International Journal For Technological Research In Engineering
Volume 5, Issue 3, November-2017 *ISSN (Online): 2347 - 4718*

PERFORMANCE EVALUATION OF GRAPHITE INCLUSIONS IN CUTTING FLUID WITH MQL TECHNIQUES DURING TURNING OF AISI 8620 STEEL

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ABSTRACT: The present paper outlines an experimental study to optimize the effects of cutting parameters on surface finish and MRR of AISI8620 work material by employing Taguchi techniques. The orthogonal array and analysis of variance were employed to study the performance characteristics in turning operation. Four parameters were chosen as process variables: Speed, Feed, Depth of cut, Cutting environment (wet and mix). The experimentation plan is designed using Taguchi's L18 Orthogonal Array (OA) and Minitab 15 statistical software is used. Optimal cutting parameters for, minimum surface roughness (SR) and maximum material removal rate were obtained. Thus, it is possible to increase machine utilization and decrease production cost in an automated manufacturing environment
Keywords: Taguchi method, Surface roughness, MRR, Lathe, L18 Orthogonal array, AISI8620 steel, Software Minitab15

I. INTRODUCTION

Useful production time and energy are being wasted during regrinding or resharpening of cutting tools during machining operations. Machining is one of the methods used in manufacturing engineering. Other methods include: casting, forming, grinding, shaping, finishing etc. The quest for profit maximization in manufacturing processes makes it necessary for engineers and scientists to explore the optimum process. Machining is a process in which a piece of raw material is cut into a desired shape and size. Machining can also be defined as the process of removing material from a work piece in the form of chips. Cutting tools are the basic tools used in machining operations which involve turning, milling, grinding, drilling, boring, planning, and shaping. In today's industry special attention is given to dimensional accuracy and surface finish. Out of all turning is most important operation used to shape metal. Machining is done on wide range of materials. Qualities of desirable manufacturing material for this purpose would be lower shear strength, shock resistant, material must not have tendency to stick to the cutting tool .Material removed should separate from the work easily and completely. The demand of manufacturing is to produce high quality at low cost. Surface quality is used as critical quality indicator for the machined surface. The machining performance is generally increased by controlling the temperature of cutting zone. High cutting temperature adversely affects tool life, dimensional and form accuracy and surface integrity of the product. The three primary factors in any basic turning operations are speed, feed and depth of cut are:

a) Cutting speed - The speed of the work piece surface relative to the edge of the cutting tool during a cut, measured in surface feet per minute (SFM).

b) Spindle speed - The rotational speed of the spindle and the work piece in revolutions per minute (RPM). The spindle speed is equal to the cutting speed divided by the circumference of the work piece where the cut is being made.

c) Feed rate - The speed of the cutting tool's movement relative to the work piece as the tool makes a cut.

d) Depth of cut - The depth of the tool along the radius of the work piece as it makes a cut, as in a turning or boring operation. A large depth of cut will require a low feed rate, or else it will result in a high load on the tool and reduce the tool life.

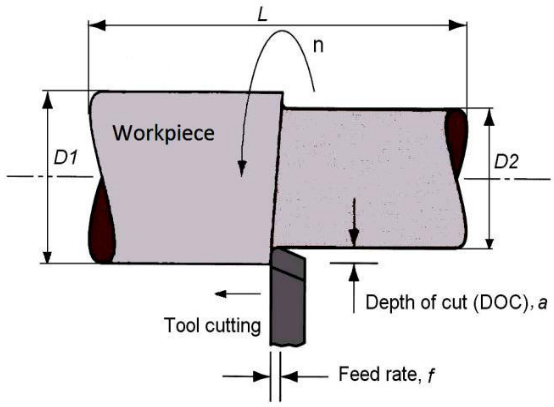

Figure 1.1: Principle of Turning Process

e) Cutting Fluid:-Cutting fluid is type of coolant and lubricant designed specifically for metal working process, such as machining and stamping. There are various kinds of cutting fluid which include oils, oil-water emulsions, pastes, gels, aerosols and air or other gases. The function of cutting fluids is as follows:

To cool the tool and work piece and conduct the heat generated in cutting away from the cutting zone. To decrease adhesion between chip and tool, provide lower friction and wear, and smaller built up edges.

f) Classification of Cutting Fluid:- Cutting fluid used may be in form of Solids, Liquids or Gases. Their purpose is to decrease the friction between chip and tool

Solid cutting fluids are in the form of free machining additives to the work material. It is a material used as powder

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or thin film to provide protection from damage during relative movement and to reduce friction and wear. Solid lubricants normally used are graphite, molybdenum disulfide and stick waxes etc.

Liquid and gases are broadly referred as cutting fluids. The liquid cutting fluids are of two general types first is material having water bases and second is material having mineral oil bases.

II. LITERATURE REVIEW

Kankaanpaa and Korhonen [1987] studied the effect of cutting tool geometry on the performance of Tin coated high speed steels. Turning test were carried out with inserts made of conventional and powder metallurgical HSS. Two different cutting geometries were used. The results showed clearly that even small changes in the tool angles affect the performance of Tin coated tool. Machado et al. [1997] examined a comparative study of application of synthetic and semi synthetic, mineral soluble oil as well as dry cut when turning AISI 8620 steel bars with triple coating with cemented carbide tools. Tool lives, cutting forces, cutting temperature and surface roughness were considered to evaluate the cutting fluids. Generally the semi synthetic gave a longer tool life. The surface roughness was not sensitive to the lubrication quality, If wear effects are not considered. Mean tool chip interface temperature was lower with the synthetic fluid

Richetti et al.[2004] investigated the effect of the number of tools used in face milling operations and how they relate to the establishment of tool life under specified cutting condition .Flank wear curves were evaluated for AISI8620 steels using 1,2,3,4 and 6 inserts in a face milling cutter.

Rena to et al. [2006] investigated the performance of coated and uncoated carbide tools with a 3 micrometer thick monolayer of Tin when continuous turning AISI8620 steel. This methodology is considered a more realistic alternative to study crater wear when compared to the bidimensional parameters. The results indicated that two distinct crater wears are present when machining using coated cutting tools.

Taguchi method

Taguchi method is a powerful tool for the design of high quality system. It provides a simple, efficient and systematic approach to optimize designs for performance, quality and cost. The methodology is valuable when the design parameters are qualitative and discrete .Taguchi parameter design can optimize the performance characteristics through the setting of design parameter and reduce the sensitivity of the system performance to source of variation.

The steps involved in Taguchi method are:

a) Identification of response functions and machine parameter to be evaluated.

b) Of the number of levels for the design parameter

c) Verification of the optimal process parameters through a confirmation experiment.

Work piece material:

The material selected for the experiments is AISI 8620 steel with a diameter of 80 mm and a length of 450 mm .The hardness of the work piece is 35-40 HRC. The AISI 8620 steel is mostly used for light to medium stressed component and shafts requiring high surface and impact properties. Typical uses are: Arbors, Bearing, pins, piston pins, splined shafts, ratchets, sleeves etc. It is also used for number of medium strength application such as a camshafts, fasteners, gears and chains. AISI 8620 has good machinability and tapping etc. AISI 8620 steel is a low nickel-chromium-molybdenum medium hardens ability supplied as rolled condition. The chemical compositions of work piece material are shown in Table 1.1

Table 1.1: Chemical composition of AISI 8620 steel

C %	Si %	Mn %	P %	S %	Cr %	Mo %	Ni %	Hardness
0.19	0.32	0.71	0.026	0.012	0.48	0.17	0.44	40 hrc

Tool material

The square shaped carbide cutting insert were selected for the experimentation. The cutting inserts were of WIDIA, India. Carbide inserts are available in many different tool geometries and material grades. While the choice of tool geometry varied with type of cutting operation and dimension of tool holder. The designation of the cutting inserts is represented in table 4.2. The tool inserts along with their tool holder are shown in fig 4.1

Table 1.2: Designation of Cutting Insert

Insert Type	Designation
Cemented Carbide	SNMG120408

Solid lubricant used: As per Wang et al 2012 lots of metal compounds can be used as a solid lubricant, such as metal oxide, metal halide, metal sulfide metal selenide, metal borate, metal phosphate etc. In the experiment for lubrication and cooling, Graphite solid lubricant mixed with SAE-40 cutting oil is used.

Experimental Procedure:

Among the Speed and feed rate combinations available on the Lathe, three level of cutting parameters were selected. Lubricant has two levels after that cutting speed, feed and depth of cut each has three level. The factors are designated by symbol A, B, C, D for lubricant Cutting speed, feed, depth of cut.

Table 1.3: Experimental results L18 (21, 33) orthogonal array

Exp. No.	A: Lubricant (Wet/Mix)	B: Speed (mm/min.)	C: Feed (mm/rev)	D: Depth of cut(mm)	Response-1 Average Surface Roughness (R_a) (in μM)
1	Wet	100	0.15	0.2	1.68
2	Wet	100	0.18	0.25	1.89
3	Wet	100	0.2	0.3	2.41
4	Wet	140	0.15	0.2	1.25
5	Wet	140	0.18	0.25	1.50
6	Wet	140	0.2	0.3	1.53
7	Wet	180	0.15	0.25	0.88
8	Wet	180	0.18	0.3	1.18
9	Wet	180	0.2	0.2	2.01
10	Mix	100	0.15	0.3	1.12
11	Mix	100	0.18	0.2	1.09
12	Mix	100	0.2	0.25	1.12
13	Mix	140	0.15	0.25	1.02
14	Mix	140	0.18	0.3	0.99
15	Mix	140	0.2	0.2	1.14
16	Mix	180	0.15	0.3	0.89
17	Mix	180	0.18	0.2	0.98
18	Mix	180	0.2	0.25	1.12

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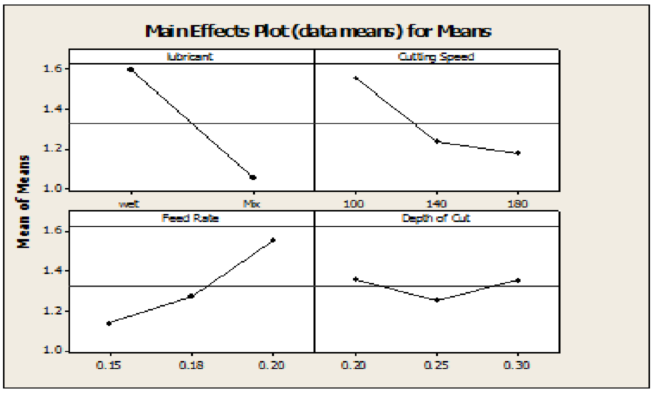

Fig.1.2 Main effect plot for means of Surface Roughness

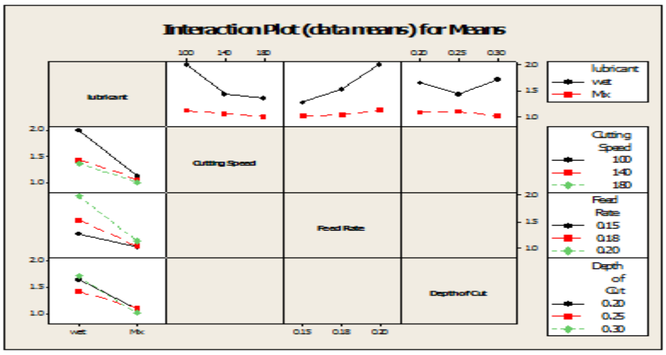

Fig.1.3 Interaction plot for means of Surface Roughness

Analysis of variance (ANOVA) –Surface Roughness: The analysis of variance results for means of surface roughness at 97% confidence interval are given in Table 5.4

Table 1.4: Analysis of Variance for means of Surface Roughness

Source	DF	Seq SS	Adj SS	Adj MS	F	P	%C
Lubricant(C)		1.31220	1.31220	1.31220	60.15	0.001	42.08
Cutting Speed(S)	2	0.48521	0.48521	0.24261	11.12	0.023	15.56
Feed Rate(F)	2	0.53968	0.49652	0.24826	11.38	0.022	17.30
Depth of Cut(D)	2	0.04074	0.09555	0.04778	2.19	0.228	1.30
Coolant* Speed	2	0.26543	0.26543	0.13272	6.08	0.061	8.51
Coolant* Feed	2	0.32484	0.32484	0.16242	7.44	0.045	10.41
Coolant * Depth of cut	2	0.06254	0.06254	0.03127	1.43	0.339	2.00
Residual Error	4	0.08727	0.08727	0.02182			2.79
Total	17	3.11791					100.00
S = 0.1477 R-Sq = 97.2% R-Sq (adj) = 88.1%							

Table 1.5: Response table for means of Surface Roughness

LEVEL	LUBRICANT	SPEED	FEED	DEPTH OF CUT
1	1.592	1.552	**1.140**	1.358
2	**1.052**	1.238	1.272	**1.255**
3	-	**1.177**	1.555	1.353
Delta	0.540	0.375	0.415	0.103
Rank	1	3	2	4

ANOVAs result show that speed, feed, depth of cut and coolant have a significant effect on the surface roughness. When F value increases the significance of parameters also increases. ANOVA table shows the percentage contribution of each parameter. The speed has 15.56% contribution for the surface roughness followed by feed 17.30%, Depth of cut 1.30% and Coolant 42.08 %.

The interaction between the Lubricant and Feed rate has a maximum influence on the Surface roughness. When F value increases the significance of the parameter also increases. Interaction between Lubricant and Cutting speed which has 8.51 % contribution to the Surface Roughness followed by interaction between lubricant and depth of cut has 2% contribution to the surface roughness. The ranks are assigned to the input parameters on the basis of delta value. The delta value for Speed is 0.375 followed by Feed 0.415, Depth of cut 0.103 and Lubricant 0.540. As Surface Roughness is the "Smaller is better", it can be seen from in that Second level of lubricant (A2), Surface roughness increases with increase in feed and decrease with increase in speed. Out of all the proportion of MQL surface roughness is coming out to be minimum for 60gm. The value of surface roughness obtained through confirmation experiment is within the 97.2% of CIce.

All the interaction was found to be significant. All the interaction was found to be significant. ANOVA results show that, Speed, Feed, depth of cut and coolants have significant affect on the surface roughness. When F value increases the significance of the parameter also increases. ANOVA table shows the percentage contribution of each parameter. The speed has 15.56 % contribution for the Surface Roughness, followed by Feed 17.30 %, Depth of cut 1.30 % and Coolant 42.08 %. All the interaction was found to be significant. The interaction between the Lubricant and Feed rate has a maximum influence on the Surface Roughness, which has 10.41% contribution to the Surface Roughness followed by the interaction between Lubricant and Cutting speed which has 8.51 % contribution to the Surface Roughness followed by the interaction between Lubricant and Depth of cut which has 2% contribution to the Surface Roughness. The rank assigned to various input parameters are shown in Table 5.5. The ranks are assigned to the input parameters on the basis of delta value. The delta value for Speed is 0.375 followed by Feed 0.415, Depth of cut 0.103 and Lubricant 0.540. As Surface Roughness is the "Smaller is better", it can be seen from in Table 5.5 that Second level of lubricant (A2), Third level of speed (B3) Ist level of feed (C1) and Second level of (D2) provide minimum of Surface roughness. Followed by Feed 17.30 %, Depth of cut 1.30 % and Coolant 42.08 %. All the interaction was found to be significant. The interaction between the Coolant 42.08 %. The interaction between the Lubricant and Feed rate has a maximum influence on the Surface Roughness, which are 10.4

Confirmation experiment

In order to validate the results a confirmation experiment for Surface Roughness at optimal level of the process variables. The average value of the Surface roughness was obtained and compared with the predicted value. The value of Surface

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Roughness is shown in Table 5.6. The value of Surface Roughness obtained through confirmation experiment is within the 97.2 % of CICE Of response characteristics. It is to be pointed out that these optimal values are 2within the specified range of process variables.

Table 1.6: Predicted Optimal Values Confidence intervals and Results of Experiments

Response	Optimal Set of Parameter	Predicted Optimal Value	Experimental Value			Average Value	% Error
Surface Roughness	A2 B3 C1 D2	0.966667	0.98	0.99	1.02	0.996	3.01

III. CONCLUSIONS

In the present work an attempt has been made to study the effect of Solid lubricant (Graphite) mixed with liquid lubricant at different proportion on the performance parameter of AISI8620 steel while machining with cemented carbide insert. On the basis of this consideration the present experimental study was done and following conclusions can be drawn regarding the effect of solid lubricant, and effect of input machining parameters (Speed, Feed, Depth of cut) on the response parameter(Surface Roughness, Chip Thickness Ratio, Material Removal Rate)

- Surface Roughness increases with increase in Feed and decrease with increase in speed. Out of all proportion of MQL Surface roughness is coming out to be minimum for 60gm.
- Chip Thickness Ratio increase with increase in Feed and decrease with increase in speed. Out of all proportion of MQL Chip Thickness Ratio is coming out to be minimum for 50gm.
- Material Removal Rate increases with increase in Feed and Speed. Out of all input parameters speed has maximum effect on Material Removal Rate. Effect of Coolant and Feed has minimum effect on Material Removal Rate

Scope of Future Work

In present work an attempt has been made to study the effect of Solid lubricant (Graphite) mixed with liquid lubricant at different proportion on machining of AISI 8620 steel. It has been observed that solid lubricant affect the response in one or the other way. This creates a lot of scope for the future work that can be taken up for the further study of AISI 8620 steel. A few of these fields may be discussed below:

- The variation of Tool life during machining while using various Solid lubricants can be studied and analyzed.
- Effect of cutting insert shapes can be studied.
- Effect of other solid lubricants mixed with other liquid lubricant on machining are still to be studied.
- The variation of forces induced during machining can be studied and analyzed

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