EFFECT OF CUTTING TOOL ON SURFACE ROUGHNESS OF WORKPIECE MATERIAL

Satish M.Rajmane
Research Scholar, WIT Research Center,
Solapur University, Solapur, India

Jeevankumar A.Sodal
ME-(Mech)-II Student,
Bharat Ratna Indira Gandhi College of Engineering, Solapur, India

ABSTRACT

The cutting operation is nothing but removal of unnecessary material on workpiece by machining which includes operations like turning, facing, Grooving etc. Turning is one of material removal operation in which material from cylindrical workpiece is removed keeping Tool stationary & workpiece rotating. The cutting operation is affected by its cutting speed, feed & depth of cut. Also other factors like shape n geometry of Tool & coolant used have some effect over turning operation, which is done on either Conventional Lathe or CNC machine.

The values of cutting speed, feed & depth of cut are responsible for the surface roughness of workpiece material after turning operation. Also they are responsible for rate of production & tool life. Because of this, these parameters needs to be optimized to achieve the best combination for achieving higher rate of production with the required surface finish of workpiece material which is the main objective.

For this experiment, CNC Machine is used for turning operation with different workpiece of same material & Inserts with different nose radius & shape. The process would be repeated for different shapes of insert, cutting speed, feed, nose radius, depth of cut & coolant used. The testing of surface roughness is done is testing labs.

Turning Operation is carried out with different combination of Shape of Insert, Nose Radius, Cutting Speed, Feed, Depth of cut & Coolant & the results for surface roughness can be obtained from lab report.

INTRODUCTION

Turning is the removal of metal from the outer diameter of a rotating cylindrical work piece. Turning is used to reduce the diameter of the work piece, usually to a specified dimension, and to produce a smooth finish on the metal. Often the work piece will be turned so that adjacent sections have different diameters.

Turning is the machining operation that produces cylindrical parts. In its basic form, it can be defined as the machining of an external surface.

With the cutting tool feeding parallel to the axis of the work piece and at a distance that will remove the outer surface of the work. Taper turning is practically the same, except that the cutter path is at an angle to the work axis. Similarly, in contour turning, the distance of the cutter from the work axis is varied to produce the desired shape. Even though a single-point tool is specified, this does not exclude multiple-tool setups, which are often employed in turning. In such setups, each tool operates independently as a single-point cutter.

Kanse Tanaji. S, Jadhav D. B. [1] carried out investigation on parameters such as feed ,speed depth of cut and surface finish in case of single point cutting tool using taguchi method. CNC machine was used for experimentations. From this study following conclusions were drawn, Taguchi's robust design method is suitable to optimize the surface roughness in Turning. It is found that the parameter of the taguchi method provides a simple, systematic, & efficient methodology for the optimization of the machining parameters significant factors for the surface roughness in Turning where the spindle speed and the tool grade, with contribution of 10.2979 and 8.36734 respectively. CBN Tools gives better surface finish compare to ceramic and carbide tools at all speeds, feeds and depth of cut.

Ashish Bhateja, Jyoti Bhardwaj, Maninder Singh and Sandeep Kumar Pal [2] investigated different machining Parameters of En24 Alloy Steel using Different grades of Coated and uncoated Rhombus Geometry Insert of EN-24 tool. Selecting parameters such as Cutting environment, Cutting Fluid Grade, Cutting Fluid Flow rate, Speed rate, Feed rate, Depth of Cut, Diameter (Actual & Measured), Specimen Wear, Length. The results concluded that in the first step of step turning the roughness value for TNMG is least, showing the optimal value. In second step of step turning we observed that the roughness value for coated CNMG is least indicating optimal value. In third step of turning the roughness value of TNMG is least and constant from the second step. Hence giving the optimum value for surface roughness. TNMG (triangular) has the least value of TWR, C (TNMG) has the maximum value of MRR which fulfill the condition. More is the MRR; more is the optimality of work specimen. If the cutting parameters such as the feed rate, spindle speed, or depth of cut are too high, the surface of the workpiece will be rougher than desired and may contain scratch marks or even burn marks. Also, a large depth of cut may result in vibration of the tool and cause inaccuracies in the cut. The sharp edge will wear down and become dull. A dull tool is less capable of making precision cuts.

Umesh Khandey [3] carried out experimentation on surface roughness of in case of single point cutting tool and from his experimentation he concludes that reduction in cutting tool flank wear also increases tool life. Multi-response optimization problem has been solved by searching an optimal parametric combination, capable of producing high surface quality turned product in a relatively lesser time and at the same time ensuring reduced flank wear of the cutting tool. Multi-objective optimization problem has been converted into a single objective function optimization problem which can be solved by Taguchi method.

Jigar Talati[4] carried out investigations on surface finishing in case of single point cutting tool considering various important parameters, also considered surface texture , waviness, lay, surface finish imperfections and concluded from his study that If we want to distinguish between surfaces that differ in shape or spacing, we need to calculate other parameters for a surface that measure peaks and valleys and profile shape and spacing. The more complicated the shape of the surface, we want and the more critical the function of the surface, the more sophisticated we need to be in measuring parameters beyond Ra.

Walid Jomaa, Victor Songmene* and Philippe Bocher[5] conducted research on the surface finish and residual stresses induced by the orthogonal dry machining of AA7075-T651 alloys. The effect of cutting conditions and analyzed the surface topography using two groups of surface roughness parameters height and distribution parameters. Surface

damage mechanisms were investigated in detail. After detail study some of the important conclusions were revealed
Assessment of the surface finish shows that surface profiles displayed different features and are sensitive to cutting conditions in the axial as well as in the hoop direction. The formation of BUE was intensified by an increase in the cutting feed; however, an increase in the cutting speed reduced it and promoted the formation of the BUL on the rake face. The EDS analyses showed that the BUE and BUL have a dissimilar nature. SEM and EDS analyses showed that the primary origin of surface damage was the interaction between the tool edge and the iron-rich inter metallic phases present within the work material matrix. The hoop stress was predominantly compressive on the surface, and tended to be tensile as the cutting speed increased. The reverse occurred for the surface axial stress. The smaller the cutting feed, the greater the effect of the cutting speed on both axial and hoop stresses.
SThamizhmanii*, K. Kamarudin, E. A. Rahim, A. Saparudin, S. Hassan [6] studied the tool wear and surface roughness of AISI 8620 material using coated ceramic tool by turning process. The tests were carried under various combinations of cutting speed, feed rate, and depth of cut and fixed time period. The study concludes that surface finish is an important attribute in any machining operation. Surface roughness decreased when the cutting speed was increased and tool wear was not noticeable for a few tests. It increased rapidly at higher cutting speed, feed rate, higher depth of cut and increase in time. The flank wear, crater wear and nose wear were measured. During turning, built up edge formed and was due to diffusion of the work piece material. Higher cutting speed, feed and depth of cut, produced better surface finish for longer cutting time. The worn out tool has produced better surface roughness than new tool initially. The cutting edge of the worn tool acting like an un-uniformly larger nose radius which produced better surface. The flank wear increased when the cutting speed and feed rate and depth of cut was increased which may be due to abrasive action between the tool cutting edge and work piece, and temperature generated between cutting edge and work piece.
G. Harii Krishna Rao, M. N. M Ansari, Shahida Begum [7] carried out research on effect of cutting parameters using CNC Milling to obtain quality surface finish that is specified by customer for machined parts an attempt was made to study the effects of cutting parameter that influence the surface roughness quality. The depth of cut is the most dominant factor of this study. Tests concluded that Regardless of the category of the quality characteristic, the-smaller-the better for surface roughness, a good surface quality can be achieved at the highest feed rate (C = 30 mm/min), the lowest cutting speed(B = 1000 rpm) and lowest depth of cut (A = 0.4 mm) lead to optimal surface roughness value. Control parameters (A, B, and C) can be monitored using p-values from ANOVA analysis table which is fairly more accurate. Finally, the study shows that depth of cut is the most dominant factor of those studied. The medium significant factor is feed rate and followed by spindle speed.

PROBLEMS WITH THE TURNING OPERATION

In machining operations, the quality of the surface finish was playing an important role for many turned work pieces. However, human operators or programmer normally inspecting the surface according to their experiences with regard to the quality characteristics of turning parts, some of the problems included surface roughness, burr, and tool wear, etc. The machining parameters such as cutting speed, feed rate, depth of cut, features of tools, work piece material and coolant conditions were highly affect the performance characteristics. To select the most appropriate machining settings is necessary in order to improve cutting efficiency, lower the process cost, and produce high-quality components.

CNC MACHINE AND CUTTING TOOLS USED

A) CNC MACHINE:-

General Description of Machine

The DGX 100 turning center is designed to perform a variety of machining operations such as straight , taper turning, drilling, boring, contouring with linear& circular interpolation, internal & external threading (parallel & taper) etc. The machine is suitable for chucking & bar type of work pieces.

The basic structure of the machine is a mono block reinforced structure; computerized-optimized withstands torsional loads & compressive loads with graded casting having maximum rigidity & stability. The linear motion guide ways are used for saddle and cross side movements

Figure 1: CNC Machine Used For Turning Operation

The head stock is rigid closed box construction without any big opening as the spindle assembly with cartridge inserted in the head stock. At the rear end of spindle, the poly V-groove pulley for the main drive motor and encoder-timing pulley are directly mounted. The main spindle is driven by a 5.5/7 kW variable speed AC servo motor through the poly V-belt. The rpm range of spindle is from 50 to 4500 with constant torque and from 750 to 4500 with constant power.

The feed drive of saddle (z-axis) and the feed drive of cross slide (x-axis) are by AC servomotors, which are coupled with ball screw by below coupling. The ball screw nut and the bearings are preloaded to eliminate backlash and to improve stiffness. The standard rapid transverse rate for both Z and X-axes are 24 m/minute.

The gang type tooling system is provided for improving the cycle time of machining. Turning tool holders with wedge locking (both left hand tool & right hand tool with shank size of 25X25 mm can accommodate) and Boring tool holders (with maximum shank Ø32 mm) are provided for rigid machining.

The lubrication of spindle bearing is by grease of life. The guide ways for both Z and X-axes along with the ball screw nut are pulse lubricated by a centralized automatic lubrication / manual greasing system.

b) CUTTING TOOLS USED:-

Tool Material: - Carbide Insert Cutting Tools with different Nose Radius are used for this turning operation. They are shown in figure below

Figure 2: Rhombus Shape Insert Used For Turning Operation

The rhombus shaped insert cutting tool is used for turning operation which is shown in figure.2. This tool has nose radius as 0.4. This tool is specially used for removing the unwanted material on work piece material. This tool can be used for the operations like Turning, Facing etc.

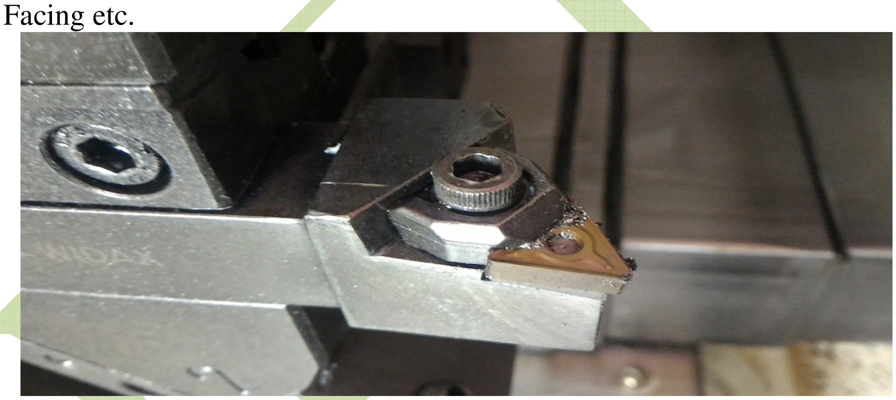


Figure 3: Triangular Shape Insert Used For Turning Operation

The triangular shaped insert cutting tool is used for turning operation which is shown in figure 3. This tool has nose radius as 0.8. This tool is also specially used for removing the unwanted material on work piece material. This tool can be used for the operations like Turning, Facing etc.

TAGUCHI METHOD FOR PROCESS OPTIMISATIONN

The Taguchi method developed by Genuchi Taguchi is a statistical method used to improve the product quality. It is commonly used in improving industrial product quality due to the proven success and With the Taguchi method; it is possible to significantly reduce the number of experiments. The Taguchi method is not only an experimental design technique, but also a beneficial technique for high quality system design & The Taguchi technique includes the following steps:

- Determine the control factors,
- Determine the levels belonging to each control factor & select appropriate orthogonal array,
- Assign the control factors to the selected orthogonal matrix & conduct the experiments,
- Analyze data and determine the optimal levels of control factors,
- Perform the confirmation experiments and obtain the confidence interval,
- Improve the quality characteristics.

In parameter design, there are two types of factors that affect a product's functional characteristic: control factors and noise factors. Control factors are those factors which can easily be controlled such as material choice, cycle time, or mold temperature in an injection molding process. Noise factors are factors that are difficult or impossible or too expensive to control. There are three types of noise factors: outer noise, inner noise, and between product noise. Noise factors are primarily response for causing a product's performance to deviate from its target value. Hence, parameter design seeks to identify settings of the control factors which make the product insensitive to variations in the noise factors, i.e., make the product more robust, without actually eliminating the causes of variation. Design of experiments techniques, specifically Orthogonal Arrays (OAs), is employed in Taguchi's approach to systematically vary and test the different levels of each of the control factors. Commonly used OAs includes the L_4, L_9, L_{12}, L_{18}, and L_{27}, some of which are listed in table 1(a), table 1(b) & table 1(c). The columns in the OA indicate the factor and its corresponding levels, and each row in the OA constitutes an experimental run which is performed at the given factor settings. It is up to experimental designer to establish appropriate factor levels for each control factor; typically either 2 or 3 levels are chosen for each factor. Selecting number of levels and quantities properly constitutes bulk of the effort in planning robust design experiments.

Table 1 (a): L_4 Array

RUN	FACTORS		
	A	B	C
1	1	1	1
2	1	2	2
3	2	1	2
4	2	2	1

Table 1 (b): L_8 Array

RUN	FACTORS						
	A	B	C	D	E	F	G
1	1	1	1	1	1	1	1
2	1	1	1	2	2	2	2
3	1	2	2	1	1	2	2
4	1	2	2	2	2	1	1
5	2	1	2	1	2	1	2
6	2	1	2	2	1	2	1
7	2	2	1	1	2	2	1
8	2	2	1	2	1	1	2

ISSN: 2394-3696
VOLUME 3, ISSUE 1, JAN.-2016

Table 1 (c): L_9 Array

RUN	FACTORS			
	A	B	C	D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

To implement robust design, Taguchi advocates the use of an “inner array” and “outer array” approach. The “inner array” consists of the OA that contains the control factor settings; the “outer array” consists of the OA that contains the noise factors and their settings which are under investigation. The combination of the “inner array” and “outer array” constitutes what is called the “product array” or “complete parameter design layout.” The product array is used to systematically test various combinations of the control factor settings over all combinations of noise factors after which the mean response and standard deviation may be approximated for each run using the following equations.

$$\text{Mean Response} = \frac{1}{n}\sum_{i=1}^{n} yi$$

$$\text{Standard Deviation} = \sqrt{\sum_{i=1}^{n} \frac{(yi-y)2}{n-1}}$$

The preferred parameter settings are then determined through analysis of the “signal-to-noise” (SN) ratio where factor levels that maximize the appropriate SN ratio are optimal. There are three standard types of SN ratios depending on the desired performance response

Nominal is the best;

$$\eta = S / N_T = \log (y / S_y^2) \text{ …… (1)}$$

Larger is better;

$$\eta = S / N_L = -10 \log \left\{\frac{1}{n}\sum_{i=1}^{n}\left(\frac{1}{y2}\right)\right\} \text{ …… (2)}$$

Smaller is better;

$$\eta = S / N_s = -10 \log \left\{\frac{1}{n}\sum_{i=1}^{n} yi2)\right\} \text{ …… (3)}$$

Where

y is the mean of observed data

S_y^2 is the variance of *y*,

n is the number of observations and
y is the observed data.
These SN ratios are derived from the quadratic loss function and are expressed in a decibel scale. Once all of the SN ratios have been computed for each run of an experiment, Taguchi advocates a graphical approach to analyze the data. In the graphical approach, the SN ratios and average responses are plotted for each factor against each of its levels. The graphs are then examined to "pick the winner," i.e., pick the factor level which (1) best maximize SN and (2) bring the mean on target (or maximize or minimize the mean, as the case may be). Using this information, the control factors can also be grouped as follows.
1. Factors that affect both the variation and the average performance of the product.
2. Factors that affect the variation only.
3. Factors that affect the average only.
4. Factors that do not affect either the variance or the average.
Factors in the first and second groups can be utilized to reduce the variations in the system, making it more robust. Factors in the third group are then used to adjust the average to the target value. Lastly, factors in the fourth group are set to the most economical level. Finally, confirmation tests should be run at the "optimal" product settings to verify that the predicted performance is actually realized.

EXPERIMENTAL PROCEDURE

The work piece was mounted using a chuck in CNC turning centre. The machining parameters like feed, depth of cut, cutting speed, etc. were selected based on the manufacturer's recommendations. Only the cutting speeds, feed, nose radius, depth of cut, cutting tool inserts, and coolant was changed. Here we have used Taguchi's Smaller is the better approach.
According to Taguchi's L8 Array, the different combinations of feed, speed, depth of cut, nose radius & coolant were selected & the turning operations are carried out using those combinations.
The Parameters & combinations of parameters are given in Table 2 & Table 3 below

Table 2: Parameters Used For Turning Operation

Sr. No.	Parameter		
A	Shape of Insert	Rhombus (a1)	Triangular (a2)
B	Nose Radius	0.4 (b1)	0.8 (b2)
C	Cutting Speed	1500 (c1)	2000 (c2)
D	Feed	0.4 (d1)	0.5 (d2)
E	Depth of Cut	0.5 (e1)	0.4 (e2)
F	Coolant	Supplier 1 (f1)	Supplier 2 (f2)

Table 3: Different Combinations Used For Turning Operation

Test No.	Combinations of Parameters
1	a1 b1 c1 d1 e1 f1
2	a1 b1 c2 d2 e2 f2
3	a1 b2 c1 d2 e2 f1
4	a1 b2 c2 d1 e1 f2
5	a2 b1 c1 d2 e1 f2
6	a2 b1 c2 d1 e2 f1
7	a2 b2 c1 d1 e2 f2
8	a2 b2 c2 d2 e1 f1

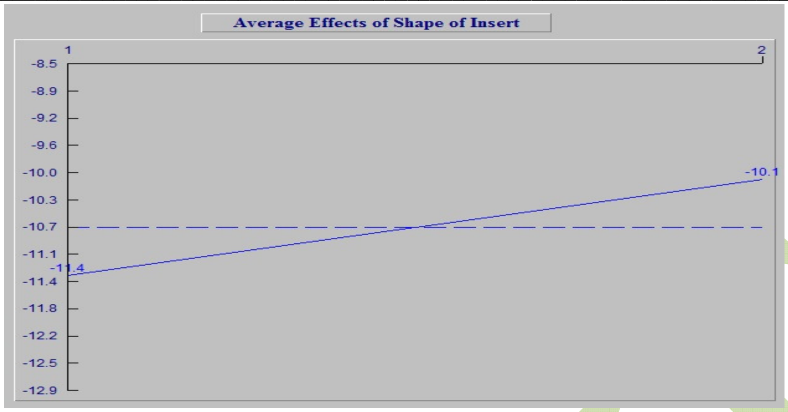
RESULTS

After the turning operations are carried out successfully, the material were sent to test laboratories for the inspection of surface roughness of material after turning operation. Results are obtained with two different laboratories which contribute two different levels in calculating the S/N ratio. The results obtained from the laboratories & S/N ration from Taguchi method are listed in Table 4 shown below

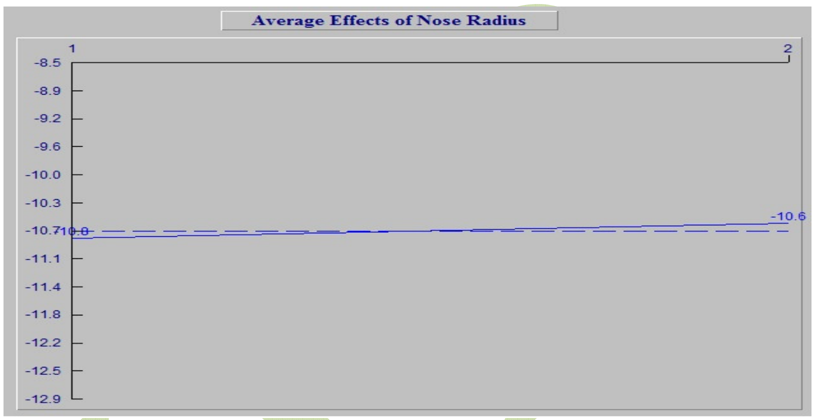
Table 4: Results Obtained From Laboratories & S/N Ratio By Taguchi Method

Test No.	Combinations of Parameters	Results from Lab A in µm (Level 1)	Results from Lab B in µm (Level 2)	S/N Ratio
1	a1 b1 c1 d1 e1 f1	3.59	4.22	-11.861
2	a1 b1 c2 d2 e2 f2	2.70	3.38	-9.712
3	a1 b2 c1 d2 e2 f1	3.41	4.13	-11.567
4	a1 b2 c2 d1 e1 f2	3.60	4.56	-12.273
5	a2 b1 c1 d2 e1 f2	2.40	5.97	-13.16
6	a2 b1 c2 d1 e2 f1	2.42	2.88	-8.498
7	a2 b2 c1 d1 e2 f2	1.86	2.47	-6.795
8	a2 b2 c2 d2 e1 f1	3.46	4.28	-11.803

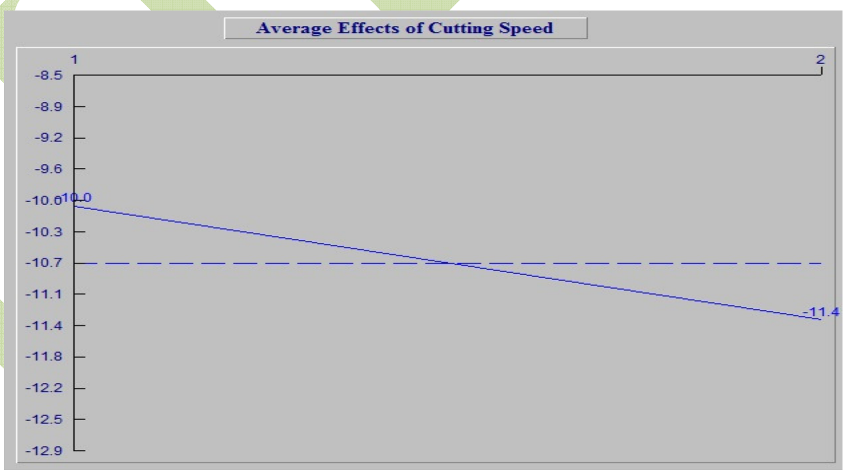
The Graphical representation of both level results from laboratories are plotted against S/N ratio for different parameter, which are shown in graphs 1 to 6 below



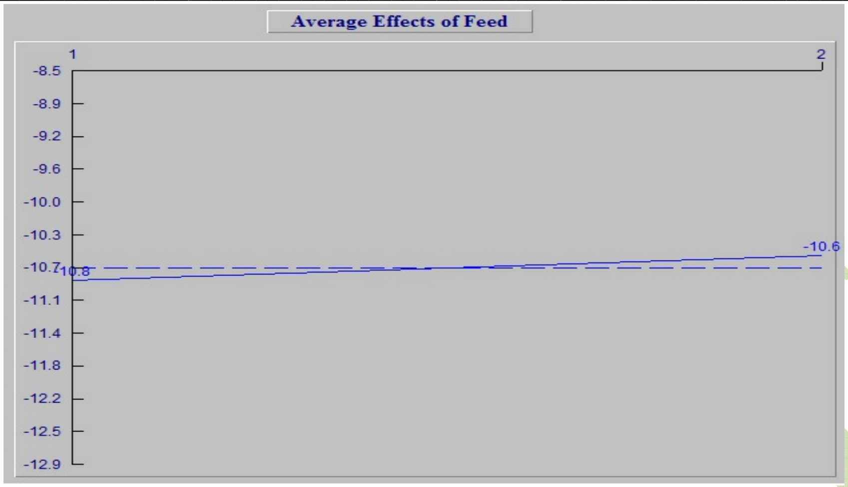
Graph 1: Average Effect of Shape of Insert



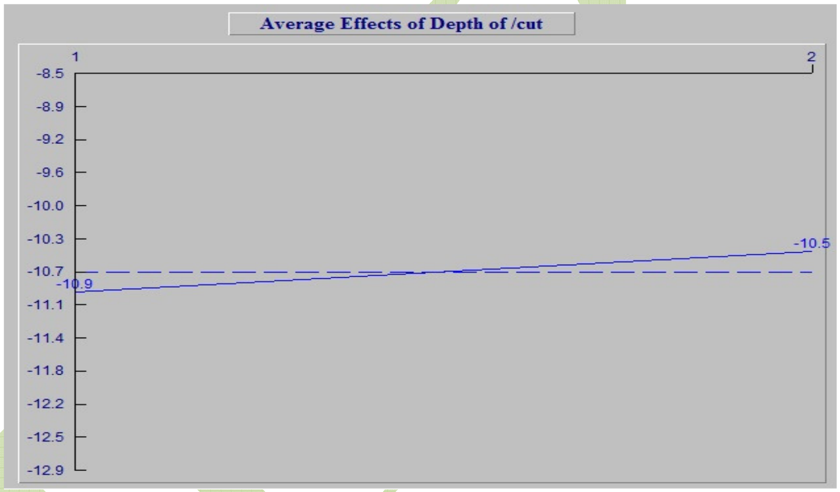
Graph 2: Average Effect of Nose Radius



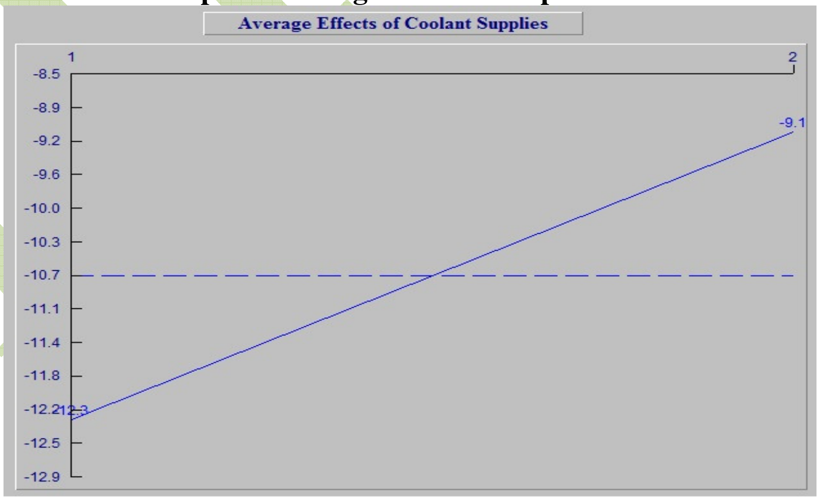
Graph 3: Average Effect of Cutting Speed



Graph 4: Average Effect of Feed



Graph 5: Average Effect of Depth of Cut



Graph 6: Average Effect of Coolant

CONCLUSIONS

According to results from Taguchi L8 approach,

- It was found that the most optimized results are obtained with the combination (a2 b2 c1 d2 e2 f2) which is Shape of Insert – Triangular, Nose Radius – 0.8mm, Cutting Speed – 1500, Feed – 0.5mm, Depth of Cut – 0.4mm & Coolant – Supplier 2.
- The Graphs plotted shows variation of S/N ratio of each parameter separately, from which we can say that, the variation of S/N ratio is larger for Shape of Insert, Cutting Speed & Coolant used whereas it is minimum for Nose Radius, Feed & Depth of cut.
- Finally we can say that, the process can be further optimized if we use more level or iterations.

REFERENCES

1 Kanse Tanaji. S, Jadhav D. B. "*Enhancement of Surface Finish for CNC turning Cutting Parameters by Using Taguchi Method", VOLUME: 3, ISSUE: 5, June 2013*

2 Ashish Bhateja, Jyoti Bhardwaj, Maninder Singh and Sandeep Kumar Pal, "*Optimization of Different Performance Parameters i.e. Surface Roughness, Tool Wear Rate & Material Removal Rate with the Selection of Various Process Parameters Such as Speed Rate, Feed Rate, Specimen WEAR, Depth Of Cut in CNC Turning of EN24 Alloy Steel – An Empirical Approach", The International Journal of Engineering And Science (IJES), Volume: 2, Issue 1, Page 103-113, 2013*

3 Umesh Khandey, "*Optimization of Surface Roughness, Material Removal Rate & Cutting Tool Flank Wear in Turning using Taguchi Approach", National Institute of Technology, Rourkela 769008, INDIA*

41 Jigar TALATI, "Surface Roughness – *Significance and symbol interpretation in drawing", Hexagon Design Centre, Vadodara*

5 Walid Jomaa, Victor Songmene and Philippe BOCHER, *"Surface Finish and Residual Stresses Induced by Orthogonal Dry Machining of AA7075-T651", Materials 2014,7, 1603-1624; doi:10.3390/ma7031603*

6 SThamizhmanii*, K. Kamarudin, E. A. Rahim, A. Saparudin, S. Hassan, "*Tool Wear and Surface Roughness in Turning AISI 8620 using Coated Ceramic Tool", WCE 2007, July 2 - 4, 2007, London, U.K.*

7 G. Harii Krishna Rao1, M. N. M Ansari, Shahida Begum, "*Effect of Cutting Parameters on the Surface Roughness of MWCNT Reinforced Epoxy Composite Using CNC End-Milling Process", International Journal of Science and Research (IJSR), ISSN (Online): 2319-7064, Nov 2013*

AUTHORS BIOGRAPHY:

Mr.S.M.Rajmane.
He is having ME from Solapur University. He is Research Scholar for WIT Research Center, Solapur University, Solapur. He is having more than 10 years teaching exerience.His area of interest is in Fluid machinery,FEM,Design engineering.

Mr.J.A.Sodal.
He is student of M.E. (Mech.)-II in Bharat Ratna Indira Gandhi College of Engineering, Kegaon, Solapur affiliated to Solapur University, Solapur,Maharashtra,India