International Journal of Engineering, Management, Humanities and Social Sciences Paradigms (IJEMHS)
Volume 32, Issue 01, Quarter 01 (2020)
Publishing Month and Date: 11th January, 2020
An Indexed, Referred and Peer Reviewed Journal with Impact Factor: 2.75
ISSN (Online): 2347-601X
www.ijemhs.com

Effect of Process Parameters on the Performance Measure of CNC Lathe

Deepak Kumar Jha[1] and Amit Kumar[2]

[1]M. Tech. Scholar, Deptt. of M.E., CBS Group of Institutions, Jhajjar, Haryana (India)
[2]Assistant Professor, Deptt. of M.E., CBS Group of Institutions, Jhajjar, Haryana (India)

Abstract

Lean Manufacturing is a systematic approach to identifying and eliminating waste through continuous improvement. Lean is about doing more with less: Less time, inventory, space, people, and money. Lean is about speed and getting it right the first time. Lean production is aimed at the elimination of waste in every area of production including customer relations, product design, supplier networks and factory management. Its goal is to incorporate less human effort, less inventory, less time to develop products, and less space to become highly responsive to customer demand while producing top quality products in the most efficient and economical manner possible. Lean Manufacturing uses less of everything compared with mass production half the human effort in the factory, half the manufacturing floor space, half the investment in tools, half the engineering hours to develop a new product in half the time. Also it requires keeping far less than half the needed inventory on site results in, fewer defects .This is accomplished through Teamwork, Communication, and Efficient Use of Resources & Continuous Improvement. Lean Thinking methods are inclusive of all employees.

Keywords: *CNC Lathe, ANOVA, L-9, Process Parameters, Quality.*

1. Introduction

The demand for high quality and fully automated production focus attention on the surface condition of the product, surface finish of the machined surface is most important due to its effect on product appearance, function, and reliability. For these reasons it is important to maintain consistent tolerances and surface finish. This experiment gives the effect of different process parameters (cutting speed, feed, and depth of cut) on Surface Roughness and Material Removal Rate in cnc lathe.

This experimental investigation outlines the Taguchi optimization methodology, which is applied to optimize machining parameters in turning operation. The experiment is conducted on EN18 die steel. The processing of the job is done by tools under finishing conditions. The machining parameters evaluated are cutting speed, feed rate and depth of cut. The experiments are conducted by using L-9 (34) orthogonal array as suggested by Taguchi. Signal-to-Noise (S/N) ratio and Analysis of Variance (ANOVA) is employed to analyze the effect of process parameters on surface roughness and material removal rate.

Turning is a process of producing round shapes products with the use of single point cutting tool, which is called a turning cutter and the cutting edges are called nose.

1.1 Quality and Productivity

1.1.1 Quality

The quality of a product or service refers to the perception of the degree to which the product or service meets the customer's expectations. Quality has no specific meaning unless related to a specific function and/or object. Quality is a perceptual, conditional and somewhat subjective attribute.

1.1.2 Productivity

Productivity may be designated in many ways such as output per workers, direct labor or group of workers, or unit of material or unit of energy or Rupee of capital investment etc.

Importance of productivity:

– Keeps costs down to improve profits and/or reduce prices.
– Enables firms to spend more on improving customer service and supplementary services.
Productivity is a measure of output resulting from a given input.
Productivity = (Output) / (Input).

International Journal of Engineering, Management, Humanities and Social Sciences Paradigms (IJEMHS)
Volume 32, Issue 01, Quarter 01 (2020)
Publishing Month and Date: 11th January, 2020
An Indexed, Referred and Peer Reviewed Journal with Impact Factor: 2.75
ISSN (Online): 2347-601X
www.ijemhs.com

Taguchi's work includes three principal contributions to statistics:

1. A specific loss function
2. The philosophy of off-line quality control
3. Innovations in the design of experiments

1.2 Loss Functions

Taguchi knew statistical theory mainly from the followers of Ronald A. Fisher, who also avoided loss functions. Reacting to Fisher's methods in the design of experiments, Taguchi interpreted Fisher's methods as being adapted for seeking to improve the mean outcome of a process. Indeed, Fisher's work had been largely motivated by programmes to compare agricultural yields under different treatments and blocks, and such experiments were done as part of a long-term programme to improve harvests.

1.3 Off-Line Quality Control

Taguchi realized that the best opportunity to eliminate variation is during the design of a product and its manufacturing process. Consequently, he developed a strategy for quality engineering that can be used in both contexts. The process has three stages:

1. System design
2. Parameter (measure) design
3. Tolerance design

1. System Design:-

   In the system design by using the scientific methods and principal the prototypes are made. This includes design at the conceptual level by involving creativity & innovation.

2. Parameter Design:-

   Once the concept is established, the nominal values of the various dimensions and design parameters need to be set, the detail design phase of conventional engineering. Taguchi's radical insight was that the exact choice of values required is under-specified by the performance requirements of the system. In many circumstances, this allows the parameters to be chosen so as to minimize the effects on performance arising from variation in manufacture, environment and cumulative damage. This is sometimes called robustification.

3. Tolerance Design:-

   With a successfully completed parameter design, and an understanding of the effect that the various parameters have on performance, resources can be focused on reducing and controlling variation in the critical few dimensions.

1.4 Turning Operation

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.
The three primary factors in any basic turning operation are speed, feed, and depth of cut. Other factors such as kind of material and type of tool have a large influence, of course, but these three are the ones the operator can change by adjusting the controls, right at the machine.

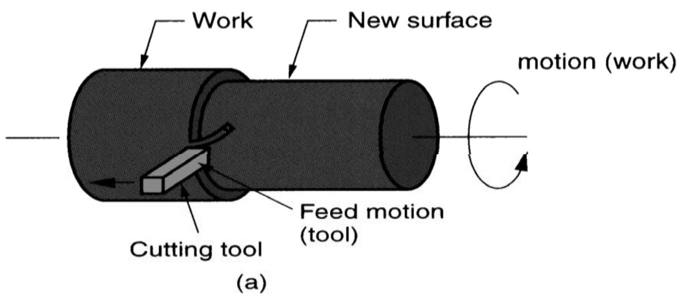


Fig. 1.1: Adjustable parameters in turning operation

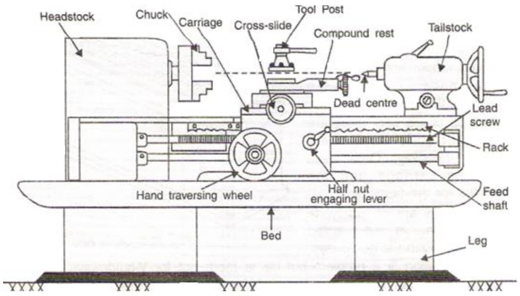


Fig. 1.2: Centre lathe used for turning

1.5 Surface Structure and Properties Turning Material

Surface roughness is an important measure of product quality since it greatly influences the performance of mechanical parts as well as production cost. Surface roughness has an impact on the mechanical properties like fatigue behavior, corrosion resistance, creep life, etc. It also affects other functional attributes of parts like friction, wear, light reflection, heat transmission, lubrication, electrical conductivity, etc.

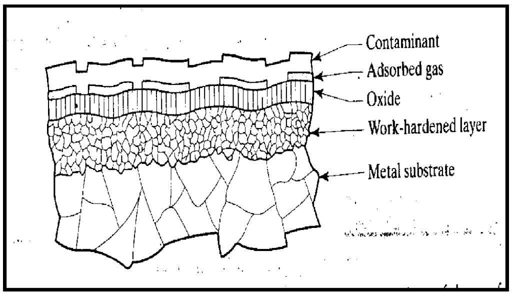


Fig. 1.3: Schematic of a cross-section of the surface structure of metals

1.6 Surface Finish in Machining

The resultant roughness produced by a machining process can be thought of as the combination of two independent quantities:

a. Ideal roughness, and
b. Natural roughness.

1.7 Factors Affecting the Surface Finish

Whenever two machined surfaces come in contact with one another the quality of the mating parts plays an important role in the performance and wear of the mating parts. The height, shape, arrangement and direction of these surface irregularities on the work piece depend upon a number of factors such as:

A) The machining variables which include
   a) Cutting speed
   b) Feed, and
   c) Depth of cut.

B) The tool geometry
Some geometric factors which affect achieved surface finish include:
   a) Nose radius
   b) Rake angle
   c) Side cutting edge angle, and
   d) Cutting edge.

C) Work piece and tool material combination and their mechanical properties
D) Quality and type of the machine tool used,
E) Auxiliary tooling, and lubricant used, and
F) Vibrations between the work piece, machine tool and cutting tool.

1.8 Roughness Parameters

Each of the roughness parameters is calculated using a formula for describing the surface. There are many different roughness parameters in use, but Ra is the most common. Other common parameters include Rz, Rq, and R^. Some parameters are used only in certain industries or within certain countries. For example, the Rk family of parameters is used mainly for cylinder bore linings.

1.9 Measurement of Surface Roughness

Inspection and assessment of surface roughness of machined work pieces can be carried out by means of different measurement techniques. These methods can be ranked into the following classes:

1. Direct measurement methods
2. Comparison based techniques
3. Non-contact methods
4. On-process measurement

The main objective of the thesis is as following:-

1. Define the parameter which effect performance significantly.
2. Define the significant factor which contributed to the surface roughness.

Methodology

2.1 -Taguchi Method

Taguchi methods are statistical methods developed by Genichi Taguchi to improve the quality of manufactured goods, and more recently also applied to, engineering, biotechnology, marketing advertising. Professional statisticians have welcomed the goals and improvements brought about by Taguchi methods, particularly by Taguchi's development of designs for studying variation.

2.1.1-Steps Applied In Taguchi Methods

1. Determine Quality characteristics to be optimized
2. Identify the noise factors and test conditions
3. Identify the control factors and their alternative levels
4. Design the matrix experiment and define the data analysis procedure
5. Conduct the matrix experiment
6. Analyze the data and determine optimum levels for control factors
7. Predict the performance at these levels

2.1.2- SIGNAL TO NOISE (S/N) RATIO & ANOVA APPROACHES

The S/N ratio was developed by Dr. Taguchi. It is a measure of performance to choose control levels that best cope with noise.

DEFINITION:-

The S/N ratio may be defined as the ratio of “Average” to the “Standard Deviation”. Thus

S/N = Average/Standard Deviation

The type of signal to noise ratio given in above equation is just the reciprocal of the coefficient of variation (CV), a statistical measure which is often used in industrial statistics.

Experiment	P1	P2	P3	P4
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

Table No. 1 Orthogonal Array L9

Experiment	Impeller	Motor Speed	Control	Valve
1	A	300	PID	BF
2	A	350	PI	G
3	A	400	P	G
4	B	300	PI	BF
5	B	350	P	BF
6	B	400	PID	G
7	C	300	P	G
8	C	350	PID	BF
9	C	400	PI	BF

Table No. 2 Experiment Runs of Impellor

Analyzing Experimental Results:-

Experiment Number	P1	P2	P3	P4	T1	T2	...	T_N
1	1	1	1	1	$T_{1,1}$	$T_{1,2}$	...	$T_{1,N}$
2	1	2	2	2	$T_{2,1}$	$T_{2,2}$	...	$T_{2,N}$
3	1	3	3	3	$T_{3,1}$	$T_{3,2}$	...	$T_{3,N}$
4	2	1	2	3	$T_{4,1}$	$T_{4,2}$	...	$T_{4,N}$
5	2	2	3	1	$T_{5,1}$	$T_{5,2}$	...	$T_{5,N}$
6	2	3	1	2	$T_{6,1}$	$T_{6,2}$	...	$T_{6,N}$
7	3	1	3	2	$T_{7,1}$	$T_{7,2}$	...	$T_{7,N}$
8	3	2	1	3	$T_{8,1}$	$T_{8,2}$	...	$T_{8,N}$
9	3	3	2	1	$T_{9,1}$	$T_{9,2}$	...	$T_{9,N}$

Experiment Number	P1	P2	P3	P4	S_N
1	1	1	1	1	S_{N1}
2	1	2	2	2	S_{N2}
3	1	3	3	3	S_{N3}
4	2	1	2	3	S_{N4}
5	2	2	3	1	S_{N5}
6	2	3	1	2	S_{N6}
7	3	1	3	2	S_{N7}
8	3	2	1	3	S_{N8}
9	3	3	2	1	S_{N9}

Table No. 3 S/N Ratio

Level	P1	P2	P3	P4
1	$SN_{P1,1}$	$SN_{P2,1}$	$SN_{P3,1}$	$SN_{P4,1}$
2	$SN_{P1,2}$	$SN_{P2,2}$	$SN_{P2,2}$	$SN_{P4,2}$
3	$SN_{P1,3}$	$SN_{P2,3}$	$SN_{P3,3}$	$SN_{P4,3}$
Δ	R_{P1}	R_{P2}	R_{P3}	R_{P4}
Rank	...	...	...	...

Table No. 4 Rank at Various Level

2.2 Planning Of Experiment

There are various process parameters of turning which are machine parameters, work piece properties, cutting tool properties and cutting phenomenon. But out of these the machine parameters gives the significant results to performance measures.

The process parameters selected are

- Cutting Speed
- Feed Rate
- Depth of Cut

The performance measures are

- Surface Roughness
- Material Removal Rate

2.2.1 Machine Used With Operation

In order to perform this operation LMW LL20T L5 CNC Lathe machine is used. The machine is capable of performing the maximum turning diameter up to 200 mm. The machine makes use of following accessories:-

1. Station Indexing Chuck
2. Chip Conveyor
3. Collet Chucking
4. Special Fixture for holding complex parts
5. Manual Indexing Chuck

Fig. 2.1: LMW LL20T L5 CNC lathe

2.2.2 Material Used With Specifications:-

In this project EN8 which is a type of steel is used for analysis. EN8 is a very popular grade of through-hardening medium carbon steel, which is readily machinable in any condition. EN8 is suitable for the manufacture of parts such as general-purpose axles and shafts, gears, bolts and studs. EN8 in its heat treated forms possesses good homogenous metallurgical structures, giving consistent machining properties.

EN8 DIE STEEL SPECIMENS

2.2.3 Tool Used For Experiments

The tool used in this experiment is a DNMG 150404 H11+PDJNL 2525 insert, which is made by H11 hot die steel material and mainly used for precision turning of steel's only. The material used for the experiment is of 100 mm in length and 20 mm in diameter of carbon die steel.

2.2.4 Surface Roughness Tester

In this project MITUTOYO Surftest SJ-201P surface roughness tester is used.

2.3 Model Building and Optimization

2.3.1 Software Used With Features:-

The software used for the analysis purpose is Minitab 15. The calculations of signal to noise ratio are very lengthy so in avoid the time wastage The Minitab 15 is used. The Minitab 15 is powerful tool in statistics.

2.3.2 Design of Experiment

1. Determine the Quality Characteristics to Be Optimized:-

The output characteristics of the study are:

i).Surface Finish

ii).Material removal rate

In the Taguchi method there are three types of quality characteristics i,e smaller is better, larger is better, nominal is best. For the surface finish the smaller is better characteristic is selected while for the MRR the larger is better is selected.

2. Identify the Noise Factor and Test Conditions:-

The next step is to identify the noise factor and test condition that can have a negative impact on system performance and quality. Noise factors are those parameters which are either uncontrollable or are too expensive to control. Noise factors include variations in environmental operating conditions, deteriorations of components with usage, and variations in response between products of same design with same input. Here the human interactions and wok piece location are considered as the noise factors.

3. Identify the Control Parameters and their Alternatives Levels:-

In this experiment the cutting speed (A), Feed rate (B), Depth of Cut (C) are the controllable factors since these have a potential effect on the surface roughness & MRR. Since these factors are controllable in the machining process, so these can be considered as controllable factors.

Process Parameters	Parameter Designation	Levels		
		1	2	3
Cutting Speed	A	100	110	120
Feed (mm/Rev.)	B	.15	.17	.19
Depth of Cut (mm)	C	.25	.50	.40

4. Design the Matrix and Define the Data Analysis Procedure:-

Experiment No.	1 (A) Cutting Speed (m/min)	2 (B) Feed Rate (mm/rev.)	3 (C) Depth of Cut (mm)	4 (D)
1	100	.15	.25	1
2	100	.17	.50	2
3	100	.19	.40	3
4	110	.15	.50	3
5	110	.17	.40	1
6	110	.19	.25	2
7	120	.15	.40	2
8	120	.17	.25	3
9	120	.19	.50	1

5. Conducting The Experiments
Raw data for surface roughness

Ex.No.	(A) Cutting speed	(B) Feed rate	(C) Depth of cut	Surface roughness at diff locations			Signal to noise ratio (dbi)	Mean response value
				Response 1	Response 2	Response 3		
1.	100	.15	.25	1.29	1.42	1.40	-2.74196	1.37000
2.	100	.17	.50	.61	.55	.69	4.16159	0.61667
3.	100	.19	.40	.75	.82	.77	2.15193	0.78000
4.	110	.15	.50	1.04	1.06	1.08	-0.50715	1.06000
5.	110	.17	.40	.56	.49	.41	6.18704	0.48667
6.	110	.19	.25	.76	.79	.83	2.00522	0.79333
7.	120	.15	.40	.65	.71	.78	2.91013	0.71333
8.	120	.17	.25	.51	.54	.48	5.83859	0.51000
9.	120	.19	.50	.70	.78	.84	2.20885	0.77333

Raw Data of MRR

Sample Number	Weight before turning (gm)	Weight after turning first trial (gm)	Weight after turning second trial (gm)	Machining time first trial process (min)	Machining time second trial process (min)	Material removal rate for first trial process (mm^3/min)	Material removal rate for second trial process (mm^3/min)	Mean response value of MRR (mm^3/min)	SN ratio (dbi) (biggest is the best)
1	262	252	242	.3333	.3166	3846.15	4273.50	72.1340	4059.82
2	260	250	238	.3000	.2833	4273.50	5454.54	73.5474	4864.02
3	266	254	242	.2833	.2666	5454.54	5714.29	74.9325	5584.42
4	260	250	240	.3333	.3166	3846.15	4000	71.8675	3923.07
5	262	252	242	.3000	.3166	4273.50	4000	72.3189	4136.75
6	262	250	242	.2833	.2666	5454.54	5454.54	74.7352	5454.54
7	264	254	240	.3333	.3333	3846.15	5384.61	72.9205	4615.38
8	266	250	242	.3000	.2833	6956.52	4273.50	74.2354	5615.01
9	260	250	236	.2833	.2666	4545.45	7272.72	74.7297	5909.09

6. Analyzing the Results and Determining the Optimum Level for Control Factors:-

International Journal of Engineering, Management, Humanities and Social Sciences Paradigms (IJEMHS)
Volume 32, Issue 01, Quarter 01 (2020)
Publishing Month and Date: 11th January, 2020
An Indexed, Referred and Peer Reviewed Journal with Impact Factor: 2.75
ISSN (Online): 2347-601X
www.ijemhs.com

Surface Roughness:-

A). Analysis of Raw Data and S/N Ratio:-

Average effect response signal to noise ratio

Level	Cutting speed (A)	Feed rate (B)	Depth of cut (c)
1	1.1905	-0.1130	1.7006
2	2.5617	5.3957	3.7497
3	3.6525	2.1220	1.9544
Delta	2.4620	5.5087	2.0491
Rank	2	1	3

Average effect response table for mean data

Level	Cutting speed (A)	Feed rate (B)	Depth of cut (c)
1	0.9222	1.0478	0.8911
2	0.7800	0.5378	0.6600
3	0.6656	0.7822	0.8167
Data	0.2567	0.5100	0.2311
Rank	2	1	3

B). Analysis of Variance:-

ANOVA table for SN ratios (surface roughness)

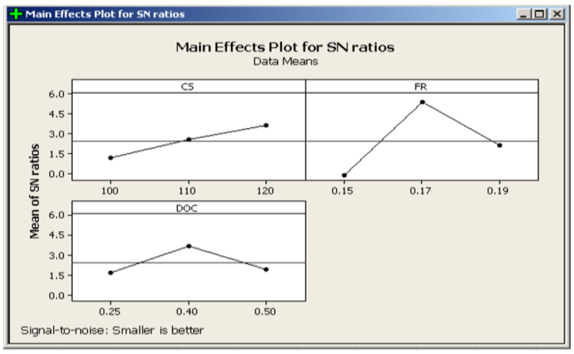
Source	Degree of freedom	Sum of square	Mean of square	F value	P value
Cutting speed(A)	2	9.131	4.5657	4.67	0.046
Feed rate(B)	2	46.059	23.0294	23.55	0.041
Depth of cut(C)	2	7.486	3.7431	3.83	0.037
Residual error	2	1.956	0.9780		
Total	8	64.632			

ANOVA table for means(surface roughness)

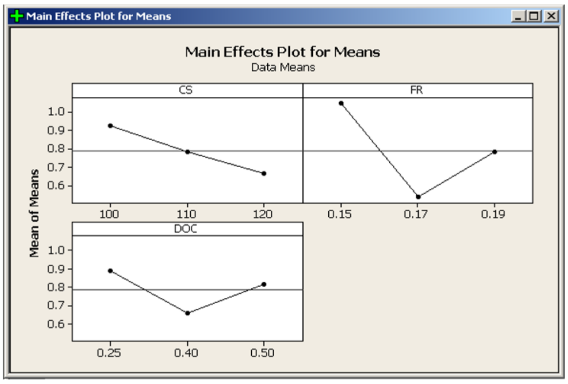
Source	Degree of freedom	Sum of square	Mean of square	F value	P value
Cutting speed(A)	2	0.09920	0.04960	2.31	0.037
Feed rate(B)	2	0.39037	0.19519	9.09	0.049
Depth of cut(C)	2	0.08350	0.04175	1.94	0.040
Residual error	2	0.04294	0.02147		
Total	8	0.61602			

d). Determination of the Optimum:-

Main effects plot for S/N ratios (surface roughness)



Main Effect plots for means (Surface Roughness)



Material Removal Rate

a) Analysis of Raw Data and S/N Ratios:-

Average effect response table for signal to noise ratio

Level	Cutting speed (A)	Feed rate (B)	Depth of cut (c)
1	73.54	72.31	73.70
2	72.97	73.37	73.39
3	73.96	74.80	73.38
Data	0.99	2.49	0.32
Rank	2	1	3

Average effect response for mean data (MRR)

Level	Cutting speed (A)	Feed rate (B)	Depth of cut (c)
1	4836	4199	5043
2	4505	4872	4779
3	5380	5649	4899
Delta	875	1450	264
Rank	2	1	3

a) Analysis Of Variance:-

ANOVA table for SN ratios (MRR)

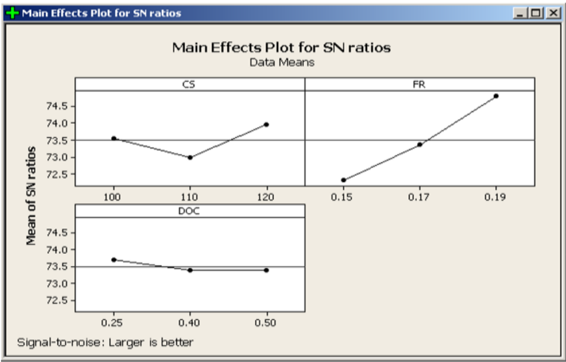
Source	Degree of freedom	Sum of square	Mean of square	F value	P value
Cutting speed(A)	2	1.4740	0.73702	1.76	0.036
Feed rate(B)	2	9.3827	4.69136	11.20	0.022
Depth of cut(C)	2	0.1991	0.09957	0.24	0.048
Residual error	2	0.8380	0.41902		
Total	8	11.8939			

ANOVA table for mean data (MRR)

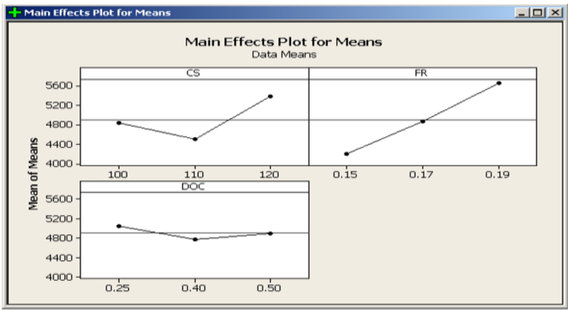
Source	Degree of freedom	Sum of square	Mean of square	F value	P value
Cutting speed(A)	2	1171099	585550	6.00	0.034
Feed rate(B)	2	3158906	1579453	16.19	0.021
Depth of cut(C)	2	105064	52532	0.54	0.044
Residual error	2	195063	97531		
Total	8	4630132			

Determination of Optimum:-

Main Effects plot SN ratios for MRR (larger is better)



Main effects plots for Means data (MRR)



7. Predicting Optimum Performance At These Levels:-

Using signal to noise ratio and mean ANNOVA calculations the optimum output is predicted by Minitab 15.

Surface Finish

The optimum surface finish at cutting speed (A3=120 m/min), feed rate (B2=0.19 mm/rev.), depth of cut (C2=0.40 mm) is:-

S/N Ratio = 7.86147

Mean = 0.284815 µm.

Material Removal Rate

The optimum Material Removal Rate at cutting speed (A3= 120 m/min), Feed rate (B3 = 0.19 mm/rev.), Depth of cut (C1 = 0.25 mm) is:-

S/N Ratio = 75.4801

Mean = 6258.50 µm.

Results and Conclusion

Effect of Various Input Parameters on Output Measures (Surface Roughness):-

The average value of surface roughness (µm) at each parameter (cutting speed, feed rate, depth of cut) is computed and the results are tabulated. Similarly the result obtained for S/N data (db) are given. The main effect along with the corresponding S/N ratio value is plotted.

Effect of Various Input Parameters on Output Measures (MRR):-

The average value of MRR at each parameter (cutting speed, feed rate, and depth of cut) is computed and the results are tabulated. The main effect along with corresponding S/N ratio value is plotted.

The Following Are the Conclusions Drawn From the Work Done In This Investigation

1. Taguchi’s robust design method is suitable to analyze the metal cutting problems as described in the present work.
2. In turning operation the cutting speed (120 m/min), feed rate (.17 mm/rev.), depth of cut (.40 mm) for the surface roughness were found to be having higher S/N ratio.
3. In turning operation, use of cutting speed (120 m/min), feed rate (.19 mm/rev), depth of cut (.25 mm) were found to be having larger value of S/N ratio so, these are considered as optimum parameters for MRR.
4. Low cutting speed should be used for longer cutting tool life.
5. High cutting speed and low feeds give best surface finishes; depth of cut should be low but not so slow that it led to the vibration of tool.
6. For mild steel cutting speed should be 30-50 m/min.
7. For hot die steel cutting speed should be 250-350 m/min.

Future Scope

The following are the modifications and additional features to be provided in product developed in this report

1. Further study could consider higher orthogonal array (L18, L27 etc.), different analysis methods (response surface methodology, Particles swarm optimization etc.) and multiple responses could be considered.
2. Further study could consider more factors (e.g. tool vibration, lubricant, etc.) in the research to see how the factors would affect surface roughness.
3. Further study could consider the different operations such as drilling, milling etc.
4. Further study can be carried on material other than steel that is materials like carbon steel etc.

References

[1] Anil Gupta, Hari singh Aman agarwal (2011),” Taguchi-fuzzy multi output optimization (MOO) in high speed CNC turning of AISI P-20 tool steel” elsevier journal ,measurement, app.,38,2011,6822-6828.

[2] Al-Ahmari A. M. A., (2007),"Predictive machinability models for a selected hard material in turning operations", Journal of

Materials Processing Technology, Volume 190, pp. 305-311.

[3] 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.

[4] Abburi N. R. and Dixit U. S., (2006), "A knowledge-based system for the prediction of surface roughness in turning process" Robotics and Computer-Integrated Manufacturing, Volume 22, pp. 363–372.

[5] Chien W.-T. and Tsai C.-S., (2003), "The investigation on the prediction of tool wear and the determination of optimum cutting conditions in machining 17-4PH stainless steel", Journal of Materials Processing Technology, Volume 140, pp. 340–345.

[6] Doniavi A., Eskanderzade M. and Tahmsebian M., (2007), "Empirical Modeling of Surface Roughness in Turning Process of 1060 steel using Factorial Design Methodology", Journal of Applied Sciences, Volume 7, Number17, pp. 25092513.

[7] Fnides B., Aouici H., Yallese M. A., (2008), "Cutting forces and surface roughness in hard turning of hot work steel X38CrMoV5-1 using mixed ceramic",Mechanika, Volume 2, Number 70, pp. 73-78.

[8] Fu P. and Hope A. D., (2008), "A Hybrid Pattern Recognition Architecture for Cutting Tool Condition Monitoring" Technology and Applications, Volume 24, Number 4, pp. 548-558.

[9] 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. 348–356.

[10] Ilhan Asiltürk , Harun Akkus (2011) ," Determining the effect of cutting parameters on surface roughness in hard turning using the Taguchi method" elsevier journal ,measurement 44 (2011) 1697-1704.

[11] Kassab S. Y. and Khoshnaw Y. K., (2007), "The Effect of Cutting Tool Vibration on Surface Roughness of Work piece in Dry Turning Operation", Engineering and Technology, Volume 25, Number 7, pp. 879-889.

[12] 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.

[13] Kirby E. D., Zhang Z. and Chen J. C., (2004), "Development of An Accelerometer based surface roughness Prediction System in Turning Operation Using Multiple Regression Techniques", Journal of Industrial Technology, Volume 20, Number 4, pp. 1-8.

[14] Lan T.-S., Lo C. Y., Wang M.-Y. and Yen A-Y, (2008), "Multi Quality Prediction model of CNC Turning Using Back Propagation Network", Information technology Journal, Volume 7, Number 6, pp. 911-917.

[15] Lee S. S. and Chen J. C., (2003), "Online surface roughness recognition system using artificial neural networks system in turning operations" International Journal of Advanced Manufacturing Technology, Volume 22, pp. 498–509.

[16] Lin W. S., Lee B. Y., Wu C. L., (2001), "Modeling the surface roughness and cutting force for turning", Journal of Materials Processing Technology, Volume 108, pp. 286-293.

[17] M.Kaladhar, K.Venkata and Shrinivasa rao,(2012), "The study about Performance evaluation of coating materials and process parameters optimization for surface quality during turning of AISI 304 austenitic stainless steel." International journal of Engg. Science and Technology, volume 3,2011, pp.89-102.

[18] Mahmoud E. A. E. and Abdelkarim H. A., (2006), "Optimum Cutting Parameters in Turning Operations using HSS Cutting Tool with 450 Approach Angle", Sudan Engineering Scoeiety Journal, Volume 53, Number 48, pp. 25-30.

[19] Natarajan U., Arun P., Periasamy V. M., (2007), "On-line Tool Wear Monitoring in Turning by Hidden Markov Model (HMM)" Institution of Engineers (India) Journal (PR), Volume 87, pp. 31-35.

[20] Özel 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.

[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] Reddy B. S., Padmanabhan G. and Reddy K. V. K., (2008), “Surface Roughness prediction Techniques for CNC turning”, Asian Journal of Scientific Research, volume 1, Number 3, pp. 256-264.

[23] Srikanth T. and Kamala V., (2008), “A Real Coded Genetic Algorithm for optimization of Cutting Parameters in Turning IJCSNS”, International Journal of Computer Science and Network Security, Volume 8 Number 6, pp. 189-193.

[24] Sahoo P., Barman T. K. and Routara B. C., (2008), “Taguchi based practical dimension modeling and optimization in CNC turning”, Advance in Production Engineering and Management, Volume 3, Number 4, pp. 205-217.

[25] Shetty R., Pai R., Kamath V. and Rao S. S., (2008), “Study on Surface Roughness Minimization in Turning of DRACs using Surface Roughness Methodology and Taguchi under Pressured Steam Jet Approach”, ARPN Journal of Engineering and Applied Sciences, Volume 3, Number 1, pp. 59-67.

[26] Singh H. and Kumar P., (2006), “Optimizing Feed Force for Turned Parts through the Taguchi Technique”, Sadhana, Volume 31, Number 6, pp. 671–681.

[27] Suresh P. V. S., Rao P. V. and Deshmukh S. G., (2002), “A genetic algorithmic approach for optimization of surface roughness prediction model”, International Journal of Machine Tools and Manufacture, Volume 42, pp. 675–680.

[28] Thamma R., (2008), “Comparison between Multiple Regression Models to Study Effect of Turning Parameters on the Surface Roughness”, Proceedings of the 2008 96IAJC-IJME International Conference, ISBN 978-1-60643-379-9, Paper133, ENG,pp. 103-12.

[29] Thamizhmanii S., Saparudin S. and Hasan S., (2007), “Analysis of Surface Roughness by Using Taguchi Method”, Achievements in Materials and Manufacturing Engineering, Volume 20, Issue 1-2, pp. 503-505.

[30] Wang M. Y. and Lan T. S., (2008), “Parametric Optimization on Multi-Objective Precision Turning Using Grey Relational Analysis” Information Technology Journal, Volume 7, pp.1072-1076.

[31] Wang M. Y. and Lan T. S., (2008), “Parametric Optimization on Multi-Objective Precision Turning Using Grey Relational Analysis”. Information Technology Journal, Volume 7, pp.1072-1076.

[32] Zhong Z. W., Khoo L. P. and Han S. T., (2006), “Prediction of surface roughness of turned surfaces using neural networks”, International Journal of Advance Manufacturing Technology, Volume 28, pp. 688–693.