A Literature Review on Optimization of Input Cutting Parameters for Improved Surface Finish in Turning Process

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Abstract - *The purpose of this paper is to make an attempt to review the literature on optimization of input cutting parameters for improved surface finish by acquiring minimum surface roughness in turning process and to present various methodologies and practices that are being employed for the prediction of surface roughness. Surface roughness is one of the most commonly used criteria to determine quality of a turned surface. This literature review compiles different work presented on optimization of process parameters and concludes the most significant cutting parameters and most frequently used optimization techniques for improving surface finish The cutting parameters like Cutting speed, Feed rate, Depth of cut, Insert radius and Cutting fluid are taken into consideration.*

Key Words: *Turning process, Optimization Techniques, Surface Roughness, Taguchi Method*

1. INTRODUCTION

Turning is a machining process used to obtain the desired dimension of round metal. The main target in present industrial era is to produce low cost quality product with required dimensions in an optimum time. Therefore, the optimum cutting parameters are to be recognized first. In turning, the metal is in rotational motion (axially) and a cutting tool is used to shear away the undesired metals. This process requires lathe or turning machine, cutting tool, work piece and fixture [1]. The work piece is fixed in the machine chuck and is rotated at high speed. The cutting tool (insert) is fed in parallel to the axis of rotation as shown in Fig. 1. During this machining process the cutting parameters highly depends upon the work piece, cutting tool material, etc. These are determined by experience or machine catalogue. Surface roughness is a widely used attribute of product quality and in most cases a technical necessity for mechanical products. Achieving the desirable surface quality is of great importance for the functional behaviour of a part [2]. Thus the optimum selection of cutting parameters such as feed rate, depth of cut, cutting speed, etc, generates optimum conditions during machining and becomes the main exigency of manufacturing industry. Surface roughness of a material after turning is measured using portable surface roughness tester. Surface roughness is an important criterion to find the quality of a surface. It is an important response parameter. Surface finish can be measured using simple surface roughness tester [3, 4].

In machining process various parameters are:
Input Parameters: Cutting speed, Feed rate, Depth of cut, Insert radius, Cutting fluid, etc
Output Parameters: Surface roughness, MRR, Tool wear, Cutting forces, MAZ, etc.

Surface engineering aims to achieve desired properties or characteristics of surface-engineered components including:

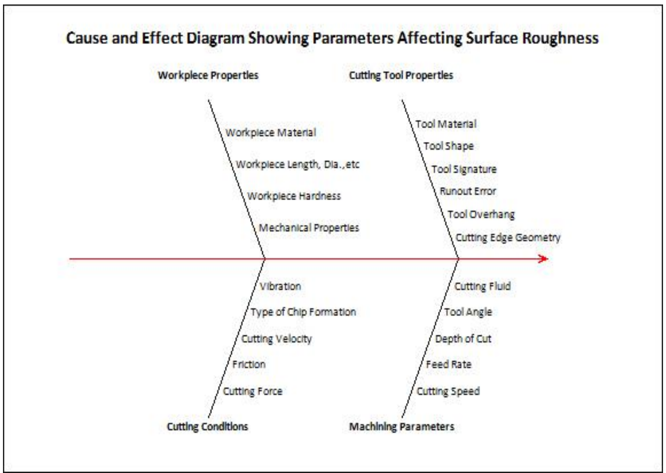
- Improved wear resistance;
- Reduced friction energy losses;
- Improved mechanical properties, for example, enhanced fatigue life, hardness or toughness;
- Improved aesthetic appearance, etc.

Factors influencing surface roughness in turning:

- Cutting parameters i.e. feed, cutting speed and depth of cut
- Vibration
- Material of work piece
- Rigidity of the system consisting of machine tool, fixture cutting tool and work
- Type, form, material and sharpness of cutting tool
- Type of coolant used

Cause and effect diagram also called as fishbone diagram in Figure-1 shows different machining parameter that affects surface roughness.

Figure-1: Cause and effect diagram for surface roughness



Various optimization techniques used are:

- Taguchi Methedology
- Response Surface Methodology
- Full Factorial Analysis
- Multiple Regression Analysis
- Artificial Neutral Network

2. LITERATURE SURVEY

Several experimental investigations have been carried over the years in order to study the influence of various cutting parameters on the surface finish of the workpiece, tool life using workpieces of different materials.

M.Nalbant et al. [5] implemented the Taguchi method to find out optimum cutting parameters for surface roughness in turning. ANOVA method was employed to study the performance characteristics in turning of AISI 1030 steel bar using TiN-coated tools. The study reveals that the feed rate and the insert radius were the main machining parameters that affect the surface roughness in turning of AISI 1030.

Ilhan Asilturk et al. [6] focuses on optimization of turning parameters based on Taguchi method to minimize surface roughness (Ra&Rz). Experimental have been carried out using L9 orthogonal array in CNC turning. Dry turning tests were carried out on hardened AISI 4140 with coated carbide tools. It has been observed that feed rate has the most significant effect on the surface roughness.

M. Antony Xavior et al. [7] carried out an experimental investigation to determine the influence of different cutting fluids on tool wear and surface roughness in turning of AISI 304 with carbide cutting insert. Additionally, an attempt was made to determine the influence of coconut oil as cutting fluid in reducing the tool wear and surface roughness in the turning process. The performance of coconut oil was in contrast with another two cutting fluids namely an emulsion and neat cutting oil (immiscible with water). The investigation results indicated that coconut oil as a cutting fluid performed better than the other two cutting fluids by improving the surface finish and reducing the tool wear.

M.Z.A. Yazid et al. [8] observed surface integrity when finish turning Inconel 718, a highly corrosive resistant, nickel-based super alloy, under three cutting conditions (DRY, MQL 50 mL/h and MQL 100 mL/h). The microstructure analysis using SEM on the machined surface suggests that severe deformation took place, leading to microstructure alteration at subsurface level measuring from a few to several micron in thickness. Work hardening under the machined surface was evident from the micro-hardness. The results of this study show that MQL may possibly improve surface integrity characteristics.
Table-1 Shows Tabulated Literature Survey.

TABLE - 1 LITERATURE SURVEY

S. No.	Year of Publish	Author	Material	Sample Size (d x l) (mm)	Tool/Insert Material	Machining Method	Machining Parameters					Output Parameters	Optimization Methods	Most Significant Factor		References
							Cutting Speed V_c (m/min)	Feed f (mm/rev)	D.O.C (mm)	Other	Cutting Fluid			1st	2nd	
1	2002	Michael Jacobson, Patrik Dahlman	Bainite steel	310OD 170 ID 65mm thick rings	CBN 100 insert	Dry Turning (CNC)	50 to 999	0.1	0.1	-	Conventional Cooling	Surface Roughness, Residual Stress	-	Cutting Speed	-	9
2	2006	N.R. Dhar, M. Kamruzzaman	AISI 4340	125 x 760	Carbide insert	Dry & Wet Turning (Lathe Machine)	110	0.16	1.5	-	Air: 7.0 bar, Lubricant: 60 ml/h	Surface Roughness, Tool Wear, MQL	-	Coolant	-	10
3	2006	M. Nalbant, H. Gokkaya	AISI 1030	-	TiN-coated tools	-	-	0.15, 0.25, 0.35	0.5, 1.5, 2.5	0.4, 0.8, 1.2 *Insert Radius (mm)	-	Surface Roughness (Ra)	Taguchi	Insert Radius	Feed Rate	5
4	2007	Tugrul Ozel, Yigit Karpat	AISI D2	Not specified	PCBN insert	Dry Turning (CNC)	80, 115, 150	0.05, 0.10, 0.15	0.2	(5, 10, 15)min *Cutting Time	Conventional Cooling	Roughness Parameters(R_a, R_t), Tool flank wear	Multiple Linear Regression Models, Neural network models	Feed Rate	Cutting Speed	11
5	2008	R.S. Pawade, Suhas S. Joshi	Inconel 718	70OD 60 ID 5mm thick rings	PCBN insert	Dry Turning (CNC)	125, 300, 475	0.05, 0.10, 0.15	0.50, 0.75, 1.00	-	Conventional Cooling	Residual Stress, Degree of work hardening	Taguchi	Cutting Edge	Depth Of Cut	12
6	2008	D.I. Lalwani, N.K. Mehta	MDN250 18Ni(250)	20 x 250	Ceramic Coated Insert (TNMA160408S 01525)	Lathe Machine	55, 74, 93	0.04, 0.08, 0.12	0.1, 0.15, 0.2	-	Conventional Cooling	Surface Roughness, Cutting forces	Taguchi	Depth of Cut	Feed Rate	13
7	2008	M. Anthony Xavior, M. Adithan	AISI 304	Not specified	Carbide insert (CNMG)	Lathe Machine	38.95, 61.35, 97.38	0.2, 0.25, 0.28	0.5, 1.0, 1.2	-	Coconut oil, Soluble oil, Straight cutting oil	Effect of cutting fluid, Surface Roughness	Taguchi	Cutting Speed	Feed Rate	7
8	2010	Khaider Bouacha, Mohamed Athmane Yallese	AISI 52100	56 x 400	CBN insert	Lathe Machine	125, 176, 246	0.08, 0.12, 0.16	0.15, 0.3, 0.45	-	Conventional Cooling	Surface Roughness, Cutting forces	Taguchi	Feed Rate	Cutting Speed	14
9	2011	A. Devillez, G. Le Coz	Inconel 718	180 (Round Bar)	Coated Carbide inserts S05F	Dry & Wet Turning (CNC)	40, 60, 80	0.1	0.5	-	5% emulsion	Surface Roughness, Residual Stress	-	Coolant	-	15
10	2011	S. Bissey-Breton, J. Graviera	Copper	Not specified	Carbide insert	Dry & Wet Turning (CNC & Lathe Machine)	138, 86	0.05, 0.2	0.05 to 0.3	0.4, 0.8 *Insert Radius (mm)	Not specified	Surface Roughness, Quadratic Stress, Crystallographic anisotropy	Taguchi	-	-	16
11	2011	J. Guddat, R. M'Saoubi	AISI 52100	Ring (initial thickness: 25mm)	PCBN inserts	Dry Turning (CNC)	120 - 180	0.1 - 0.3	0.15	0.4 - 1.2 *Insert Radius (mm)	Conventional Cooling	surface integrity, Cutting forces	-	Cutting Edge	-	17
12	2011	M.Z.A.Yazid, C.H. CheHaron	Inconel 718	103 x 157 (Round Bar)	PVD coated carbide insert	Dry & Wet Turning (CNC)	90, 120, 150	0.10, 0.15	0.30, 0.50	-	MQL 50 mL/h, MQL 100 mL/h	Surface Roughness & Texture, Microstructure Alteration	-	Coolant	-	8
13	2011	A. Esteves Correia, J. Paulo Davim	AISI 1045	51 x 119	Cemented carbide conventional and wiper insert	Dry Turning (CNC)	345, 410, 470	0.075, 0.15, 0.25	0.5	-	Conventional Cooling	Surface Roughness, Influence of the wiper inserts	-	Cutting Edge	Feed Rate	18

TABLE - 1 LITERATURE SURVEY Continue...

S. No.	Year of Publish	Author	Material	Sample Size (d x l) (mm)	Tool/Insert Material	Machining Method	Machining Parameters: Cutting Speed V_c (m/min)	Feed f (mm/rev)	D.O.C (mm)	Other	Cutting Fluid	Output Parameters	Optimization Methods	Most Significant Factor: 1st	2nd	References
14	2011	Ilhan Asilturk, Harun Akkus	AISI 4140	110 x 600	TiC-coated Carbide insert	Dry Turning (CNC)	90, 120, 150	0.18, 0.27, 0.36	0.2, 0.4, 0.6	-	Conventional Cooling	Surface Roughness (Ra), (Rz)	Taguchi	Feed Rate	-	6
15	2012	Adem Cicek, Turgay Kıvak	AISI 316	100 x 170 x 15	HSS, (M35)	Vertical Drilling	12, 14	0.08, 0.1	-	CHT, CT *Tool Material	Conventional Cooling	Surface Roughness (Ra), Roughness Error	Taguchi, Multiple regression analysis	Cutting Speed	Tool Material	19
16	2012	Srinivas Athreya, Dr Y.D.Venkatesh	Mild Steel	-	Tungsten Carbide Tipped tool	Lathe Machine	960, 640, 1280 (RPM)	145, 130, 160 (mm/min)	0.3, 0.2, 0.4	-	Conventional Cooling	Surface Roughness (Ra)	Taguchi, Full Factorial Analysis	Cutting Speed	Depth Of Cut	20
17	2013	Dr. C. J. Rao, Dr. D. Nageswara Rao	AISI 1050	40 x 300 (Round Bar)	Ceramic (Al2O3+TiC matrix)	Dry Turning (CNC)	50, 75, 95	0.05, 0.10, 0.15	0.25, 0.50, 0.75	-	Conventional Cooling	Surface Roughness (Ra), Cutting Forces	Taguchi, Full Factorial Analysis	Depth of Cut	Feed Rate	21
18	2013	Yacov sahijpaul, Gurpreet singh	EN8 or AISI 1040	32 x 200 (Round Bar)	Carbide (CNMG 431-PF 4225)	Wet Turning (CNC)	1000, 2000 (RPM)	0.125, 0.250	0.5, 1.0	-	Cool-cut-Nirma 40 A, Cool-cut-Nirma 30 A	Surface Roughness (Ra), Effect of cutting fluid	Taguchi	Feed Rate	Coolant	22
19	2013	P Subhash, Chandra Bose	NIMONIC 75	-	PVD coated carbide insert	Dry Turning (CNC)	100, 175, 250	0.02, 0.03, 0.04	0.01, 0.125, 0.15	-	Conventional Cooling	Surface Roughness (Ra), MRR	Response Surface Methodology	Feed Rate	Depth Of Cut	23
20	2014	Rajendra Singh, Rahul kr.Gupta	SS 316L	1000 x 120 x 5 (Pipe)	Carbide insert	-	110, 150, 190	0.10, 0.15, 0.20	0.10, 0.15, 0.20	-	-	Surface Roughness (Ra)	Full Factorial Analysis, MRA, ANN	Feed Rate	-	24
21	2015	Prajwalkumar M. Patil, Rajendrakumar V. Kadi	AISI 316	30 x 360 (Round Bar)	Carbide insert (CVD Coated)	Dry Turning (CNC)	120, 150, 180	0.20, 0.25, 0.30	0.5, 1.0, 1.5	-	Conventional Cooling	Surface Roughness (Ra, Rz), Hardness	Taguchi	Feed Rate	Cutting Speed	25
22	2015	Aswathy V G, Rajeev N,	Ti-6Al-4V	37.9 x 125 (Round Bar)	Carbide insert (CVD Coated)	Wet Turning (CNC)	50, 60, 70	0.010, 0.020, 0.030	0.02, 0.035, 0.05	0.1, 0.4, 0.5 *Insert Radius (mm)	Not specified	Surface Roughness (Ra), MRR, Roughness Error	Taguchi	Feed Rate	Depth Of Cut	26
23	2015	Roopa K Rao, Vinay Murgod	EN19	25 x 70 (Round Bar)	Carbide Tip	Dry Turning (CNC)	420, 630, 1000 (rpm)	0.040, 0.048, 0.054	0.04, 0.08, 0.12	-	Conventional Cooling	Surface Roughness (Ra), MRR (with and without HT)	Taguchi, Full Factorial Analysis, Linear Regression Model	Depth of Cut	Feed Rate	27
24	2015	Mehmet Alperince, Ilhan Asilturk	Co28Cr6Mo ASTM F 1537	50 x 500 (Round Bar)	PVD coated carbide insert	Dry Turning (CNC)	318, 477, 636 (RPM)	0.1, 0.15, 0.25	0.5, 0.7, 0.9	0.4, 0.8, 1.2 *Insert Radius (mm)	Conventional Cooling	Surface Roughness (Ra)	Full Factirial Analysis	Insert Radius	-	28
25	2016	Devendra Singh, Vimanyu Chadha	Al 6061	-	Carbide insert	Dry Turning (CNC)	1600, 1900, 2200 (RPM)	0.12, 0.18, 0.24	0.25, 0.50, 0.75	0.4, 0.8, 1.2 *Insert Radius (mm)	Conventional Cooling	Surface Roughness (Ra)	Response Surface Methodology	Insert Radius	Feed Rate	29
26	2016	Lavish Sharma, Jai Prakash Sharma	EN 47	32 x 102	Carbide insert	Wet Turning (CNC)	47, 79, 103	0.05, 0.1, 0.2	0.4, 0.6, 0.8	0.4, 0.8, 1.2 *Insert Radius (mm)	-	Surface Roughness (Ra)	Taguchi	Depth of Cut	Cutting Speed	30

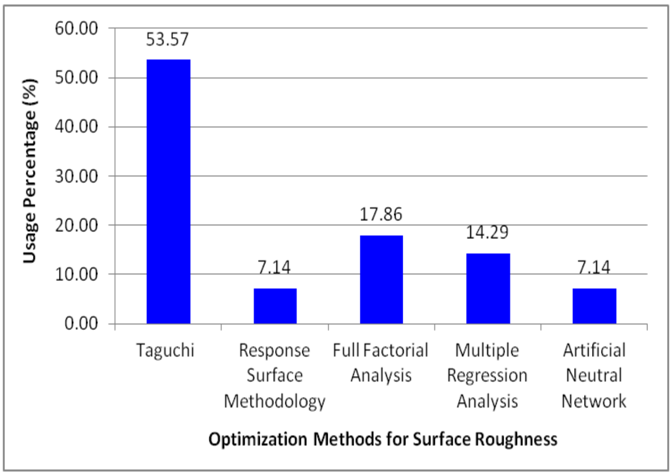
3. CONCLUSION

Surface roughness is considered as the main response factor. Along with the Machining parameters, output parameters and the most significant factor is also tabularized. The percentage distribution of various methods used during optimization is shown in Table-2 and with the help of histogram in Figure-2.

Table-2: Percentage distribution for Optimization methods

Optimization Methods for Surface Roughness	
Optimization Methods	**%**
Taguchi Methodology	53.57
Response Surface Methodology	7.14
Full Factorial Analysis	17.86
Multiple Regression Analysis	14.29
Artificial Neutral Network	7.14
Total	100.00

Figure-2: Histogram showing % distribution of Optimization Methods

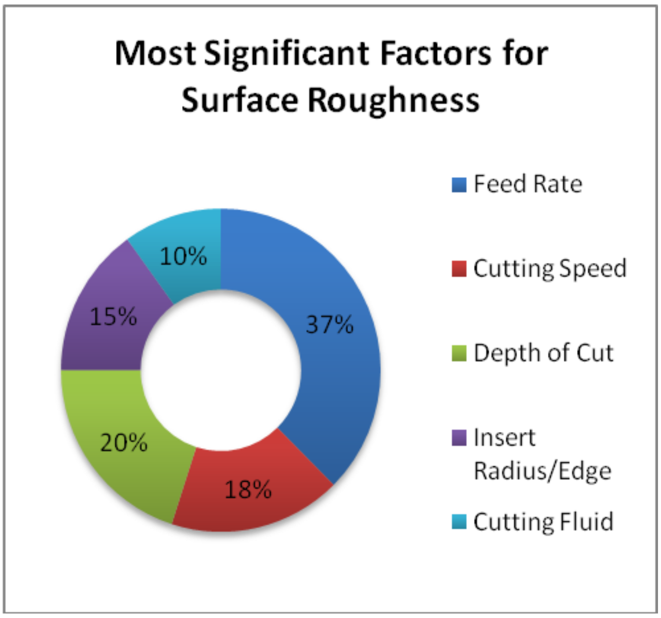


A Pie Chart is designed to find out the percentage contribution of the most significant factors in optimization of surface roughness in review of all these research papers. Table-3 and Figure-3 shows the % contribution of the most significant factors.

Table-3: Percentage Contribution of the most significant factors.

Most Significant Factors for Surface Roughness	
Machining Parameter	**%**
Feed Rate	37.50
Cutting Speed	17.50
Depth of Cut	20.00
Insert Radius/Edge	15.00
Cutting Fluid	10.00
Total	100.00

Figure-3: Pie-chart showing % Contribution of the most significant factors.



From the above literature review it is observed that various methods are used to minimize surface roughness by optimizing cutting parameters like Cutting speed, Feed rate, Depth of cut, tool angle, nose radius, Cutting Fluid, etc. Among all these methods it is observed that Taguchi Method is the most widely used method. The use of other methods like Multiple Regression Analysis, Response Surface Method and Artificial Neural Network are gradually increasing. In optimization of surface roughness Feed Rate is found to be the most Significant factor followed by Depth of cut and cutting speed.

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