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Experimental Investigation and Process Parameter Optimization on En353 with PCBN Inserts

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Abstract **- Machining of materials by super hard tool like PCBN is to reduce tool wear to obtain dimensional accuracy, smooth surface and more number of parts per cutting edge. Wear of tools inevitable due to rubbing action between work material and tool edge. However, the tool wear can be minimized by using super hard tools by enhancing the strength of the cutting inserts. Extensive study has been conducted in the past to optimize the process parameters in any machining process to have the best product. Current investigation on turning process is a Taguchi optimization technique applied on the most effective process parameters i.e. feed, cutting speed and depth of cut while machining the work piece with tool. The experiments were carried out by a CNC lathe, using PCBN tool for the machining of EN 353 steel. The Taguchi technique and ANOVA were used to obtain optimal Turning parameters in the Turning of SS420 under wet conditions. The optimal factor for Surface Roughness-A1(Speed - 1500)B2(Feed – 0.04)C3(DOC – 0.75), Machining Timing-A1(Speed-1500)B2(Feed 0.04)C3(DOC 0.75), Material Removal Rate-A2(Speed-1750)B1(Feed 0.02)C3(DOC 0.75). The Percentage of contribution for each Process parameter is Surface Roughness-Speed 38.59%, Machining Timing - Speed 35.98%, Material Removal Rate- Feed 29.83%.**

Keywords: Turning, EN 353 steel, PCBN inserts, Surface Roughness, MRR, and Machining time

1. INTRODUCTION

Metal cutting is one of the vital processes and widely used manufacturing processes in engineering industries. Highly competitive market requires high quality products at minimum cost. Products are manufactured by the transformation of raw materials. Industries in which the cost of raw material is a big percentage of the cost of finished goods, higher productivity can be achieved through proper selection and use of the materials. To improve productivity with good quality of the machined parts is the main challenge of metal industry; there has been more concern about monitoring all aspects of the machining process. Surface finish is an important parameter in manufacturing engineering and it can influence the performance of mechanical parts and the production costs. The ratio of costs and quality of products in each production phase has to be monitored and good corrective actions have to be taken in case of deviation from desired output. Surface roughness measurement presents an important task in many engineering applications. Many life attributes can be also determined by how well surface finish is maintained.

Surface roughness is also a vital measure as it may influence frictional resistance, fatigue strength or creep life of machined components. As far as turned components are concerned, better surface finish (low surface roughness) is important as it can reduce or even completely eliminate the need of further machining. Many researchers have found that surface roughness has bearing on heat transmission, ability to hold lubricant, surface friction, wear etc. Despite the fact that surface roughness plays a very important role in the utility and life of a machined component due to its dependence on several process parameters and numerous uncontrollable factors machining process has no complete control over surface finish obtained. So the venture of controlling process parameters so as to produce best surface finish is an on-going process varying from various materials to tool combinations and the machining conditions. The present work is aimed at studying the influence of the three major process parameters in a turning operation namely, speed, feed and depth of cut and surface roughness for a predefined combination of material and tool under the given set of machining conditions.

2. RELATED WORK

Literature is very rich in terms of turning operations owing to its importance in metal cutting. The three important process parameters in this research are speed, feed and depth of cut. Surface roughness of a turned work-piece is dependent on these process parameters and also on tool geometry. In addition, it is also depends on the several other exogenous factors such as: work piece and tool material combination and their mechanical properties, quality and type of the machine tool used.

Sujan Debnath, Moola Mohan Reddy and Qua Sok Yi [1] studied the effect of various cutting fluid levels and cutting parameters on surface roughness and tool wear. R.K.Bharilya and Ritesh Malgaya [2] investigated the optimization of machining parameters for turning operation of given work piece, the material being carburized Mild steel (hard material), Aluminium alloys and Brass (soft material) which were machined on CNC machine and analysed through the cutting force dynamometer. V.Kryzhaniskyy and V.Bushlys [3] studied the cutting tool temperature that develops during rough turning of hardened cold-work tool steel is modeled on the basics of experimental data. Wojciech Zebala and Robert Kowalczyk [4] research the cutting forces (F_f, F_p, F_c) when machining of sintered carbides WC-Co (25% Co) with tools made of polycrystalline diamond PCD. Jinming Zho and Volodymyr Bushlya [5] analysis of subsurface microstructural alterations and residual stresses caused by machining significantly affect component lifetime and performance by influencing fatigue, creep, and stress corrosion cracking resistance. Rachid M Saoubi and Tobias Czotscher [6] focused on machinability of power metallurgy steel using PcBN inserts. Dipti Kanta Das and Ashok Kumar Sahoo [7] investigated on surface roughness during hard machining of EN 24 steel with the help of coated carbide insert. Harsh Y Valera and Sanket N Bhavsar [8] done an experimental study of power consumption and roughness characteristics of surface generated in turning operation of EN-31 alloy steel with TiN+$Al_2 0_3$+TiCN coated tungsten carbide tool under different cutting parameters. S.A.Khan and S.L.Soo [9] done an experimental work on tool wear/life evaluation when finish turning Inconel 718 using PCBN tooling. Dr.C.J. Rao and Dr.D. Nageswara Rao [10] investigated the influence of speed, feed and depth of cut on cutting force and surface roughness while working with tool made of ceramic with an Al_2O_3+TiC matrix (KY1615) and the work material of AISI 1050steel (hardness of 484 HV). V.Bushlya and J.Zhou [11] studied the tool life, tool wear and surface integrity of superalloy Inconel 718 when machined with coated and uncoated PCBN tools, aiming on increased speed and efficiency. SU Honghua and LIU Peng [12] investigated the performance and wear mechanism of the tools (PCD and PCBN) for machining the TA15 alloy. J.Guddat and R.M Saoubi [13] investigating the effect of wiper PCBN inserts on surface integrity and cutting forces by hard turning of through hardened AISI 52100. Lin et al. [14] adopted an abdicative network to construct a prediction model for surface roughness and cutting force. Feng and Wang [15] investigated the influence on surface roughness in finish turning operation by developing an empirical model through considering exogenous variables: work piece hardness, feed, cutting tool point angle, depth of cut, spindle speed, and cutting time. Suresh et al. [16] focused on machining mild steel by Tic coated tungsten carbide cutting tools for developing a surface roughness prediction model by using response surface methodology. Lee and Chen [17] have used ANN using sensing technique to monitor the effect of vibration produced by the motions of the cutting tool and work piece during the cutting process developed an on-line surface recognition system. Kirby et al. [18] developed the prediction model for surface roughness in turning operation.

Ozel and Karpat [19] worked on the prediction of surface roughness and tool flank wear by utilizing the neural network model in comparison with regression model. Kohli and Dixit [20] proposed a neural network based methodology with the acceleration of the radial vibration of the tool holder as feedback. Pal and Chakraborty [21] studied on development of a back propagation neural network model for prediction of surface roughness in turning operation and used mild steel work piece with HSS as the cutting tool for performing a large number of experiments. Sing and Kumar [22] studied on optimization of feed force through setting of optimal value of process parameters namely speed, feed and depth of cut in turning of EN24 steel with TiC coated tungsten carbide inserts. Ahmed [23] developed the methodology required for obtaining optimal process parameters for prediction of surface roughness in A1 turning. Zhong et al. [24] predicated the surface roughness of turned surfaces using networks with seven inputs namely tool inserts grade, work piece material, tool nose radius, rake angle, depth of cut, spindle speed, feed rate.

3. RESEARCH METHODOLOGY

The research is basically a hypotheses testing research making use of design of experiments based on Taguchi method. Hypotheses have been constituted for testing the main effect of the cutting parameters based on the literature review.

3.1 Machine and the Material

The turning operation was conducted using LMW Smarturn Industrial type CNC lathe machine with a range of spindle speed from 50 rpm to 3500 rpm, and a 10 KW motor drive. The cutting tool is PCBN insert, which is designated by KB5610. The material used was EN 353 steel (hardness of 64 HRC). These bars (32mm in diameter and 75mm in length) were machined under wet condition. The work material bars were turned, centred and cleaned by removing a 1mm depth of cut from the outside surface, prior to the actual machining tests.

3.2 Surface roughness measurement

The instrument used to measure surface roughness was Qualitest TR200. For a probe movement of mm, surface roughness readings were recorded at three locations on the work piece and average value is used for analysis.

- Ra Range: 0.01 – 40 µm
- Tracing Length Lt: (1 – 5 cut-off) + 2 cut-off
- Detector: Diamond tip radius 5 µm

3.3 Cutting conditions and experimental procedure

Among the speed, feed rate, and depth of cut combinations available on the lathe, three levels of cutting parameters were selected based on similar earlier studies (Table-1)

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Table-1: Factors and their Levels

Factor	Level 1	Level 2	Level 3
A: Speed (rpm)	1500	1750	2000
B: Feed (mm/rev)	0.20	0.04	0.06
C: Depth of Cut (mm)	0.25	0.50	0.75

Taguchi design L-9 for three levels and three factors yielded 9 experiments were carried out. The experimental data is given in table-2.

Table-2: Experimental data

Sl no	Designation	Speed (rpm)	Feed (mm/rev)	Depth of Cut (mm)	Machining Time (sec)	Weight Before Machining (g)	Weight After Machining (g)	Material Removal Rate (g/sec)	Surface Roughness (microns)
01	$A_1B_1C_1$	1500	0.02	0.25	1.47	393	380	8.84	0.947
02	A_1 B_2 C_2	1500	0.04	0.50	1.36	392	380	8.82	0.452
03	A_1 B_3 C_3	1500	0.06	0.75	1.12	394	391	11.60	0.854
04	A_2 B_1 C_2	1750	0.02	0.50	1.34	392	391	8.20	0.194
05	A_2 B_2 C_3	1750	0.04	0.75	0.38	392	391	28.94	0.428
06	A_2 B_3 C_1	1750	0.06	0.25	1.23	392	391	8.94	0.656
07	A_3 B_1 C_3	2000	0.02	0.75	1.23	392	391	8.94	0.336
08	A_3 B_2 C_1	2000	0.04	0.25	0.47	393	391	25.53	0.376
09	A_3 B_3 C_2	2000	0.06	0.50	0.35	393	391	33.33	0.659

4. RESULT ANALYSIS

4.1 Surface Roughness analysis

The response table for Signal to Noise ratio results is very clear to support the optimum control factors A_1, B_2 and C_3 (table 3). This can be seen in the main effect plot for SN ratio (figure 1). The analysis of variance (ANOVA) result gives the percentage contribution of process parameter for speed as 38.59% (table 4).

Table-3: Response Table for Signal to Noise Ratios
Smaller is better

Level	Speed	Feed	DOC
1	2.914	8.063	4.210
2	8.426	7.588	8.254
3	7.197	7.588	6.072
Delta	5.512	5.178	4.044
Rank	1	2	3

Table-4: ANNOVA for Surface Roughness

Source	DF	Seq SS	Adj SS	Adj SS	F	P	Percentage of contribution
SPEED	2	0.19302	0.19302	0.09651	2.41	0.293	38.59
FEED	2	0.15125	0.15125	0.07563	1.89	0.346	30.24
DOC	2	0.07584	0.07584	0.03792	0.95	0.514	15.16
Error	2	0.08007	0.08007	0.04003	-	-	16.01
Total	8	0.50018	-	-	-	-	100
S = 0.200083 R-Sq = 83.99% R-Sq(adj) = 35.97%							

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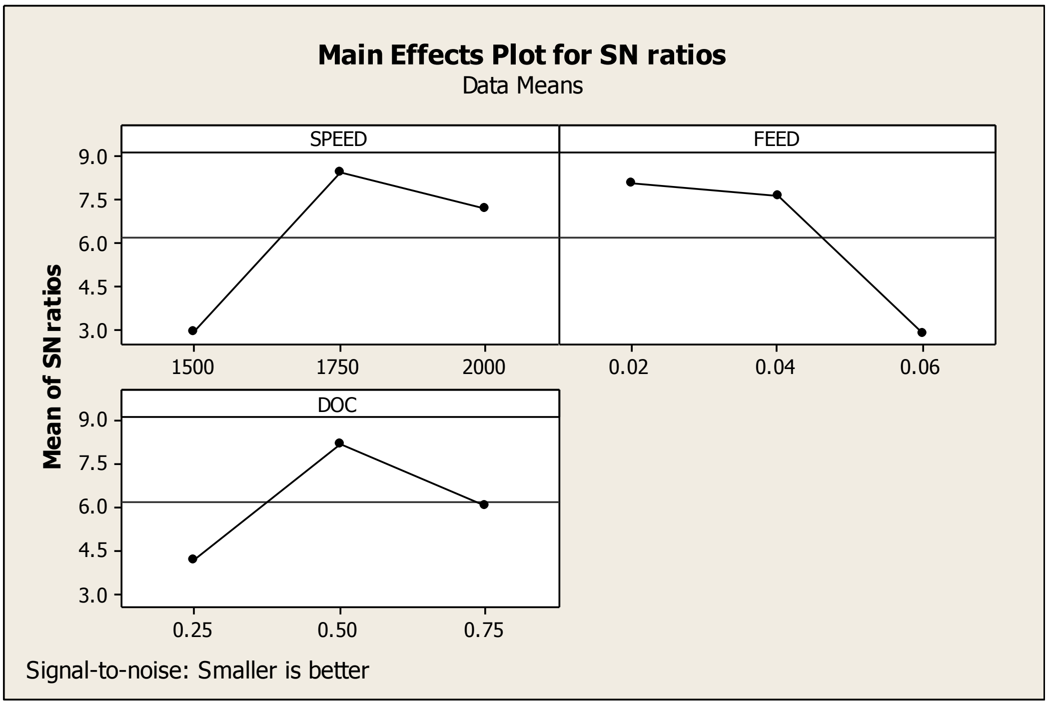

Figure – 1 Main Effects Plot for SN Ratios

4.2 MRR Analysis

The response table for Signal to Noise ratio results is very clear to support the optimum control factors $A_{2,}$ B_1, and C_3 (table 5). This can be seen in the main effect for SN ratio (figure 2). The analysis of Variance (ANOVA) result gives the percentage contribution of process parameter for Feed as 29.83% (table 6).

Table-5: Response Table for Signal to Noise Ratios
Larger is better

Level	Speed	Feed	DOC
1	19.17	18.74	22.03
2	22.18	25.43	22.55
3	25.87	23.59	23.18
Delta	6.17	6.68	
Rank	2	1	3

Table-6 ANOVA for MRR

Source	DF	Seq SS	Adj SS	Adj SS	F	P	Percentage of Contribution
SPEED	2	248.9	248.9	124.4	0.75	0.571	29.59
FEED	2	251.0	251.0	125.5	0.76	0.569	29.83
DOC	2	9.8	9.8	4.9	0.03	0.971	1.17
Error	2	331.5	331.5	165.8			39.41
Total	8	841.2					100
S = 12.8753 R-Sq = 60.59% R-Sq(adj) = 0.00%							

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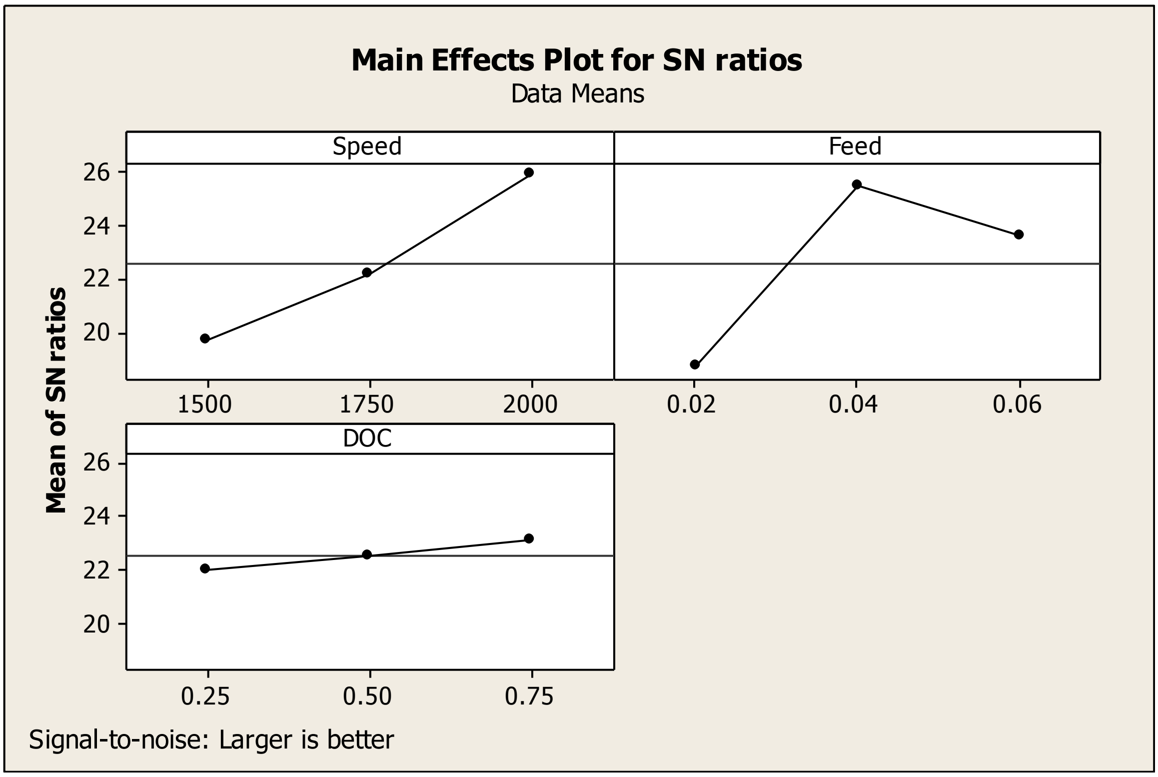

Figure – 2 Main effect plots for SN ratio

4.3 Machining Time Analysis

The response table for Signal to Noise ratio results is very clear to support the optimum control factors A_1, B_2 and C_3 (table 7). This can be seen in the main effect plot for SN ratio (figure 3). The analysis of variance (ANOVA) result gives the percentage contribution of process parameter for speed as 35.98% (table 8).

Table-7: Response Table for Signal to Noise Ratios
Smaller is better

Level	Speed	Feed	DOC
1	-2.3338	-2.5622	0.4712
2	1.3547	4.0972	1.3019
3	4.6262	2.1121	1.8740
Delta	6.9600	6.6594	1.4028
Rank	1	2	3

Table-8 ANOVA for Machining Time

Source	DF	Seq SS	Adj SS	Adj SS	F	P	Percentage of Contribution
SPEED	2	0.6022	0.6000	0.3011	1.37	0.422	35.98
FEED	2	0.5983	0.5983	0.2991	1.36	0.433	35.75
DOC	2	0.0345	0.0345	0.0172	0.08	0.927	2.06
Error	2	0.4388	0.4388	0.2194			26.21
Total	8	1.6738					100
S = 0.468413 R-Sq = 73.78% R-Sq(adj) = 0.00%							

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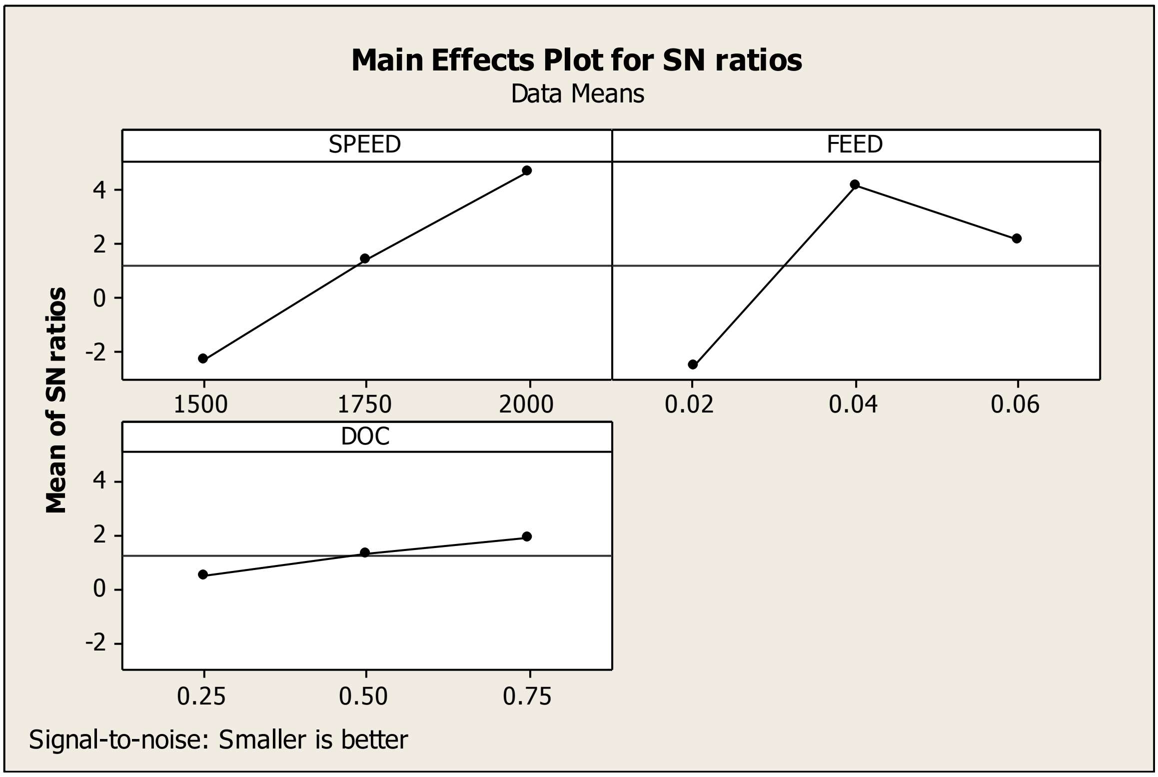

Figure-3 Main effect plots for SN ratios

5. CONCLUSION

In this study, the Taugchi technique and ANOVA were used to obtain optimal Turning parameters in the Turning of EN 353 steel under wet conditions. The experimental results were evaluated using Taguchi technique. The following conclusion can be drawn.

5.1 Optimal Control Factor

1. Surface Roughness –

A_1 (Speed - 1500), B_2 (Feed – 0.04), C_3 (DOC – 0.75)

2. Machining Timing –

A_1 (Speed-1500), B_2 (Feed 0.04), C_3 (DOC 0.75)

3. Material Removal Rate –

A_2 (Speed-1750), B_1 (Feed 0.02), C_3 (DOC 0.75)

5.2 Percentage of Contribution of Process Parameter

1. Surface Roughness - Speed 38.59%

2. Machining Timing - Speed 35.98%

3. Material Removal Rate - Feed 29.83%

REFERENCES

[1] Sujan Debnath, Moola Mohan Reddy, Qua Sok Yi " Influence of cutting fluid conditions and cutting parameters on surface roughness and tool wear in turning process using Taguchi method" Received in revised form 11 September 2015, Accepted 15 September 2015, Available online 26 September 2015.

[2] R.K.Bharilya, Ritesh Malgaya, Lakhan Patidar, R.K.Gurjar, Dr.A.K.Jha "Study of optimized process parameters in turning operation through Force Dynamometer on CNC Machine" Materials Today: Proceedings 2 (2015) 2300 – 2305.

[3] V. Kryzhanivskyy, V. Bushlya, O. Gutnichenko, I.A. Petrusha, J.-E. Ståhl "Modelling and Experimental Investigation of Cutting Temperature when Rough Turning Hardened Tool Steel with PCBN Tools" Procedia CIRP 31 (2015) 489 – 495.

[4] Wojciech Zębala, Robert Kowalczyk, Andrzej Matras "Analysis and Optimization of Sintered Carbides Turning with PCD Tools" Procedia Engineering 100 (2015) 283 – 290.

[5] Jinming Zhou, Volodymyr Bushlya, Ru Lin Peng, Zhe Chen, Sten Johansson and Jan Eric Stahl "Analysis of subsurface microstructure and residual stresses in machined Inconel 718 with PCBN and Al2O3-SiCw tools" Procedia CIRP 13 (2014) 150 – 155.

[6] Rachid M'Saoubi, Tobias Czotscher, Olof Andersson, Daniel Meyer "Machinability of powder metallurgy steels using PcBN inserts" Procedia CIRP 14 (2014) 83 – 88.

[7] Dipti Kanta Das, Ashok Kumar Sahoo, Ratnakar Das, B. C. Routara "Investigations on hard turning using coated carbide insert: Grey based Taguchi and regression methodology" Procedia Materials Science 6 (2014) 1351 – 1358.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 05, May-2016

[8] Harsh Y Valera, Sanket N Bhavsar "Experimental Investigation of Surface Roughness and Power Consumption in Turning Operation of EN 31 Alloy Steel" Procedia Technology 14 (2014) 528 – 534.
[9] Dr. C. J. Rao , Dr. D. Nageswara Rao, P. Srihari "Influence of cutting parameters on cutting force and surface finish in turning operation" Procedia Engineering 64 (2013) 1405 – 1415.
[10] S.A. Khan, S.L. Soo, D.K. Aspinwall, C. Sage, P. Harden, M. Fleming, A. White, R. M'Saoubi "Tool wear/life evaluation when finish turning Inconel 718 using PCBN tooling" Procedia CIRP 1 (2012) 283 – 288.
[11] V. Bushlya, J. Zhou, J.E. Ståhl "Effect of Cutting Conditions on Machinability of Superalloy Inconel 718 During High Speed Turning with Coated and Uncoated PCBN Tools" Procedia CIRP 3 (2012) 370 – 375.
[12] SU Honghua, LIU Peng, FU Yucan, XU Jiuhua "Tool Life and Surface Integrity in High-speed Milling of Titanium Alloy TA15 with PCD/PCBN Tools" Chinese Journal of Aeronautics 25 (2012) 784-790.
[13] J. Guddat, R. M'Saoubi, P. Alm, D. Meyer "Hard turning of AISI 52100 using PCBN wiper geometry inserts and the resulting surface integrity" Procedia Engineering 19 (2011) 118 – 124.
[14] Lin W.S., Lee B.Y., Wu C.L., (2001), "Modeling the surface roughness and cutting force for turning", Journal of Materials Processing Technology, Vol. 108, pp.286-293.
[15] Feng C.X (jack) and Wang X., (2002), "Development of Empirical Models for Surface roughness Prediction in Finish Turning", International Journal of Advanced Manufacturing Technology, Volume 20, pp, 348-359.
[16] Suresh P.V.S., Rao P.V. and DEshmukh S.G, (2002), " A genetic algorithm approach for optimization of surface roughness prediction model", International Journal of Machine Tools and Manufature, Volume 42, pp. 675-680.
[17] Lee S.S and Chen J.C., (2003), "Online surface roughness system using artificial neural networks system in turning operations" International Journal of Advanced Manufacturing Technology, Volume 22, pp, 498-509.
[18] Kirby E.D., Zhang Z. and Chen J.C., (2004), "Development of An Accelerometer based surface roughness system in Turning Operation Using Multiple Regression Techniques" Journal of Industrial Technology, Volume 20, Number 4, pp. 1-8.
[19] Ozel T. and Karpat Y.,(2005), "Predictive modeling of surface roughness and tool wear in hard turning using regression and neural networks", International Journal of Machine Tools and Manufacture, Volume 45, pp. 467-479.
[20] Kohli A. and Dixit U.S., (2005), " A neural-network-based methodology for the prediction of surface roughness in a turning process", International Journal of Advanced Manufacturing Technology, Volume 25, pp..118-129.
[21] Pal S.K. and Chakraborty D., (2005), "Surface Roughness Prediction in turning using artificial neural network", Neural Computing and Application, Volume14, pp-. 319-324.
[22] Singh H, and Kumar P., (2006), "Optimizing Feed Force for Turned Parts though the Taguchi Technique", Sadhana, Volume 31, Number 6, pp. 671-681.
[23] Ahmed S.G., (2006), "Development of a Prediction Model for Surface Roughness in Finish Turning of Aluminium", Sudan Engineering Society Journal, Volume 52, Number 45, pp. 1-5.
[24] Zhong Z.W., Khoo L.P. and Han S.T., (2006), "Prediction of surface roughness of turned surfaces using neural networks", International Journal of Advanced Manufacturing Technology, Volume 28, pp. 688-693.