DESIGN AND DEVELOPMENT OF MINIMAL FLUID APPLICATION SYSTEM FOR HARD TURNING OF HARDENED STEELS

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***Abstract*- The main purpose of cutting fluid in a machining is to cool the work piece, reduce friction, and wash away the chips. Introducing cutting fluid in a metal-cutting process can reduce the rate of tool wear and improve surface quality also. The large usage of cutting fluid causes hike in machining cost as well as environmental threats. In the past, there have been some attempts to minimize the amount of cutting fluid in turning. To accomplish that purpose, a minimal-cutting-fluid system was developed. In the present investigation a specially formulated cutting fluid with rich water as 80% applied as a high velocity, thin pulsed jet at the immediate cutting zones at an extremely low rate of 8 ml/min by using a minimal fluid application system during turning of Oil hardened non shrinkable steel. In this investigation the work piece selected was OHNS steel. The performance of hard turning of OHNS steel with minimal cutting fluid is studied and then compared with conventional wet and dry turning. The minimal fluid application system can reduce environmental pollution, improves machining performances, and consequently reduces total production cost because of minimum consumption of cutting fluid.**

***Index Terms*- minimal fluid application system, OHNS steel, ANOVA, Taguchi technique, hard turning, and comparison with wet and dry.**

I. INTRODUCTION

Minimal Fluid application is a recent technique for hard turning in metal cutting which is characterized by fluid application in the form of extremely small high velocity jet in very small quantities at critical zones in the form of a pulsing slug. The function of Cutting fluids is to reduce friction, cool the work piece, and wash away the chips. The application of cutting fluid in hard turning reduces the tool wear and improves the surface finish. Another advantage is that use of cutting fluid protects the machined surface from corrosion. They also minimize the cutting forces thus saving the energy. These advantages of using cutting fluids in machining are accompanied by a number of drawbacks. Hard turning with minimal fluid application is a solution for all problems associated with large scale use of cutting fluid and at the same time superior than conventional wet turning. Procurement, storage and disposal of cutting fluid incur expenses and large scale use of cutting fluid causes serious environmental and health hazards on the shop floor. Hard turning usually requires ultra hard cutting tools and extremely rigid machine tools that can sustain the severity of hard turning. Such tools are very costly and may be unaffordable on the shop floor. But minimal fluid application system can be practiced on the shop floor with the existing machine tools. By introducing the cutting fluid precisely at the cutting zone, better cutting performance can be achieved which will result reduction in cutting force. In minimal cutting fluid application, two nozzles are used to get high pressurized and high velocity jet of cutting fluids. It is found that minimal cutting fluid application can bring better cutting performance during hard turning. In the present investigation we carried out a 9 run experiment on hard turning of OHNS steel with minimal fluid application system. And the cutting force required for the metal cutting is analyzed and finally comparison study has been conducted with wet and dry turning.

A. SELECTION OF WORK MATERIAL

Hardened OHNS steel rod with the following compositions is the work material in this investigation. The specialty of the work material is that it is through hardenable steel. OHNS steel is selected as a work piece because of its wide range of application in manufacturing industries. They are mainly used for the production of punching tools, all press cutting tools, thread cutting tools, Milling cutters, Reamers, Measuring tools, Gauging tools, Wood working tools, Broaches, Chasers etc. OHNS steel is an important tool and die material, mainly because of its high strength, high hardness, and high wear resistance. It has a high specific strength due to that it cannot be easily machine by conventional machining techniques.

B. SELECTION OF CUTTING TOOL AND TOOL HOLDER

The cutting tool inserts and the tool holder were selected as per the recommendations of M/s TaeguTec India (P) Limited who extend their technical/material support for this research work. Accordingly, multicoated hard metal inserts with sculptured rake face with a specification SNMG 120408 and tool holder with the specification PSBNR 2525 were used in the investigation.

C. CUTTING FLUID COMPOSITION

The cutting fluid developed will have some special binding properties which will help the cutting fluid to withstand its properties when subjected to high temperatures of cutting. The cutting fluid composition was 20% of normal cutting oil with water.

D. MINIMAL FLUID APPLICATION SYSTEM

An overall view of the minimal fluid applicator developed for injecting the cutting fluid is shown in fig. 1. It consists of a fuel pump generally used for diesel fuel injection in truck engines coupled to a variable electric drive. The system provides independent variation of the injection pressure (*p*) the frequency of injection (*N*) and the rate of injection (*Q*). The injection pump can deliver fluids through four outlets simultaneously, so that cutting fluid could be injected to more than one location or more than one machine tool at the same time. Here we take two outlets of the injection pump and rests are blocked or it can be directed back in to cutting fluid reservoir. By selecting proper settings, the rate of injection could be made as small as 8 ml/min. Special fixtures were designed, so that the injection nozzle could be located in any desired position without interfering with the tool or work during actual cutting.

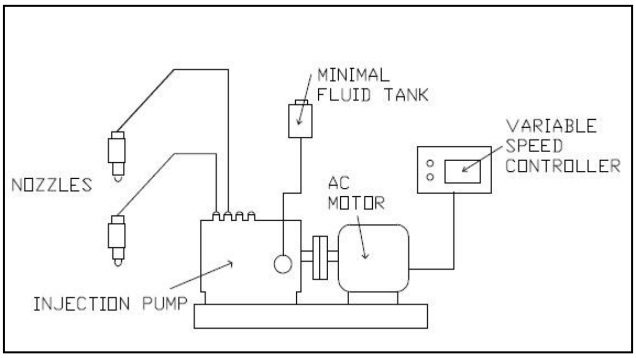

Fig: 1 Overall View of the Fluid Application System

II. METHODOLOGY AND PROCEDURE

A. CUTTING PARAMETERS SELECTION

Table: 1 Design matrix

Input parameters	Level 1	Level 2	Level 3
Cutting velocity(m/min)	75 (v1)	95 (v2)	115 (v3)
Feed (mm/rev)	0.05 (f1)	0.075 (f2)	0.1 (f3)
Depth (mm)	0.5 (d1)	0.75 (d2)	1 (d3)

All the three input cutting parameters will vary at 3 levels during experimentation. Levels of cutting velocity for the present investigation are fixed as 75, 95 and 115m/min. Levels of feed rate are fixed as 0.05, 0.075 and 0.1mm/rev. Levels of depth of cut are selected as 0.5, 0.75 and 1mm. Design matrix is shown in the table 1.

B. FLUID APPLICATION PARAMETERS

- Pressure at the Injector : 100 bar
- Frequency of Pulsing : 600 pulses/min
- Quantity of Application : 8ml/min
- Composition of Cutting Fluid : 20% of oil in water

C. OUTPUT PARAMETERS

The parameters selected for output is purely based on the availability of testing and measuring instruments in our lab. These parameters play a vital role in machining operation. In order to compare the performance of hard turning with minimal fluid application and conventional dry and wet machining, cutting force is selected as the output parameter.

D. CUTTING EXPERIMENTS

Tabular column for the investigation is selected by using Taguchi's technique. A 9 run experiment has been carried out with minimal fluid application. The experimental setup consisting of a Lathe machine, a three component dynamometer, a charge amplifier, an 8 channel data recorder and a pc based software for online monitoring and recording of the cutting force. The experiments are to be carried out during finish turning operation.

In a first phase of the experiments, the pressure of the cutting fluid, frequency of pulsing, quantity of lubricant, direction of application and composition of cutting fluid are considered and they are kept constant. Cutting force during cutting was analyzed at various stages of experiments using the standard precision. The experimental data collected during 9 run experiment is shown in table 2.

Table: 2 Experimental Data Collected During 9 Run Experiment

Sl.No.	v (m/min)	d (mm)	f (mm/rev)	R_a (μm)	F_z (N)	Temp (°C)
1.	75	0.5	0.05	1.034	220.6	55
2.	75	0.75	0.075	1.262	250	88
3.	75	1	0.1	1.321	298.6	120
4.	95	0.75	0.05	0.865	195.65	102
5.	95	1	0.075	0.976	245.56	123
6.	95	0.5	0.1	0.967	297.56	140
7.	115	1	0.05	0.645	175.56	110
8.	115	0.5	0.075	0.676	145.6	130
9.	115	0.75	0.1	0.754	245.45	147

III. RESULTS AND DISCUSSION

The reading for 9 trials obtained in the experimentation phase is analyzed by using Excel sheet and it is then verified by Minitab software. The analysis of the results was done by using MINITAB 16 statistical software for finding the optimized value and its influence on cutting force.

A. SIGNIFICANCE OF CUTTING PARAMETERS ON CUTTING FORCE

We analyze the variation of cutting force for different levels of input parameters from the average value of cutting force through the graph generated by the excel sheet. The graphical representation of variation of cutting force for different levels of input parameters is shown in fig. 2. This graph is plotted by the excel sheet based on the response values given. From the graph it is clear that the cutting force required was minimal for velocity at level 3 that is 115m/min, feed at level 1, say 0.05mm/rev and depth as 0.5mm.

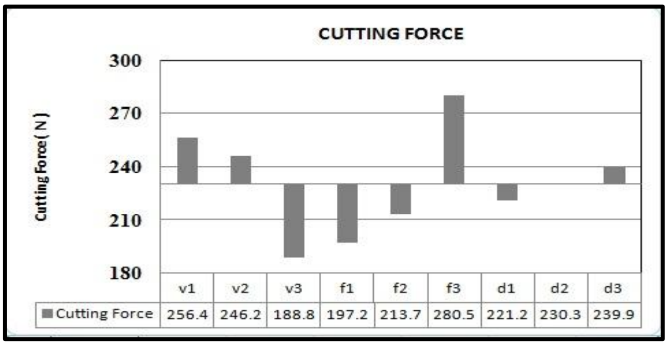

Fig: 2 Significance of Input Parameters on Cutting Force

Now it is verified by using Minitab 16. Experimental values for 9 run experiment are given as input in Taguchi analysis. Software will make a response table for means which is shown in the Table 3 and based on the table graph (fig. 3) is plotted. The table gives the average values of cutting force for cutting velocity, feed and depth of cut. The average value of cutting force is smaller when the velocity is at level 3, feed at level 1 and depth at level 1.

Table: 3 Response Table Generated for Means of Cutting Force

Level	Velocity	Feed	Depth
1	256.4	197.2	221.2
2	246.2	213.7	230.3
3	188.8	280.5	239.9

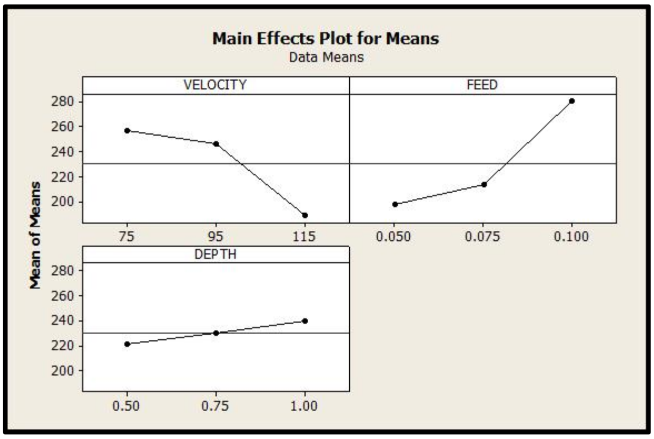

Fig: 3 Main Effect Plots for Cutting Force

B. ANOVA ANALYSIS FOR CUTTING FORCE

The effect of input parameters on cutting force was done by using ANOVA method in Minitab. After giving the input values into the software and selecting proper settings, a response table for means of cutting force is generated by the Minitab software which is shown in the table 4. In the response table for means of cutting force, mean values of cutting force for each input parameter at each level is tabulated by the software itself. Also the change in maximum value and minimum value of cutting force is calculated for all input at all levels which is represented by delta. The input parameter having greater delta value has more significance on cutting force. Here out of three input parameters feed has higher delta value and thus cutting force was mostly influenced by cutting feed. The influence ranking of velocity, feed and depth of cut on cutting force are 2, 1 and 3 respectively.

Table: 4 Response Table for Means of Cutting Force by using ANOVA

Response Table for Means			
Level	Velocity	Feed	Depth
1	256.4	197.3	221.3
2	246.3	213.7	230.4
3	188.9	280.5	239.9
Delta	67.5	83.3	18.7
Rank	2	1	3

The percentage of influence of each cutting parameters on cutting force is shown in the table 5. From the ANOVA results of cutting force we came to know cutting feed is the most influencing factor and the percentage of influence is 54.261.

Table: 5 ANOVA Result for Cutting Force

Analysis of Variance for Means						
Source	DF	Seq SS	Adj SS	Adj Ms	F	P
VELOCITY	2	7956.4	7956.4	3978.2	5.86	36.999
FEED	2	11668.4	11668.4	5834.2	8.60	54.261
DEPTH	2	522.0	522.0	261.0	0.38	02.427
Residual Error	2	1357.3	1357.3	678.7		06.311
Total	8	21504.2				

C. COMPARISON WITH WET AND DRY TURNING

The minimum value of cutting force while hard turning of OHNS steel with minimal fluid application system was found when the velocity kept at level 3 (115m/min), feed at level 1 (0.05mm/rev) and depth at level 1 (0.5mm). For the above same input parameters a comparison study has been carried out with wet turning and dry turning. The result obtained during the comparison experiment is shown in the table 6.

Table: 6 Comparison with Dry and Wet Turning

Parameters	Dry turning	Wet turning	Turning with Minimal fluid
Cutting force (N)	343.7	273.2	154.43

IV. CONCLUSION

When the wet turning of OHNS steel is performed, the cutting force obtained in the Kistler dynamometer was 273.2 N and for dry turning it was 343.7 N. The comparison result shows that the cutting force required for the hard turning of OHNS steel with minimal fluid application is less compared to conventional dry and wet turning. Minimal cutting fluid application technique also promoted green environment in the shop floor, minimized the industrial hazard and usage of large quantity of cutting fluid. Also production cost is reduced by minimal usage of cutting fluid.

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