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# Investigation And Optimization Of Various Machining Parameters Affecting The Effectiveness Of Turning: A Review

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**Abstract: Optimum performance in a turning operation is governed by selecting machining parameters. Selection of desired machining parameters by experience or using handbook does not ensure that the selected machining parameters are optimal for a particular machine or environment. The effect of machining parameters is reflected on surface roughness, surface texture and dimensional deviations of the product.**

**This paper reviews the various machining parameters affecting the effectiveness of turning such as cutting speed, feed rate, depth of cut, rake angle, lubricant temperature, insert geometry etc.**



**Keywords: Cutting speed, feed rate, depth of cut, rake angle, surface roughness etc; Review**

## I. INTRODUCTION

Turning operation using a single point cutting tool has been one of the oldest and popular methods of metal machining. It has even replaced grinding in several applications with reduced lead time without affecting the surface quality [1]. The achievement of high quality, in terms of workpiece dimensional accuracy, surface finish, high production rate, less wear on machining tools, economy of machining in terms of cost saving and increase the performance of the product with reduced environmental impact are the main effective challenges of modern metal machining and machining industries [2]. CBN tools are widely used in the metal-working industry for machining various hard materials such as high-speed tool steels, die steels, bearing steels, case-hardened steels, white cast iron, and alloy cast irons. In many applications, machining of ferrous materials in their hardened condition can replace grinding to give significant savings in cost and productivity rates [3]. The aim of machining is to manufacture product with less cost of high dimensional accuracy and surface finish. At the same time, machining operations should be targeted towards dry or near dry machining to avoid environmental problems associated with the use of machining fluids. To cope up with above situations, now-a-days, 80% of all machining operations are performed with coated carbide cutting tools [4].

The aim of presented work is to discuss the various machining parameters affecting the effectiveness of turning such as cutting speed, feed rate, depth of cut, rake angle, insert geometry, lubricant temperature etc.

## II. TURNING PROCESS

Turning is a form of machining or a material removal process which is used to create rotational parts by removing unwanted material as shown in Fig. 1. The turning process is associated with the workpiece and cutting tool. The workpiece is a piece of re-shaped material that is secured to the fixture, which itself is attached to the turning machine, and allowed to rotate at high speeds. The cutter is typically a coated carbide cutting tool that is also secured in the machine. The cutting tool feeds into the rotating workpiece and cuts away material in the form of small chips to create the desired shape.

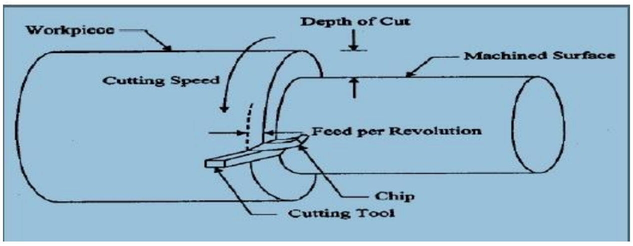


Fig.1. The Turning Process

In turning process, the machining parameters like spindle speed, feed rate, depth of cut are selected for each operation based upon the workpiece material, tool material, tool size etc. The machining parameters that influence the turning process are cutting speed, spindle speed, feed rate, depth of cut, tool temperature, insert geometry etc. [5]. The properties of work material control the chip formation. The work material properties include yield strength, shear strength, shear strength under compressive loading, strain hardening, friction behavior, hardness and ductility. The highly ductile work material not only permit extensive deformation of chip during cutting but also increases work heat generation and temperature which results in longer continuous chip. The machining parameters like spindle speed, feed rate, depth of cut also influence chip formation. Other machining parameters like tool material, tool angle, edge geometry which changes due to wear, while the cutting environment like as machine tool deflection, cutting fluid also responsible in cutting mechanism. In machining, the resultant force which consists of frictional force and normal force acting on shear plane area is mathematically calculated for given material. Some researchers are attempting to predict shear force and shear direction from dislocation theory but this has not yet been accomplished. The cutting force is the dominant force in the system and it is important to understand how it varies with changes in machining parameters. The cutting force is typically doubled when the feed rate or depth of cut is doubled but remains constant when speed is increased. [6]

## III. LITERATURE REVIEW

### A. Effect of Lubricant Temperature

L B Abhang and M Humeedullah [7] studied the effect of lubricant temperature. In this study the experimental work was carried out by turning EN-31 steel alloy as work material, this alloy is widely used in the automotive industry for the parts made by turning operations such as roller bearing, ball bearing, spline shaft and shearing blades. The aim of this study was to find out the effect of lubricant temperature using minimum quantity lubrication technique in turning process on the response (surface roughness) and to develop prediction models for surface roughness, when the lubricant temperature was varied [8]. The machining parameters namely feed rate, depth of cut; lubricant temperature was varied to observe the effects on responses. This paper has presented an application of the parameter design of the Taguchi method in the optimization of turning operation.

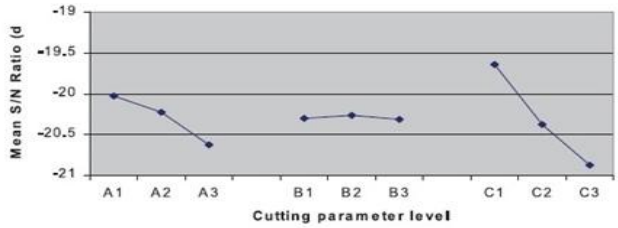


Fig.2. S/N graph for surface roughness

From this graph it can be clearly observed that A1B2C1 are the optimal levels of the design parameters for improved surface finish which implies feed rate at low level, depth of cut at medium level and lubricant temperature at low level combination gives the best surface finish within the specified range. They concluded that the lubricant temperature and feed rate are the main parameters among the three controllable factors (feed rate, depth of cut and lubricant temperature) that influence surface roughness in turning EN-31 steel. In turning for minimum surface roughness use of lower feed rate (0.05 mm/rev) medium depth of cut (0.4 mm) and low lubricant temperature ($10^0$ C) i.e. A1B2C1 are recommended to obtain better surface finish for the specific test range. Thus the surface finish is better if cooled lubricant is applied.

### B. Effect of Cutting Fluids

Yahya Isik [9] has presented the effect of cutting fluids in turning process with coated carbide cutting tools. The study highlighted the role of cutting fluids on cutting temperature, cutting forces, tool wear, and surface roughness value in machining AISI-1050 steel at industrial speed-feed condition by CVD coated carbide TiC+AI2O3+TiN insert as compared to completely dry machining. Fig. 3 shows the progression of flank wear in dry and wet-cooled turning process and volume of material removed is shown Fig. 4.

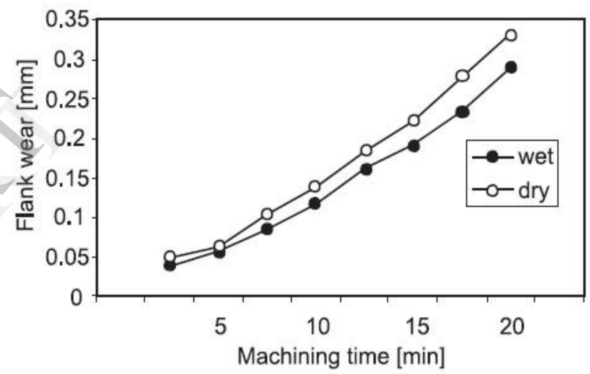


Fig.3. Flank wear vs. machining time (v=260 m/min, f=0.14 mm/rev, a=1 mm)

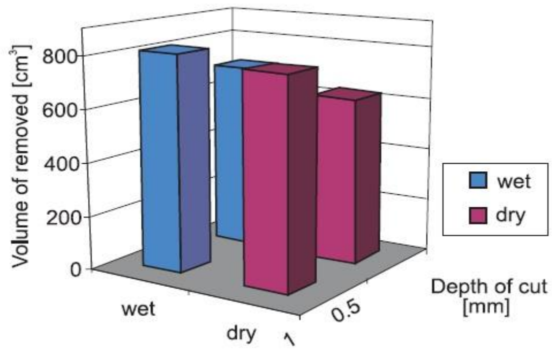


Fig.4. Volume of material removed (v=260 m/min, f=0.14 mm/rev, a=1 mm, a=0.5 mm)

Figs.5 and 6 show the variation of surface roughness at different cutting speeds, and flank wear with time for dry and wet-cooled turning.

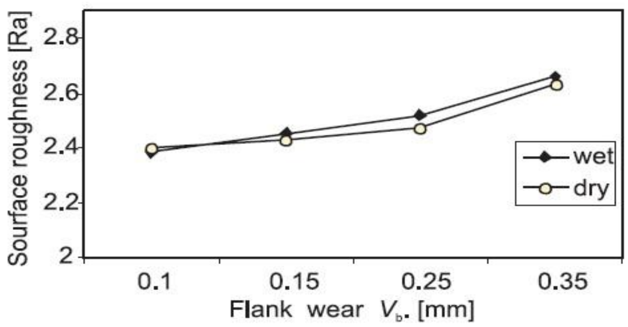


Fig.5. Flank wear versus surface roughness (v=260 m/min, f=0.14 mm/rev, a=1 mm)

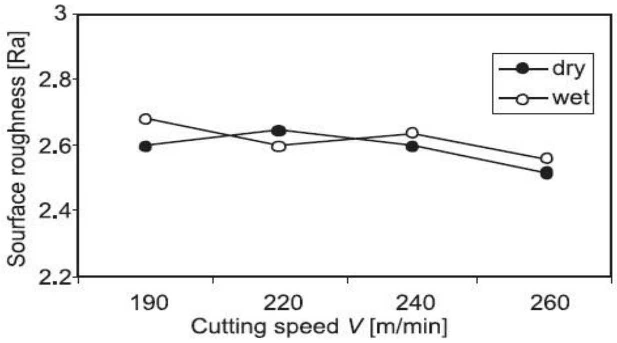


Fig.6. Cutting speed versus surface roughness

Fig. 7 illustrates the tool life at different cutting speeds and constant depths of cut at a feed rate of 0.14 mm/min with dry and wet-cooled turning. When cutting speed increases, Tool life decreases as is expected. But, tool life decrease rate is higher for wet machining than dry machining. This is because application of flood fluid reduces the coefficient of friction at the interface of the tool and chip over the rake face. This is achieved through lubrication, and by lowering the strength of welded junctions between the tool and chip.

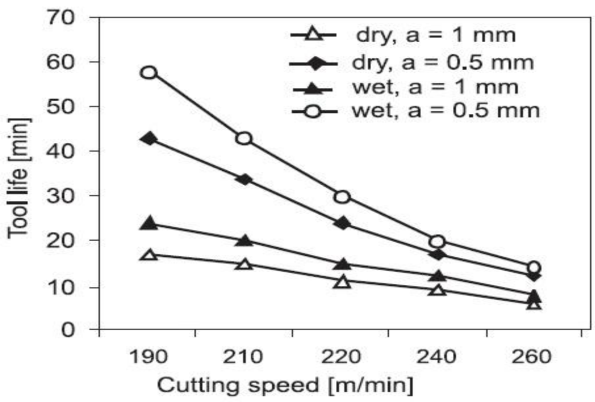


Fig.7. Tool life at different cutting speeds (f=0.14 mm/rev, a=1 mm, a=0.5 mm)

Fig.8 shows the variation of main cutting force with the machining time for certain machining conditions. The cutting force in dry turning was found compared to wet-cooled turning. In all the cases of cutting-speed turning, the cutting force is less in wet-cooled turning due to less flank wear. The relative advantage in cutting force offered by flood fluid cooling over the dry machining can also be seen from Fig.8. It is very clear from the curves that cutting force in wet-cooled machining is less than that of dry machining.

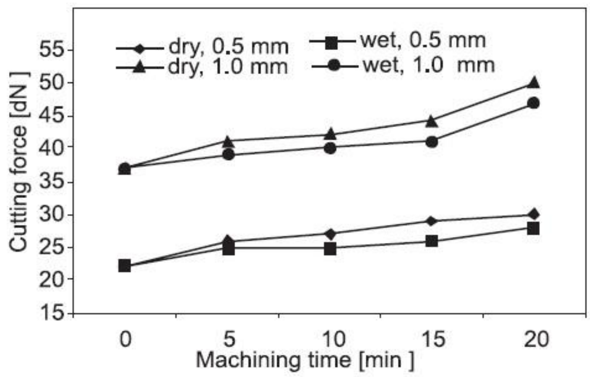


Fig.8. Tangential cutting force versus machining time with dry and wet cooled condition

The researcher concluded that the cutting fluid enabled to reduce the main cutting force due to improved and intimate chip tool interaction, the cutting fluid has significantly reduced the amount of heat and friction at the point where a tool cuts into a metal work piece.

## C. Effect of Dry, Flooded and Minimum Quantity Lubrication (MQL)



M. Venkata Ramana et al. [10] studied the Effect of dry, flooded and Minimum Quantity Lubrication (MQL) in turning of Ti-6Al-4V alloy. From Figure 9, it is observed that, the surface roughness is low for MQL compared to dry and flooded conditions. It is also observed that, the surface roughness increases as the cutting speed increases from low to moderate speeds for dry, flooded and MQL conditions, but from moderate to high cutting speeds, the surface roughness decreases for dry and flooded conditions, where as the surface roughness continuously increases for MQL conditions. This can be explained by the reason that, surface roughness increases due to temperature, stress and wear at tool tip increases. In comparison of MQL with dry and flooded lubricant conditions, the cutting fluid supplied at high pressure and velocity, which penetrates minute particles into tool-chip and tool-workpiece surfaces, causes reduction in friction leads to less surface roughness. In MQL condition, it provides both cooling and lubrication effectively and cooling occurs convective as well as evaporative heat transfer, hence less surface roughness is observed in MQL [11]. In flooded condition effective penetration of the cutting fluid into tool-chip and tool- work surface is not possible and also heat transfer takes place only with convective heat transfer. Hence, high surface roughness is observed in flooded compared to MQL condition, whereas in dry machining, no cutting fluid is supplied, which results into high friction, high tool wear and low heat transfer leads to high surface roughness. The increasing and decreasing pattern of surface roughness in dry and flooded conditions is observed. The main reason for this pattern is due to effect of other factors like interaction between feed and depth of cut.

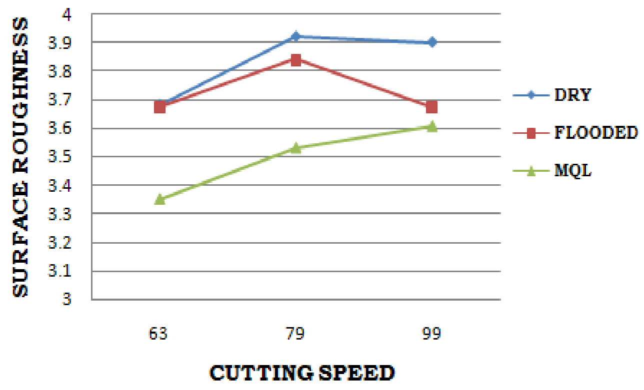


Fig.9. Variation of surface roughness with cutting Speed

Figure 10 shows the variation between feed rate and surface roughness under different lubricant conditions. As feed rate increases, the surface roughness also increases for dry, flooded and MQL conditions. It is observed from the Fig. 10 that, MQL shows reduction in surface roughness compared to dry and flooded condition under different feed rates [12]. As the feed rate increases, the surface roughness also increases due to the time available is less to carry out the heat from the machining zone, high amount of material removal rate and accumulation of chip between tool-workpiece zone.

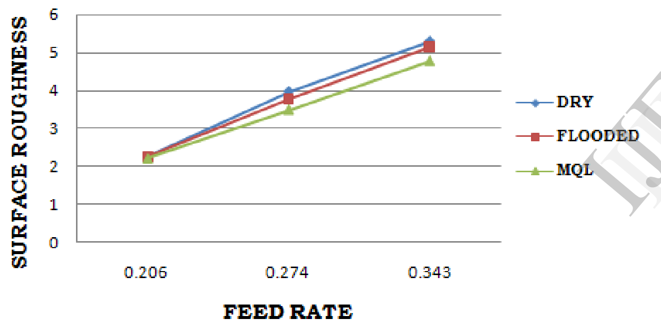


Fig.10. Variation of surface roughness with feed rate

Figure 11 shows the variation between depth of cut and surface roughness under different lubricant conditions. It is observed from the Fig.11 that, MQL shows reduction in surface roughness compared to dry and flooded condition under different depths of cut. As depth of cut increases, the surface roughness increases for dry, flooded and MQL conditions. This can be explained as more area in contact takes place between tool and workpieces, this results in high friction and tool wear leads to high surface roughness.

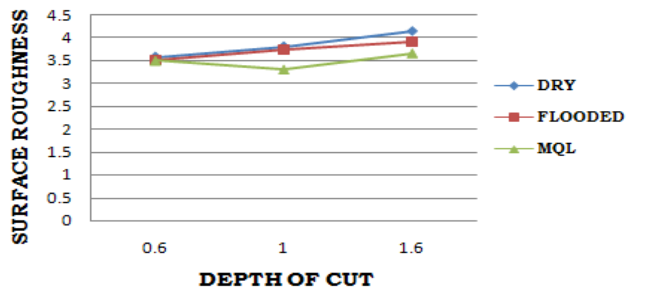


Fig.11. Variation of surface roughness with depth of cut

It is observed form Figure 12 that, uncoated carbide cutting tool shows better performance compared to CVD and PVD coated tool material in reduction of surface roughness. The reason for this is due to reaction between coated elements and titanium at high temperature forms carbide compounds. These compounds show greater wear due to its brittleness. It is seen form Figure 12, that the surface roughness is also low for MQL compared to dry and flooded conditions for each tool materials. Finally, it is concluded that MQL condition shows better performance in reduction of surface roughness compared to dry and flooded lubricant condition. Hence it is recommended that MQL can be implemented in order to improve surface finish, reduction in quantity of lubricant, cost and environmental pollution.



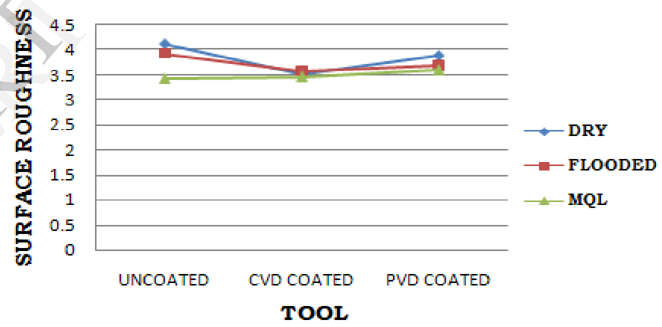


Fig.12. Variation of surface roughness with tool of material

D. Effect of Spindle Speed, Feed Rate and Depth of Cut

Neeraj Saraswat et al [13] studied the effects of spindle speed, feed rate and depth of cut in turning process on mild steel on surface roughness and as a result of that the combination of the optimal levels of the factors were obtained to get the lowest surface roughness.

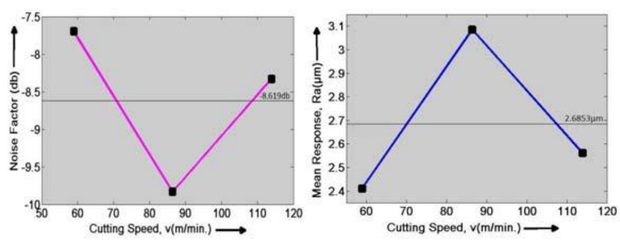


Fig.13. Effect of cutting Speed on mean response, Ra and Noise Factor

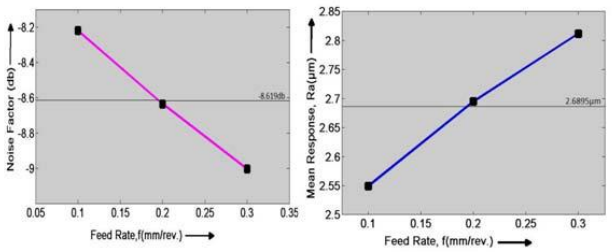


Fig.14. Effect of Feed Rate on Mean Response, Ra and Noise Factor

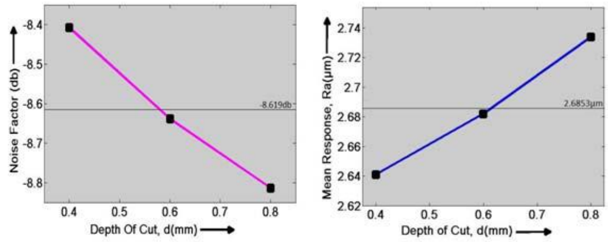


Fig.15. Effect of Depth of Cut on Mean Response, Ra and Noise Factor

E. Effect of Cutting Speed, Feed Rate and Depth of Cut

S. Ramesh et al. [14] has presented measurement and analysis of surface roughness in turning process of aerospace titanium alloy (gr5) under the influence of machining parameters like cutting speed, feed rate and depth of cut. The effect of machining parameters on surface roughness were analyzed and plotted in Figs. 16–18, showing the general trends between cause and effect.

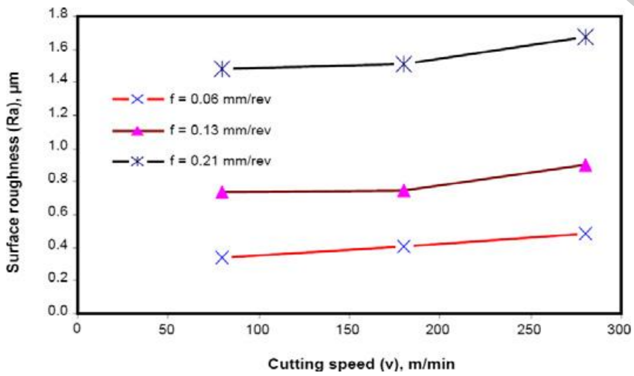


Fig.16. Effect of cutting speed and feed on surface roughness

From Fig.16 it can be seen that the increasing trend of surface roughness (Ra) is maximum for all levels of feed (f) with the increase of cutting speed (v) and an increasing trend is observed with increase in feed (f). When cutting speed and feed increase, the wear propagates on tool, so surface achieved was poor and hence the surface roughness also increases. These are the reasons for the above effect on surface roughness. It supports the findings in this investigation, that the feed is the main contributing factor.

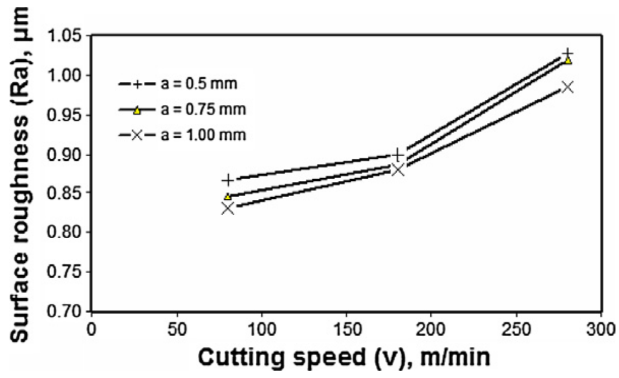


Fig.17. Effect of cutting speed and depth of cut on surface roughness

The effect of depth of cut on roughness is shown in Fig.17. It was found that the surface roughness varied drastically with the depth of cut except the higher depth of cut value. However, no systematic relationships were found between the interactions of cutting speed, depth of cut with the surface roughness value. This variation cannot be clearly explained, although it seems that it is related to the strain hardening of the materials. May be this is owing to the built-up edge formation on tool during the machining action tending to develop bad surface roughness.



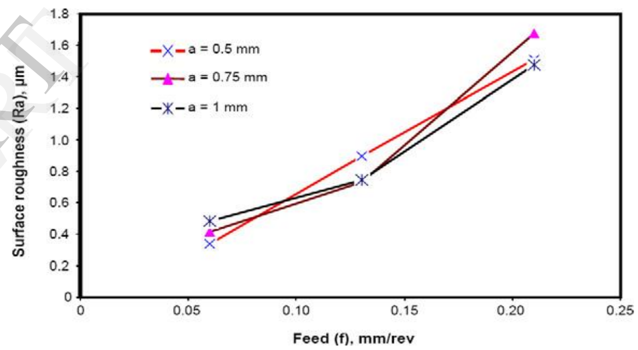


Fig.18. Effect of feed (f) and depth of cut (a) on surface roughness.

From Fig.18, it is clearly indicated that variation of depth of cut is not contributing any major change in surface roughness. Here all the three trend curves are fall in the same region to establish the findings of this investigation using model and optimization.

F. Effect of Nose Radius, Feed Rate and Depth of Cut

M. Nalbantet et al. [15] have taken orthogonal array, the signal-to-noise ratio, and analysis of variance for study the performance in turning operations of AISI 1030 steel bars using TiN coated tools. They took three parameters nose radius, feed rate and depth of cut for optimizing the surface roughness. L9 orthogonal array was used for the study. They found that for surface roughness the percentage contributions of insert radius, feed rate and depth of cut are 48.54, 46.95 and 3.39, respectively.

G. Effect of Machining Parameters (Cutting Speed, Feed Rate, Depth of Cut) and Insert Geometry (CNMG and DNMG Type Insert)

Jakhale Prashantet et al. [16] tried to investigate the effect of machining parameters (cutting speed, feed rate, depth of cut) and insert geometry(CNMG and DNMG type insert) on surface roughness in the high turning of alloy steel (280 BHN). They found that depth of cut is the most significant parameter which affects the surface finish and cutting speed and feed rate are least significant parameters.

H. Effect of Spindle Speed, Feed Rate and Depth of Cut

In the pre- experimentation for the study of dry turning on OHNS material; the relationships of spindle speed, feed rate and depth of cut versus Ra and MRR keeping all other remaining machining parameters constant is observed. The Ra varies with spindle speed, feed rate and depth of cut. The declination of $R_a$ over spindle speed from 1.16 to 0.54 and increase from 0.54 to 0.67. This variation of Ra is due to variation in shear strain, resultant shear force and normal force acting on shear plane area. The variation in MRR shows linear with spindle speed, feed rate and depth of cut.

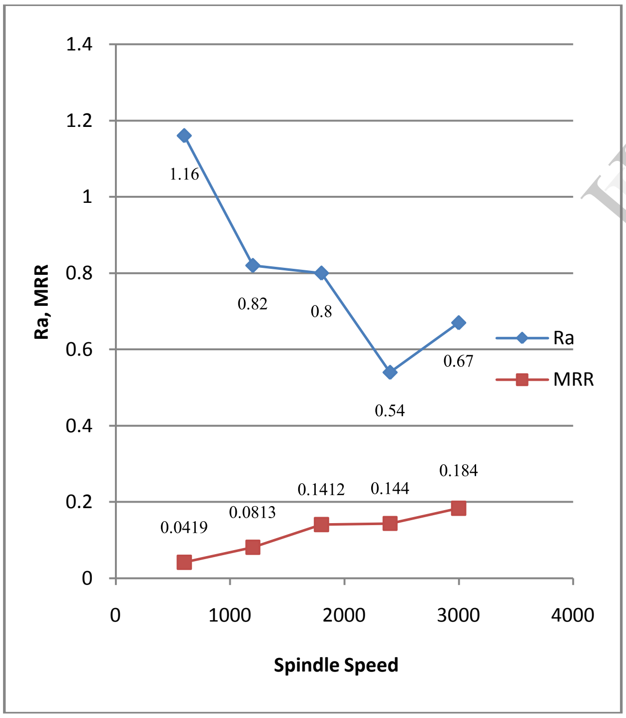


Fig.19. Spindle Speed Vs $R_a$, MRR

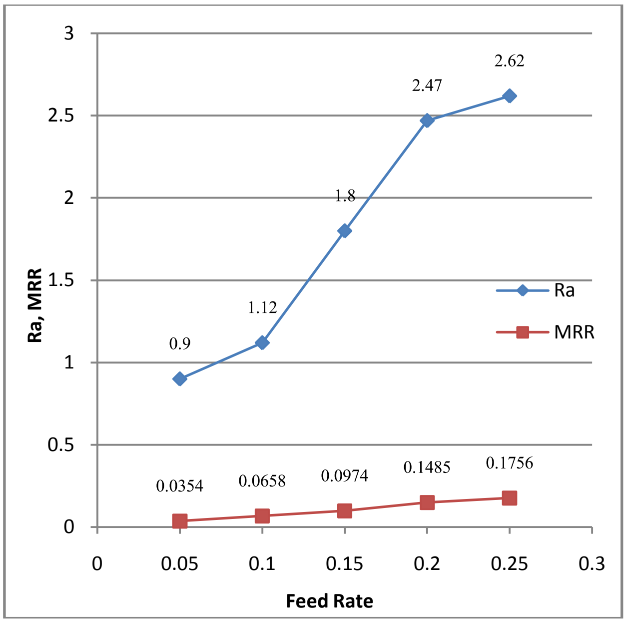


Fig.20. Feed Rate Vs $R_a$, MRR

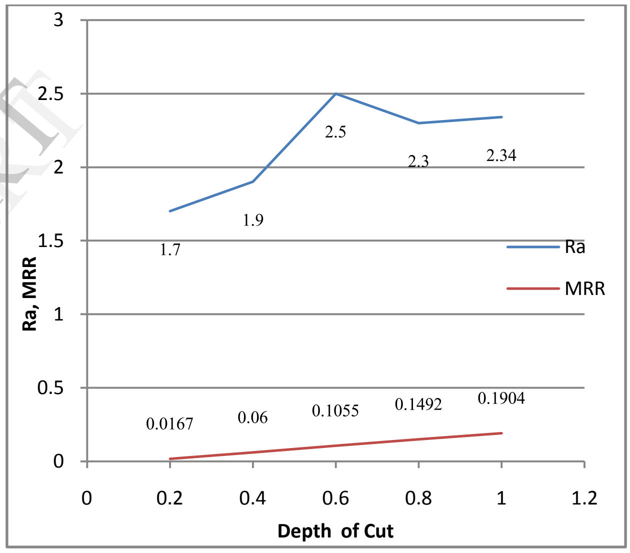


Fig.21. Depth of cut Vs $R_a$, MRR

## IV. CONCLUSION

From the above literature survey, it is presented that there are many researches on optimization techniques for machining parameters for surface roughness and material removal rate. Surface roughness and material removal rate in turning process depends upon different variable parameters like cutting speed, feed rate, depth of cut, rake angle, lubricant temperature, insert geometry etc. From pre-experimentation it is observed that the feed rate is the most influencing parameter affecting on surface roughness. As the feed rate is low the surface finish obtained is good as compared to higher feed rate. Feed rate causes the chatter marks on surface produced. At higher feed rate there may be chances of wear of the tool or in some cases the tool may get break. At high feed rate the cutting force, power required for machining is also high. For most tests, cutting speed did not show a significant effect on surface roughness for both dry and wet machining conditions. The effect of the cutting speed is negligible. However further detailed experimentation is to be carried out for precise prediction of behavior of above said variable parameters and to formulate the mathematical model of the same.

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