	25	0.63	0.5	uncoated
6	25	0.18	0.1	Coated(PVD)
7	30	0.15	0.5	Coated(PVD)
8	30	0.63	0.1	Caoted(CVD
9	30	0.18	0.3	uncoated

Table5.Experimental scheme

Output Parameters.

- Surface roughness (micron): the surface roughnes measured with the MITUTOYO SURF tester SJ 201P
- The formula for Material removal rate (mm3/min)

MRR=(Wi – Wf)/ density*t

Wi – Initial weight of material (gms)

Wf – Final weight of the material after machining (gms)

t- Machining time in min

- Cutting forces (N):The cutting forces measured with Milling Dynamometer
- Tool Wear (mm): Tool wear measured with Optical microscope.

VI. CONCLUSION

From the discussion presented in this chapter, it is apparent that MQL systems possess many advantages over flood coolant system. The experimental results compared with the dry and the flood lubrication. However, they also require some modification of machine tools for obtaining the best performance out of them. When the flood coolant system is not present, the machine tools should be equipped with a chip removal system.

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