International Journal on Emerging Trends in Mechanical & Production Engineering
http://eurekajournals.com/mechanical.html
ISSN: 2581-4486

Optimization of Machining Parameters in Turning of EN 24 and EN 31 Alloy Steel

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Abstract

The machining industry continuously strives to achieve high-quality components characterized by superior surface finish, dimensional accuracy, and durability, all while ensuring cost efficiency and environmental sustainability. This study focuses on the optimization of machining parameters in the turning of EN24 and EN31 alloy steels to minimize surface roughness, a key indicator of product quality. The specific objectives were to evaluate the effects of cutting speed, depth of cut, and feed rate on surface roughness, determine optimal parameter settings, and develop a predictive mathematical model for surface quality.

The methodology involved conducting turning experiments on a CNC lathe using coated carbide inserts (ISO TNMG 160408). Surface roughness was measured using a precision roughness tester, and experiments were designed using the Taguchi Method with an L9 orthogonal array. The analysis was performed using Minitab software, which facilitated the generation of main effect and interaction plots to understand the influence of individual and combined machining parameters. Results indicated that cutting speed and feed rate were the most significant factors affecting surface roughness, whereas the depth of cut showed minimal impact. A mathematical model was developed to predict surface roughness based on the experimental data, offering a practical tool for process planning.

The study concludes that optimizing machining parameters can significantly improve surface finish, thereby enhancing component performance and longevity. This research contributes to the field of precision manufacturing by providing a systematic approach to parameter optimization, which can be adopted across various industrial applications. The findings not only enable manufacturers to produce high-quality components more efficiently but also reduce resource wastage and operational costs, aligning with sustainable manufacturing goals. This work highlights the practical value of integrating robust experimental designs and statistical tools in machining process optimization.

Keywords: Machining, Surface Roughness, Cutting Speed, Depth of Cut, Feed Rate, EN 24, En 31.

Introduction

Machining encompasses diverse processes aimed at transforming raw materials into precise shapes and dimensions. In modern industry, the core focus lies on achieving high reliability, superior quality, and cost-effective production. The challenge for mass production firms revolves around ensuring dimensional accuracy, reduced tool wear, minimal use of cutting fluids, and high productivity within constrained timeframes. Despite advancements in machine tool technology, suboptimal operating conditions often lead to inefficiencies in manpower, materials, and productivity. This highlights the necessity of optimizing machining parameters to enhance economic viability.

Turning, a pivotal metal machining process, involves rotating a workpiece while a stationary tool removes material. This operation is fundamental to machining, applicable on both conventional lathe machines requiring manual intervention and CNC machines offering automation and precision. Modern-day machining predominantly relies on CNC technology, facilitating repeatable, accurate, and high-speed production. Key parameters influencing turning operations include cutting speed, feed rate, depth of cut, tool geometry, and coolant conditions. Proper optimization of these factors directly impacts tool life, surface roughness, cutting forces, and material removal rates.

Recent innovations, such as coated cutting tool inserts, have enabled machining of high-strength materials with defined cutting edges, making turning a viable alternative to processes like grinding. Surface finish, a critical quality metric, affects fatigue strength, corrosion resistance, and load-bearing capacity, necessitating precise control over surface roughness to suit specific applications. This paper aims to investigate the influence of machining parameters onsurface roughness during turning operations.

The aim of the present work is to optimize the cutting parameters such as cutting speed, depth of cut and feed rate so as to achieve the best surface roughness value. Optimized value of each parameter should be obtained. For these purpose two work materials EN24 and EN31 has been taken.

Objective of the Work

i. To study the effect of cutting parameters on Surface Roughness for EN24 and EN31.
ii. To optimize the cutting parameters so as to achieve best Surface Roughness.

Literature Review

Aslan et al. (2007) [1] studied the machining of AISI 4140 steel using a lathe and coated ceramic inserts. Using the Taguchi approach and ANOVA, they observed that surface roughness decreased with an increase in speed and increased with feed rate. Similarly, Thamizhmanii, S., et al. (2007) [2] analyzed optimal cutting conditions for minimizing surface roughness while turning SCM 440 alloy steel with coated ceramic tools, employing Taguchi's mixed-level L18 orthogonal array. Lalwani et al. (2008) [3] investigated the effect of cutting parameters on cutting forces and surface roughness during hard turning of

MDN250 using coated ceramic tools, utilizing response surface methodology (RSM). Bhattacharya (2009) [4] focused on machining AISI 1045 steel at high speeds using the Taguchi method, identifying cutting speed as the most significant factor influencing surface finish.

Natarajan, C., et al. (2010) [5] designed an artificial neural network (ANN) model to predict surface roughness during the dry turning of C26000 metal, revealing that feed rate had the most significant impact. Asilturk and Akkus (2011) [6] conducted a turning operation on hardened AISI 4140 with coated carbide inserts, using the Taguchi method to minimize surface roughness and finding feed rate to have a significant effect. Similarly, Babu, V. Suresh, et al. (2011) [7] developed a second-order model to predict surface roughness while machining EN24 steel alloy, showing feed rate as the most significant factor. Ilhan Asilturk and Harun Akkus (2011) [8] also studied the effect of cutting parameters on surface roughness during hard turning of AISI 4140 with coated carbide tools, confirming feed rate as the most influential factor.

D.V. Lohar et al. (2013) [9] evaluated the performance of a minimum quantity lubrication (MQL) system while turning AISI 4340, reporting reduced cutting forces, lower temperatures, and improved surface finish with MQL. Krishan Prasad, D.V.V. (2013) [10] examined the impact of machining and tool parameters on surface roughness using a full factorial design, concluding that feed rate was the most significant factor. Y.B. Kumbhar et al. (2013) [11] optimized tool life and surface roughness using PVD-coated carbide inserts during semi-hard turning of EN31 alloy steel under dry cutting conditions, with feed rate being a key factor. Francis, Vishal, et al. (2014) [12] optimized cutting parameters in turning mild steel to study surface roughness and material removal rate, with feed rate significantly influencing surface roughness.

G. Harinath Gowd et al. (2014) [13] utilized hybrid decision-making tools to determine optimal machining parameters during CNC turning of EN-31, identifying speed and depth of cut as significant factors affecting force and temperature. Harsh Y Valera and Sanket N Bhavsar (2014) [14] investigated surface roughness and power consumption in turning EN31 alloy steel with coated tungsten carbide tools, highlighting the importance of spindle speed, feed rate, and depth of cut. Koura, M. M., et al. (2014) [15] developed a surface roughness model using an artificial neural network for turning mild steel with carbide inserts, showing feed rate as the most significant factor. Lodhi, B. K., and Shukla, R. (2014) [16] optimized surface roughness and material removal rate during CNC turning of AISI 1018 alloy with titanium-coated carbide inserts, with spindle speed being the most significant parameter.

Kacal and Yildirim (2012) [17] studied high-speed turning of hardened AISI S1 steel with ceramic and CBN tools, reporting better surface roughness with CBN tools. Ravinder Tonk et al. (2012) [18] examined the effects of parametric variations on turning EN31 alloy steel using Taguchi's robust design methodology, with feed rate significantly influencing surface roughness. Rodrigues, L.L.R., et al. (2012) [19] analyzed the effect of feed, speed, and depth of cut on surface roughness and cutting force in turning mild steel with HSS tools, identifying feed and its interaction with speed as key factors. Sharma, N., et al. (2012) [20] used

ANOVA and Taguchi's L18 orthogonal array to optimize turning parameters for AISI 410 steel with TiN-coated P20 and P30 cutting tools, highlighting the significance of feed rate and insert radius on surface roughness.

Somashekara, H.M., and Swamy, N.L. (2012) [21] determined optimal settings for turning Al6351-T6 alloy using regression and ANOVA, with cutting speed significantly affecting surface roughness. Suresh et al. (2012) [22] investigated machining of hardened AISI 4340 steel with CVD-coated carbide inserts, identifying feed rate and speed combinations as crucial for achieving minimum surface roughness. Yadav, U.K., et al. (2012) [23] optimized surface roughness during turning of AISI 1045 steel, with feed rate being the most significant factor. Finally, Bala Raju, J., et al. (2013) [24] explored the effects of cutting parameters during the turning of mild steel and aluminum with HSS tools, finding feed rate to be significant for both surface roughness and cutting force.

From the literature review it is found that cutting speed, depth of cut and feed rate are the most important parameters which affect the surface roughness while turning. Many combinations has been used, however still more work can be done to find out the best possible combination of all the three parameters so as to optimize the surface roughness.

Research Methodology

➢ Experimental Description

The experiments were conducted using the Taguchi method to study the influence of machining parameters on surface roughness during turning operations. A three-factor, three-level design was selected to investigate the effects of cutting speed, depth of cut, and feed rate on the response variable, surface roughness . An L9 orthogonal array (OA) was utilized to ensure a balanced and efficient experimental design.

➢ Experimental Setup

1. **Equipment**

- Lathe machine (CNC) capable of consistent speed and precision operations.
- Carbide cutting inserts for maintaining consistent tool geometry and reducing wear effects.
- Surface roughness measuring instrument RT10 roughness tester.

2. **Material**

- Workpiece material: Alloy steel EN-24 and EN-31 were used for the experiment.
- A coated carbide insert was used for the experiment. It is TNMG 160408ISO designation, type of insert.

3. **Factors and Levels**: The levels for each factor were selected based on preliminary studies and practical operating conditions:

➢ Taguchi Design Matrix

The L9 orthogonal array ensured a minimum number of experiments to investigate the parameter space comprehensively.

➢ Procedure

1. Planning Phase

- Defined objectives and critical parameters.
- Selected levels and factors based on machine specifications and material properties.
- Designed experiments using Minitab statistical software.

2. Conducting Phase

- Conducted each experiment as per the matrix, ensuring stable spindle speed, feed rate, and depth of cut for each trial.
- Recorded surface roughness (Ra) using the Profilometer after each trial.

3. Analysis Phase

- Processed the data using signal-to-noise (S/N) ratio calculations to determine the robustness of each parameter.
- Performed ANOVA to identify the most significant factors influencing Ra

➢ Critical Steps

- Ensuring tool sharpness and alignment before each trial.
- Maintaining uniform environmental conditions (e.g., temperature, humidity) to minimize noise.

➢ Experimental Work

Experimental layout

Process Parameters

Input Parameters

Input cutting parameters selected are speed, depth of cut and feed rate at three different levels.

The following table shows the levels of the cutting parameters chosen.

Table 4.1:Input Process parameters

Parameters	**Unit**	**Levels**		
		1	**2**	**2**
Cutting Speed (v)	m/min	150	175	200
Depth of cut (d)	mm	1	1.5	2
Feed rate (f)	mm/rev	0.2	0.25	0.3

Response

- Surface Roughness.

Experimental design

- Taguchi Orthogonal Array Design L9 (3^3) was used.
- Total 18 experiments were performed, 9 for both EN24 and EN31each.

Table 4.2: Taguchi Matrix used for both EN24 and EN31

Sr. No.	Cutting Speed (v) (m/min)	Depth of cut (d)(mm)	Feed rate (f) (mm/rev)
1	150	1	0.2
2	150	1.5	0.25
3	150	2	0.3
4	175	1	0.25
5	175	1.5	0.3
6	175	2	0.2
7	200	1	0.3
8	200	1.5	0.2
9	200	2	0.25

Response Data for EN 24

Table 4.3: Factors and Response Reading Table for EN24

Sr. No.	Cutting Speed (v)	Depth of cut (d)	Feed rate (f)	SurfaceRoughness (Ra)
1	150	1	0.2	2.95
2	150	1.5	0.25	3.44
3	150	2	0.3	3.85
4	175	1	0.25	3.18
5	175	1.5	0.3	3.58
6	175	2	0.2	2.15
7	200	1	0.3	3.31
8	200	1.5	0.2	1.96
9	200	2	0.25	2.41

Response Data for EN 31

Table 4.4: Factors and Response Reading Table for EN31

Sr. No.	Cutting Speed (v)	Depth of cut (d)	Feed rate (f)	Surface Roughness (Ra)
1	150	1	0.2	2.88
2	150	1.5	0.25	3.42
3	150	2	0.3	3.95
4	175	1	0.25	3.15
5	175	1.5	0.3	3.65
6	175	2	0.2	2.29

7	200	1	0.3	3.35
8	200	1.5	0.2	2.02
9	200	2	0.25	2.55

Results and Discussion

EN 24

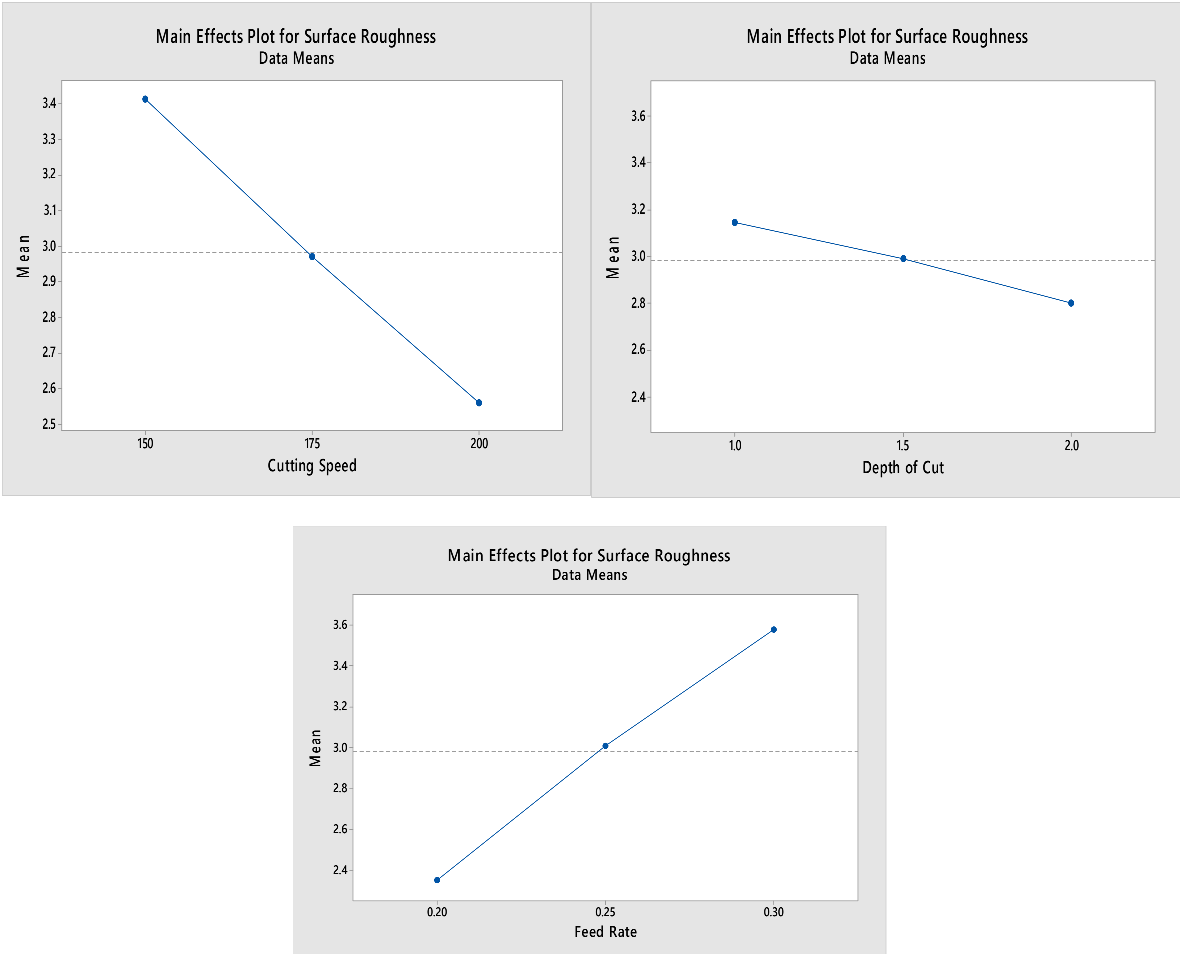

Figure 5.1: Main effects plot for Surface Roughness verses input parameters for EN 24

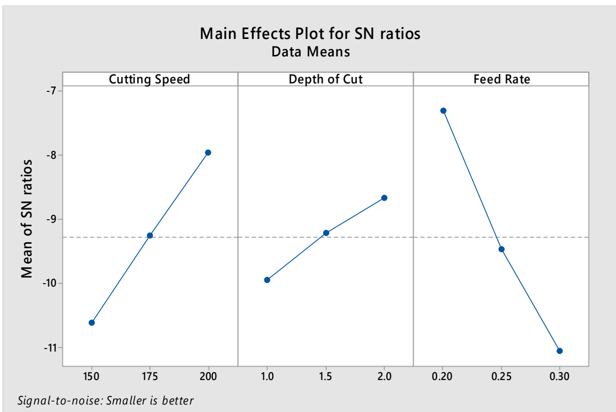

Figure 5.2: Main effects plot for SN ratios for EN 24

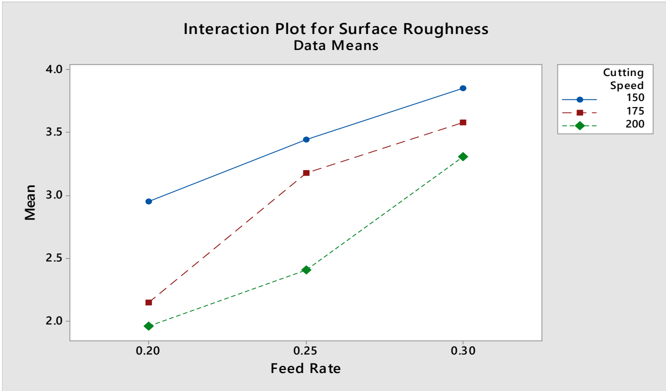

Figure 5.3: Interaction plot for Surface Roughness for cutting speed vs feed rate for EN 24

i. **Effect of Cutting Speed -** It is observed from the figure 5.1 that as cutting speed increases from 150 m/min to 200 m/min the value of surface roughness decreases from 3.41to 2.56. This is similar for various combinations of the seed rate and depth of cut. However the effect of feed rate and depth of cut is more predominant at lower speeds as compared to higher speeds.

ii. **Effect of Depth of Cut -** Effect of depth of cut on the surface roughness is minimal as shown in figure 5.1. As it increases from 1.0 mm to 2.0 mm the value of surface roughness decreases from 3.14 to 2.80.

iii. **Effect of Feed Rate -** The feed rate also strongly affects the surface roughness. As it increases from 0.2 mm/rev to 0.3 mm/rev the value of surface roughness increases from 2.35 to 3.58 as shown in figure 5.1

EN 31

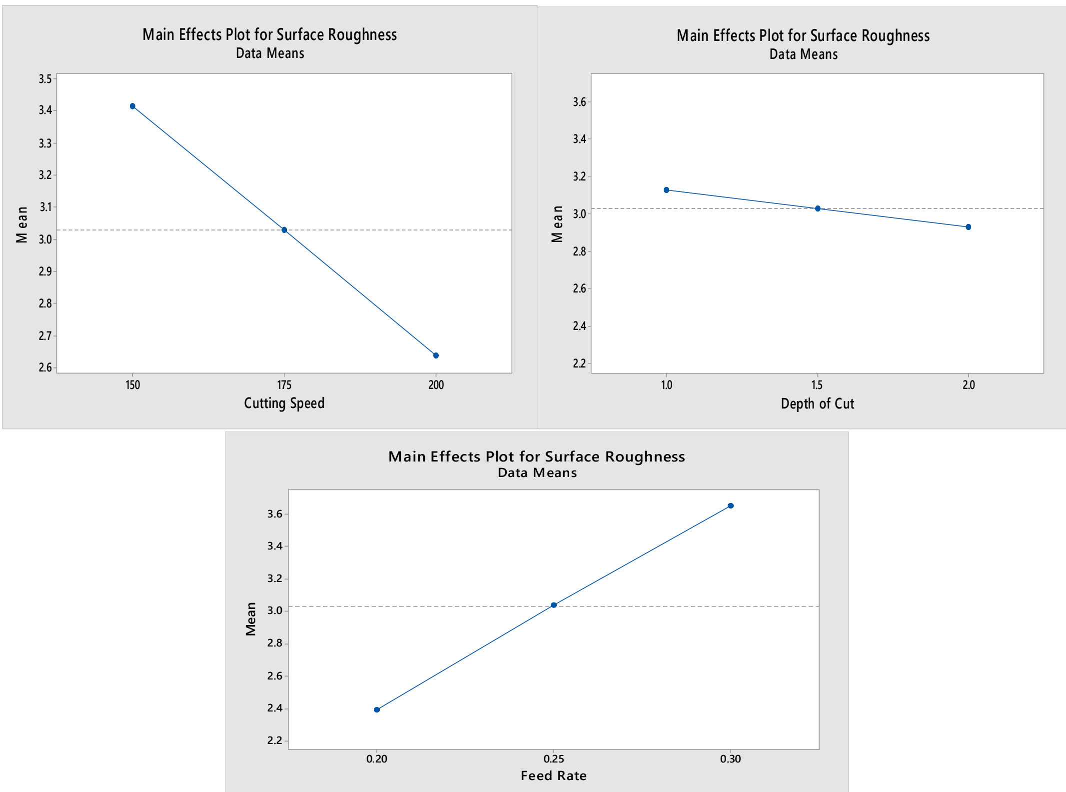

Figure 5.4: Main effects plot for Surface Roughness verses input parametersfor EN 31

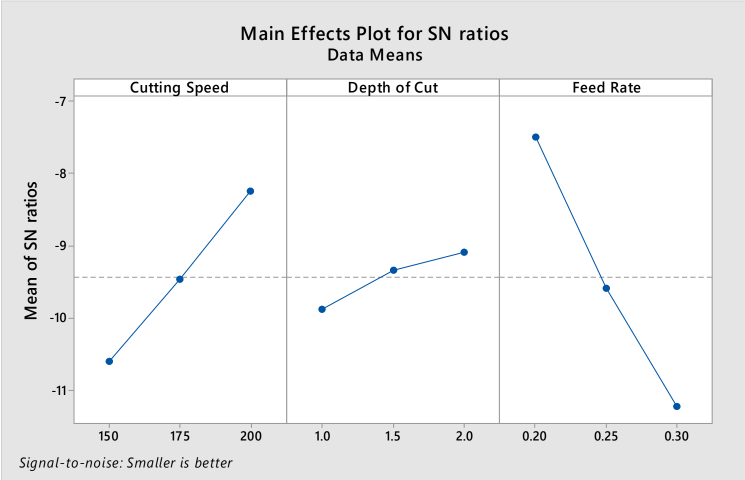

Figure 5.5: Main effects plot for SN ratios for EN 31

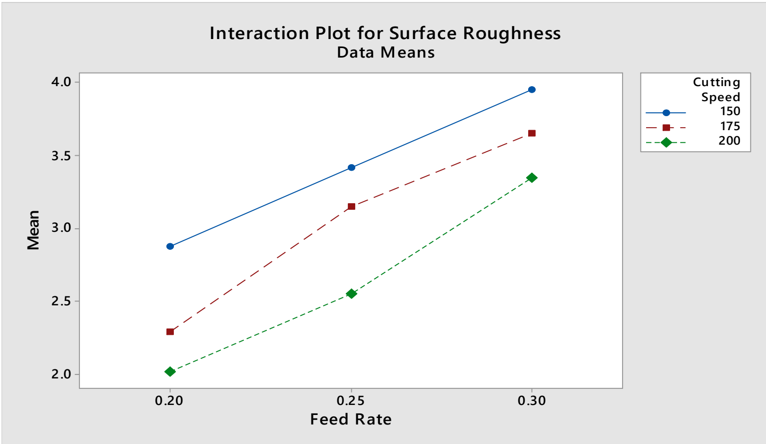

Figure 5.6: Interaction plot for Surface Roughness for cutting speed vs feed rate for EN 31

i. **Effect of Cutting Speed -** It is seen from the figure 5.4 that as cutting speed increases from 150 m/min to 200 m/min the value of surface roughness decreases from 3.41to 2.64. This is similar for various combinations of the seed rate and depth of cut. However the effect of feed rate and depth of cut is more predominant at lower speeds as compared to higher speeds.

ii. **Effect of Depth of Cut -** As depth of cut it increases from 1.0 mm to 2.0 mm the value of surface roughness decreases from 3.12 to 2.93. As shown in figure 5.4 effect of depth of cut on the surface roughness is minimal.

iii. **Effect of Feed Rate -** As the feed rate increases from 0.2 mm/rev to 0.3 mm/rev the value of surface roughness increases from 2.39 to 3.65 as shown in figure 5.4. The feed rate also strongly affects the surface roughness.

Conclusions

The following conclusions can be made from the study:-

1) Increase in cutting speed decreases surface roughness. As the cutting speed increases from 150 m/min to 200 m/min the value of surface roughness decreases from 3.41to 2.56 for EN 24 and from 3.41to 2.64 for EN 31.

2) Effect of depth of cut on the surface roughness is minimal. As depth of cut increases from 1.0 mm to 2.0 mm the value of surface roughness decreases from 3.14 to 2.80 for EN 24 and from 3.12 to 2.93 for EN 31.
3) Surface roughness increases with the increase in feed rate. As the feed rate increases from 0.2 mm/rev to 0.3 mm/rev the value of surface roughness increases from 2.35 to 3.58 for EN 24 and from 2.39 to 3.65 for EN 31.

Best surface roughness value is achieved at higher value of cutting speed and lower value of feed rate. The following combination of the parameters has given the minimum surface roughness value of 1.96 for EN 24 and 2.02 for EN 31.

Cutting speed	Depth of cut	Feed rate
200 m/min	1.5 mm	0.2 mm/rev

Scope for Future Work

1. In the present work EN 24 & EN 31 alloy steel were used for machining process so in future work, other hard materials can be used for machining by the same process varying speed, feed and depth of cut in L-9 orthogonal array design and taguchi method may be used for analysis.
2. Some other cutting inserts may be used for cutting instead of coated carbide insert and the experiment may be repeated in same way the result may be compared with previous result.
3. Other techniques may be used for analysis process instead of Taguchi method.
4. Work can be done by varying tool geometry.

References

[1]Aslan, E., Camuscu, N., &Bingoren, B. (2007). Design optimization of cutting parameters when turning hardened AISI 4140 with Al2O3+TiCN mixed ceramic tool. Journal of Materials Processing Technology, 28, 1618-1622.

[2]Thamizhmanii, S., Saparudin, S., & Hasan, S. (2007). Analyses of surface roughness by turning process using Taguchi method. Journal of Achievements in Materials and Manufacturing Engineering, 20, 503-506.

[3]Lalwani, D. I., Mehta, N. K., & Jain, P. K. (2008). Experimental investigations of cutting parameters influence on cutting forces and surface roughness in hard turning of MDN250 steel. Journal of Materials Processing Technology, 167-179.

[4]Bhattacharya, A., Das, S., Majumder, P., & Batish, A. (2009). Estimating the effect of cutting parameters on surface finish and power consumption during high speed machining of AISI 1045 steel using Taguchi design and ANOVA. Production Engineering Research and Development Journal, 3, 31-40.

[5]Natarajan, C., Muthu, S., &Karuppuswamy, P. (2011). Investigation of cutting parameters of surface roughness for a non-ferrous material using artificial neural network in CNC turning. Journal of Mechanical Engineering Research, 3, 1-14.

[6]Asiltürk, I., &Akkus, H. (2011). Determining the effect of cutting parameters on surface roughness in hard turning using the Taguchi method. Measurement, 44, 1697-1704.

[7]Babu, V. S., Kumar, S. S., Murali, R. V., & Madhava Rao, M. (2011). Investigation and validation of optimal cutting parameters for least surface roughness in EN24 with response surface method. International Journal of Engineering, Science and Technology, 3, 146-160.

[8]IlhnAsilturk, Harun Akkus (2011) "Determining the Effect of Cutting Parameter on Surface Roughness in Hardtuning Using the Taguchi Method"measurement 44 ,1697-1704.

[9]Lohar, D. V., & Nanavaty, C. R. (2013). Performance evaluation of minimum quantity lubrication (MQL) using CBN tool during hard turning of AISI 4340 and its comparison with dry and wet turning. Journal of BIJIEMS, 3, 102.

[10]Krishan Prasad, D. V. V. (2013). Influence of cutting parameters on turning process using ANOVA analysis. Research Journal of Engineering Sciences, 2, 1-6.

[11]Kumbhar, Y. B., & Waghmare, C. A. (2013). Tool life and surface roughness optimization of PVD TiAlN/TiN multilayer coated carbide inserts in semi-hard turning of hardened EN31 alloy steel under dry cutting conditions. Journal of Advanced Engineering Research Studies, 2, 22.

[12]Francis, V., Singh, R. S., Singh, N., Rizvi, A. R., & Kumar, S. (2013). Application of Taguchi method and ANOVA in optimization of cutting parameters for material removal rate and surface roughness in turning operation. International Journal of Mechanical Engineering and Technology, 4, 47-53.

[13]Gowd, G. H., & Goud, M. V. (2014). Optimal selection of machining parameters in CNC turning process of EN-31 using intelligent hybrid decision-making tools. Elsevier, 97, 125.

[14]Valera, H. Y., & Bhavsar, S. N. (2014). Experimental investigation of surface roughness and power consumption in turning operation of EN31 alloy steel. Procedia Technology, 14, 528-534.

[15]Koura, M. M., Sayed, T. H., & El-Akkad, A. S. (2014). Modeling and prediction of surface roughness. International Journal of Engineering Research & Technology, 3, 694-699.

[16]Lodhi, B. K., & Shukla, R. (2014). Experimental analysis on turning parameters for surface roughness and MRR. Journal of Emerging Technologies and Innovative Research, 1, 554-557.

[17]Kacal, A., & Yıldırım, F. (2013). Application of grey relational analysis in high-speed machining of hardened AISI D6 steel. Proceedings of IMechE Part C: Journal of Mechanical Engineering Science, 227(7), 1-13.

[18]Tonk, R., &Ratol, J. S. (2012). Investigation of the effects of the parametric variations in turning process of EN31 alloy. International Journal of Engineering Trends and Technology, 3, 160.

[19]Rodrigues, L. L. R., Kantharaj, A. N., Freitas, W. R. C., & Murthy, B. R. N. (2012). Effect of cutting parameters on surface roughness and cutting force in turning mild steel. Research Journal of Recent Sciences, 1, 19-26.

[20]Sharma, N., Ahmad, S., Khan, Z. A., &Siddiquee, A. N. (2012). Optimization of cutting parameters for surface roughness in turning. International Journal of Advanced Research in Engineering and Technology, 3, 86-96.

[21]Somashekara, H. M., & Swamy, N. L. (2012). Optimizing surface roughness in turning operation using Taguchi technique and ANOVA. International Journal of Engineering Science and Technology, 4, 1967-1973.

[22]Suresh, R., Basavarajappa, S., & Samuel, G. L. (2012). Some studies on hard turning of AISI 4340 steel using multilayer coated carbide tool. Measurement, 45, 1-10.

[23]Yadav, U. K., Narang, D., & Attri, P. S. (2012). Experimental investigation and optimization of machining parameters for surface roughness in CNC turning by Taguchi method. International Journal of Engineering Research and Applications, 2, 2060-2065.

[24]BalaRaju, J., Kumar, A., Dayal Saran, P., & Rao, C. S. K. P. (2015). Application of Taguchi technique for identifying optimum surface roughness in CNC end milling process. International Journal of Engineering Trends and Technology, 2, 103-110.