iJRASET
International Journal For Research in Applied Science and Engineering Technology



# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

**Volume:** 8 **Issue:** IX **Month of publication:** September 2020

**DOI:** https://doi.org/10.22214/ijraset.2020.31339

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
*ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429*
*Volume 8 Issue IX Sep 2020- Available at www.ijraset.com*

# Optimization of Turning Process Parameters in Machining Heat Treated Steel

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***Abstract:*** ***The present experimental approach on turning studies the process parameters that are affecting the machining performance and productivity of Plain Turning. The design of experiments is based on Taguchi's L9 orthogonal array. The response table and response graph for each level of machining parameters are obtained from Taguchi method to select the optimal levels of machining parameters. In the present work, the machining parameters are Speed, Feed Rate and Depth of Cut, which are optimized for maximum material removal rate (MRR) and minimum Surface Roughness during turning of Heat Treated Steel (EN-9).***

***Keywords: Turning, EN-9, MRR, Surface Roughness***

## I. INTRODUCTION

Today competitive market demands efficient manufacturing with high quality, optimum manufacturing cost and environmental sustainability consideration. This is achieved by advanced engineering materials and automated machining.

New industrial applications require materials with advanced properties for products particular requirements with reliable and economical manufacturing processes and higher productivity. These advanced engineering materials are used in automotive, aerospace, electronics, medical applications and others industries. The advanced and modified properties will improve the quality of these materials and help meet certain mechanical, electrical, or chemical requirements. Typical properties that are needed are tensile strength, hardness, thermal conductivity, and corrosion and wear resistance.

Studies have been performed by various researchers in the domain of plain turning. The researchers have performed analysis for providing knowledge of current plain turning trend.

S.R. Das et al [1] conducted experiments on Tungsten AISI 4340 steel with Coated Graphite tool inserts. Feed was found to be most significant parameter for the workpiece surface roughness (Ra) with a percent contribution of 52.55%. Cutting speed was found to be the next significant parameter for Ra with contribution of 25.85%. Depth of cut was found a negligible influence in case of Ra.

Jitendra. M. Varma et al [2] conducted experiments on AISI 4340 using solid lubricant with coated carbon tool inserts. It is concluded that the application of solid lubricant in dry machining has proved to be a feasible alternative to cutting fluid, if it can be applied properly. There is a considerable improvement in surface roughness and quality of product produced.

Karanam Krishna et al [3] carried an investigation using ANN for material removal rate on Aluminum in turning. This work investigated the influence of the operating parameters like feed rate, depth of cut, clamping length and spindle speed. It was evident that each of these parameters studied contributed to the error in the dimensions of the machined component. Depth of cut and the feed rate had more effect on the accuracy than the other parameters. Based on this ANN prediction, the NC program could be corrected before commencing the actual machining operation, thus improving the accuracy of the component at less cost and time.

A.Sathyavathi et al [4] carried a study on different researches conducted. The most of researchers are interested in optimization of machining condition with corresponding surface roughness. In past reviewed found, none of researcher involved for TiBN coated cemented carbide tool. In this paper uncoated carbide tool and PVD (TiBN) coated carbide tool involved for performance of quality of surface and optimization of cutting parameter with aid of DOE and GA.

M.M.A. Khan et al [5] carried an investigation to analyze the effects of minimum quantity lubrication on turning AISI 9310 alloy steel using vegetable oil-based cutting fluid. They concluded that the chips produced under both dry and wet condition are of ribbon type continuous chips at lower feed rates and more or less tubular type continuous chips at higher feed rates. The significant contribution of MQL jet in machining the low alloy steel by the carbide insert undertaken has been the reduction in flank wear, which would enable either remarkable improvement in tool life or enhancement of productivity (MRR) allowing higher cutting velocity and feed. The Surface finishes also improved mainly due to reduction of wear and damage at the tool-tip by the application of MQL.

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M. Venkata Ramana et al [6] carried experiments to study the effect of process parameters on tool wear in Turning of Titanium Alloy under different machining conditions It was concluded that the MQL machining shows advantage mostly by reducing tool wear as well as environmental problems, which reduces the friction between the chip - tool interaction. Using ANOVA, the effect each individual factors on tool wear found to be significance and the contribution of cutting speed is more followed by tool material, depth of cut, feed rate and coolant condition in order to minimizing tool wear.

Vikas B. Magdum et al [7] carried investigation to evaluate and optimize the machining parameters for turning of EN 8 steel using HSS M2, Carbide and Cermet tools. N.Zeelan Basha et al [8] optimized turning process parameters on Aluminium 6061 using Genetic Algorithm. Optimum surface finish was obtained at maximum cutting speed, minimum feed and minimum depth of cut.

## II. EXPERIMENTAL DETAILS

*1) Work Piece:* The material used for the present work is EN-9 (heat treated) with specification of 20mm diameter.

*2) Machine:* ACE CNC Turning Machine available at RR Institute of Modern Technology, Lucknow.

The present investigation is performed by varying speed, feed and depth of cut so as to analyze the MRR and surface roughness.



Fig. 1: ACE CNC Turning Machine




Fig. 2: Plain Turning machined Specimens

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Table I: Showing Parameters Used For Experimentation On Plain Turning Machine

| S.No. | Parameters | Units | Level 1 | Level 2 | Level 3 |
|---|---|---|---|---|---|
| 1 | Speed | RPM | 300 | 450 | 600 |
| 2 | Feed | mm/rev | 0.1 | 0.2 | 0.3 |
| 3 | Depth of Cut | mm | 0.2 | 0.4 | 0.6 |

Table III: Showing Experimental Values Of Mrr And Surface Roughness

| Exp. No | Speed (RPM) | Feed (mm/rev) | DOC (mm) | Speed (m/min) | MRR ($mm^3$/min) | Surface Roughness (Ra) |
|---|---|---|---|---|---|---|
| 1 | 300 | 0.1 | 0.2 | 15.072 | 301.44 | 6.13 |
| 2 | 300 | 0.2 | 0.4 | 15.072 | 1205.76 | 6.62 |
| 3 | 300 | 0.3 | 0.6 | 15.072 | 2712.96 | 6.88 |
| 4 | 450 | 0.1 | 0.4 | 22.608 | 904.32 | 7.11 |
| 5 | 450 | 0.2 | 0.6 | 22.608 | 2712.96 | 7.52 |
| 6 | 450 | 0.3 | 0.2 | 22.608 | 1356.48 | 6.77 |
| 7 | 600 | 0.1 | 0.6 | 30.144 | 1808.64 | 7.41 |
| 8 | 600 | 0.2 | 0.2 | 30.144 | 1205.76 | 6.96 |
| 9 | 600 | 0.3 | 0.4 | 30.144 | 3617.28 | 7.82 |

## III.RESULTS AND DISCUSSION

### *A. Influence of parameters on Material Removal Rate*

The following table III shows the analysis of variance for material removal rate of turned specimens. It shows that feed is the most crucial factor for material removal rate with a contribution of 40.99% while depth of cut is the second most dominating parameter with a contribution of 36.90%. It is also observed that cutting speed is the least influencing parameter for MRR and contributes only 11.40% towards it.

Table IIIII: Anova Table Of Material Removal Rate Of Turned Specimens

| Source | DOF | SS | Adj MS | F Value | Contribution |
|---|---|---|---|---|---|
| Speed | 2 | 1014671 | 507336 | 1.06 | 11..40% |
| Feed | 2 | 3649787 | 1824894 | 3.83 | 40.99% |
| Depth of Cut | 2 | 3286323 | 1643161 | 3.44 | 36.90% |
| Error | 2 | 954094 | 477047 | | 10.71% |
| Total | 8 | 8904875 | | | 100% |

Figure 3(a) shows main effect plot for MRR. While considering feed rate and depth of cut, steep lines are observed. The MRR is majorly influenced by these two turning parameters as previously depicted by ANOVA. A less influencing rather flat curve is observed for cutting speed with MRR. As the cutting parameters increases, the material is removed at a faster rate and hence MRR increases. MRR increases with increase in feed and the graph obtained shows that MRR is majorly influenced by feed rate. As we increase the feed, the thickness of material to be removed increases. This reduces lead time and hence increases material removal rate. In case of depth of cut, as the level of depth of cut is increased, material removal is observed to get increased. Depth of cut is the distance of newly machined surface to the uncut surface. Thus as it is increased, the thickness of material to be removed increases and hence it will increase the material removal rate. It can be seen from the three graphs shown above that all the three machining parameters viz. cutting speed, feed per revolution and depth of cut directly affect the MRR and increases with the increase in value of parameters. Maximum MRR is obtained at 600 RPM speed, 0.3 mm feed rate and 0.6 mm depth of cut.

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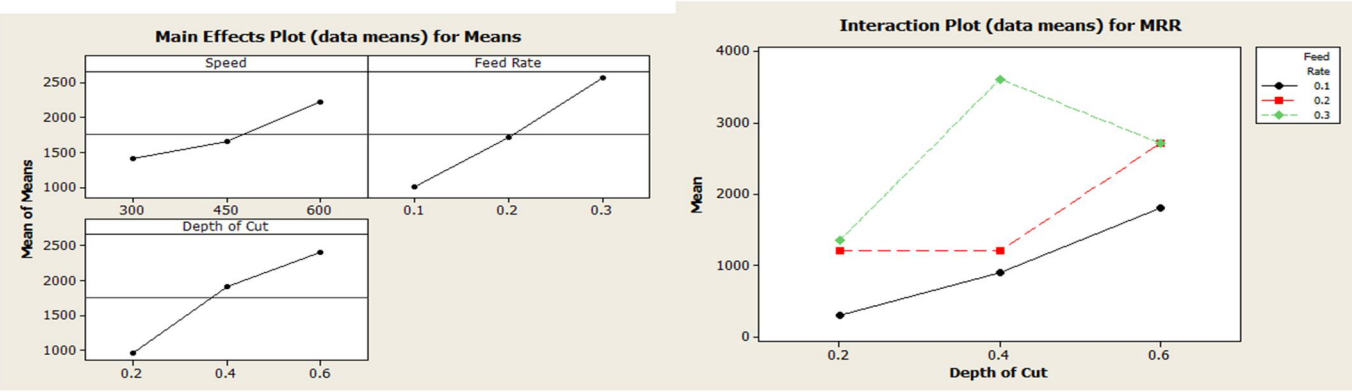



Fig. 3: (a) Main effect plot for MRR; (b) Interaction plot for MRR with parameters

The above figure 3(b) shows the interaction of MRR with plain turning parameters. It is seen from the graph that at lower feed rate, the MRR increases almost linearly with increase in the level of depth of cut. At highest level of feed rate i.e. 0.3 mm/rev, the MRR initially increases with increase in depth of cut, but with further increase in value of depth of cut the MRR tends to decrease.

*B. Influence of parameters on Surface Roughness*

The following table IV shows the analysis of variance for surface roughness. It depicts that speed is the major dominating turning parameter for the roughness of the surface machined and contributes 54.87%. It is followed by depth of cut with a contribution of 35.80%. Feed rate is found to be the least influencing parameter with only 5.38% contribution towards surface roughness.

Table IVV: Anova Table Of Surface Roughness

| Source | DOF | SS | Adj MS | F Value | Contribution |
|---|---|---|---|---|---|
| Speed | 2 | 1.14562 | 0.57281 | 13.90 | 54.87% |
| Feed | 2 | 0.11242 | 0.05621 | 1.36 | 5.38% |
| Depth of Cut | 2 | 0.74736 | 0.37368 | 9.07 | 35.80% |
| Error | 2 | 0.08242 | 0.04121 | | 3.95% |
| Total | 8 | 2.08782 | | | 100% |

Following figure 4(a) shows the main effect plot of parameters for surface roughness. From all the three graphs it is seen that the surface finish degrades with increasing the level of turning parameters. By increasing the cutting speed the surface roughness increases and the surface finish starts to degrade. Very rough surface is generated as we increase the cutting speed to the higher levels. In case of feed rate, it also affects the surface roughness in similar fashion. The surface degrades with the increase in feed rate as thicker layer of material is removed which will roughen the new exposed machined surface. Increase in depth of cut also degrades the surface finish of EN-9. The most influential factor for surface roughness is the cutting speed followed by depth of cut and lastly by feed rate. Lowest surface roughness is obtained at 300 RPM cutting speed, 0.1 mm/rev feed rate and 0.2 mm depth of cut.

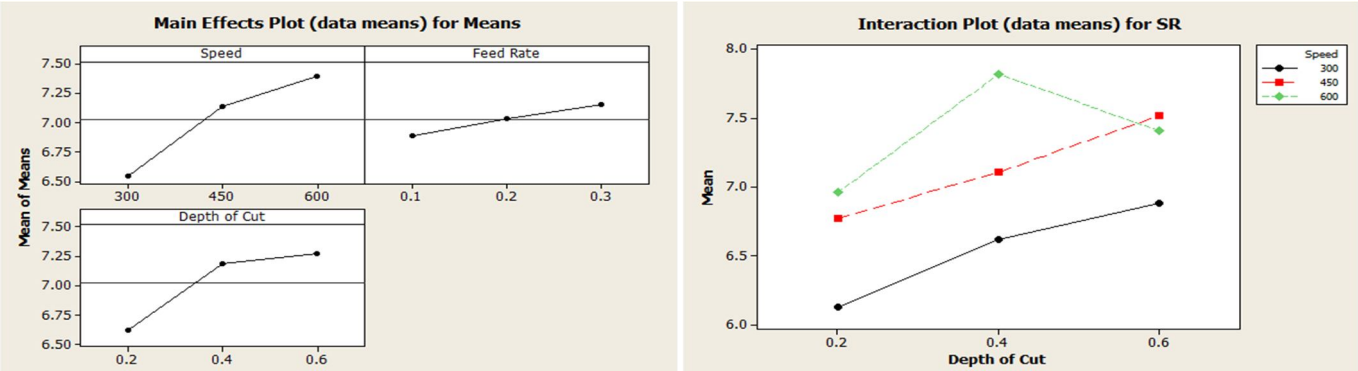



Fig. 4: (a) Main effect plot for Surface Roughness; (b) Interaction plot for Surface Roughness with parameters

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The above figure 4(b) shows the relation and interaction between surface roughness produced and plain turning parameters. A similar pattern is seen in the case of surface roughness as that of the MRR. It is seen from the graph that at lower speed, the surface degradation increases almost linearly with increase in the level of depth of cut. At highest level of speed i.e. 600 RPM, the surface initially degrades more with increase in depth of cut, but with further increase in value of depth of cut the surface roughness tends to decrease.

## IV. CONCLUSIONS

This experimental study described the optimization of input machining parameters viz. cutting speed, feed rate and depth of cut in plain turning of EN-9 using L9 orthogonal array of Taguchi method. Factors with different levels were found to play significant role in plain turning operation for maximization of MRR and minimization of Surface Roughness. Based on above work following conclusions are made:

*A.* As we increase the machining parameters, the material removal rate increases. While considering feed rate and depth of cut, steep lines are observed. The MRR is majorly influenced by these two turning parameters as previously depicted by ANOVA.

*B.* A less influencing rather flat curve is observed for cutting speed with MRR. As the cutting parameters increases, the material is removed at a faster rate and hence MRR increases. MRR increases with increase in feed and the graph obtained shows that MRR is majorly influenced by feed rate. As we increase the feed, the thickness of material to be removed increases. This reduces lead time and hence increases material removal rate.

*C.* In case of depth of cut, as the level of depth of cut is increased, material removal is observed to get increased. Depth of cut is the distance of newly machined surface to the uncut surface. Thus as it is increased, the thickness of material to be removed increases and hence it will increase the material removal rate.

*D.* It can be seen from the three graphs shown above that all the three machining parameters viz. cutting speed, feed per revolution and depth of cut directly affect the MRR and increases with the increase in value of parameters. Maximum MRR is obtained at 600 RPM speed, 0.3 mm feed rate and 0.6 mm depth of cut.

*E.* Feed rate is the most crucial factor for material removal rate with a contribution of 40.99% while depth of cut is the second most dominating parameter with a contribution of 36.90%. It is also observed that cutting speed is the least influencing parameter for MRR and contributes only 11.40% towards it.

*F.* By increasing the cutting speed the surface roughness increases and the surface finish starts to degrade. Very rough surface is generated as we increase the cutting speed to the higher levels.

*G.* In case of feed rate, it also affects the surface roughness in similar fashion. The surface degrades with the increase in feed rate as thicker layer of material is removed which will roughen the new exposed machined surface.

*H.* Increase in depth of cut also degrades the surface finish of EN-9. The most influential factor for surface roughness is the cutting speed followed by depth of cut and lastly by feed rate. Lowest surface roughness is obtained at 300 RPM cutting speed, 0.1 mm/rev feed rate and 0.2 mm depth of cut.

*I.* Speed is the major dominating turning parameter for the roughness of the surface machined and contributes 54.87%. It is followed by depth of cut with a contribution of 35.80%. Feed rate is found to be the least influencing parameter with only 5.38% contribution towards surface roughness.

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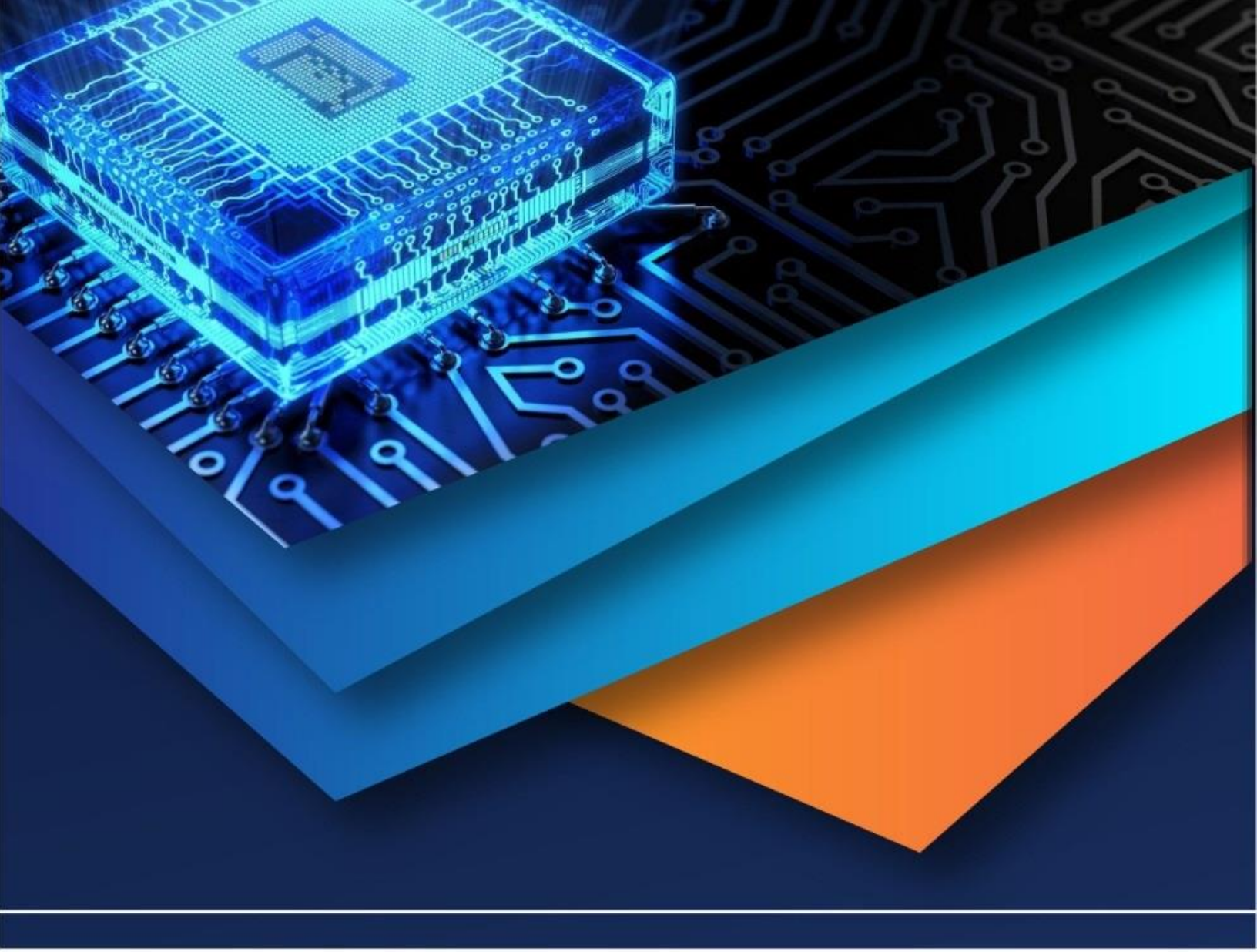
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