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Influence of Cutting Parameters on Turning Process Using Anova Analysis

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Abstract

In a turning process surface roughness depend on machining parameters and tool geometry. In this work considering three machining parameters and two tool geometrical parameters 243 experiments were conducted for full factorial design. Using ANOVA analysis the influence of these parameters on surface roughness was studied.

Keywords: Optimization, machining parameters, ANOVA, rake angles, surface finish.

Introduction

In Single pass turning the conditions during cutting such as cutting speed, feed rate and depth of cut should be selected to optimize the surface roughness. The selection to efficient machining parameters such as machining speed, feed rate and depth of cut has a direct impact in the metal cutting processes. The cutting tool geometry such as back rake, side rake also slightly affects the surface roughness.

The major efforts of earlier works were concentrated on optimization of machining parameters and not concentrated on geometry of cutting. In this work we tried to find influence of machining parameters and tool geometry on surface roughness.

Machining parameters in turning process: In metal cutting, there are many factors related to process planning for machining operations. These factors can be classified as: i. Type of machining operations (turning, facing, milling, etc.), ii. Parameters of machine tools (rigidity, horse power, etc.), iii. Parameters of cutting tools (material, geometry, etc.), iv. Parameters of cutting conditions (cutting speed, feed rate, depth of cut, etc.), v. Characteristics of work pieces (material, geometry, etc.).

Among these factors cutting parameters (speed, feed rate and depth of cut) and tool geometry (back rake, side rake) are evidently dominating ones in a machining operation.

Cutting Speed (*v*): The cutting speed of a tool is the speed at which the metal is removed by the tool from the work material. In a lathe it is the peripheral speed of the work part in m/min.
$V = \pi DN/1000$ (m/min)

Where D, N are diameter of work piece (mm) and cutting speed (rpm) respectively.

Feed (*f*): The feedof the cutting tool in lathe work is the distance, the tool advances for each revolution of the work piece in mm.
Depth of cut (*d*): The depth of cut is the perpendicular distance measured from the machined surface to the uncut surface of the work piece in mm.

Back rake angle: It is the angle provided from the cutting edge to the shank of a single point cutting tool, back rake is to help control the direction of the chip, which naturally curves into the work due to the difference in length from the outer and inner parts of the cut. It also helps counteract the pressure against the tool from the work by pulling the tool into the work piece.

5. Side rake angle: It is the angle provided between front face to the side of the single point cutting tool.

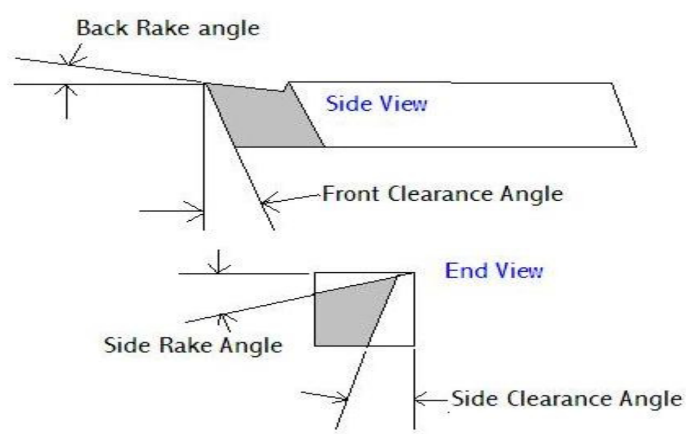

Figure-1
Two rake angles of single point cutting tool

Side rake along with back rake controls the chip flow and partly counteracts the resistance of the work to the movement of the cutter and can be optimized to suit the particular material being cut.

For a given machining operation determination of the optimum cutting conditions involves a conflict between maximizing the material removal rate and minimizing the surface roughness. The machining process optimization is to determine the most advantageous cutting condition. This is to determine optimal machining parameters such as v (cutting speed), f (feed rate), d (depth of cut) and the tool geometry back rake, side rake to optimize specified objectives such as surface roughness and MRR.

Literature-Survey: Gilbert[1] optimized of machining parameters in turning operation by considering maximum production rate and minimum production as objective functions. By expressing the production cost and production rate in terms of speed and feed rate Armaregoand Brown[2] and partially differentiating these terms with respect to speed and feed and equating to zero the optimum cutting conditions are obtained. Brewer and Rueda[3] obtained number of nomograms for facilitating the determination of the economic machining conditions by employing the criterion of reducing the machining cost to a minimum for cast iron and steels. The usage of geometric programming for selection of machining variables were studied by Walvekar and Lambert[4]andobtained optimized cutting speed and feed rate to optimize the production cost. By geometric programming Optimal selection of machining rate variables, was investigated by Petropoulos [5]. A constrained unit cost problem in turning was optimized by using carbide tipped for machining SAE 1045 steel using a goal-programming technique in metal cutting for selecting levels of machining parameters in a fine turning operation on AISI 4140 steel using cemented tungsten carbide tools was studied by Sundaram[6]. constrained multi-pass machining problem was studied by Ermerand Kromodiharajo[7]and concluded, multi-pass machining was more economical than single-pass machining if depth of cut for each pass was properly allocated. Hinduja[8]*et al* considered minimum cost or maximum production rate as the objective function and calculated the optimum cutting conditions for turning operation for a given combination of tool and work material, considered surface finish, dimensional accuracy and power available as constraints. Lambert and Taraman[9]developed a mathematical model to evaluate the cutting force for turning SAE 1018 cold-rolled steel with a carbide tool and utilized the model in the selection of levels of the machining variables such that the material removal rate could be at the highest possible value without violating the given force restrictions. Hassan and Suliman[10] presented mathematical models for the prediction of cutting time, surface roughness, tool vibration, power consumption, while using tungsten carbide tools for turning medium carbon steel under dry conditions. El Baradie[11] developed of a surface roughness model while using tipped carbide tools for turning grey cast iron under dry conditions and with constant depth of cut. The mathematical model is utilizing the response surface methodology was developed in terms of cutting speed, feed rate and nose radius of the cutting tool. These variables were investigated using design of experiments and utilization of the response surface methodology. Using of goal programming technique in for single pass turning operation. T.S. Sidhu[12] determined optimum values for speed and feed by setting different goals for a given set of conditions. Yen and Wright[13] developed a unified method of adaptive control of constraints in which a suitable cutting region is determined satisfying all the physical constraints. The objective of the optimization is to maximize the production rate under constraints of plastic deformation, crater wear and fracture.

Problem: To find the optimum parameters in order to get the minimum surface roughness and to analyze the effect of machining parameters and rake angles on the surface finish. Design of experiments is the most useful and effective statistical quality control technique to investigate and individual interaction effects of process parameters. It isolates the effect of each input variable. Full factorial experiments consist of possible combinations of the levels of factors. Turning operation was carried out at 3 levels of the back rake, side rake; speed feed and depth of cut the range of parameters are shown in table 1

Table-1
Three levels with five parameters (3^5 factors design)

Levels	Rake Angle (º)		Speed (rpm)	Feed (mm/ rev)	Depth of cut (mm)
	Back	Side			
-1	8	12	250	0.1	0.5
0	11	15	350	0.3	1
1	14	18	550	0.5	1.5

Experimental Procedure: In this work mild steel is selected as the specimen, since it is mostly used structural steel. A mild steel rod of length around 20 ft has taken for this experiment. The lengthy rod was cut into 41 pieces as per required specifications. The Specifications used are ($\emptyset = 27mm, l = 150mm$) for the specimen with the cutting tool as high speed steel. On each work piece turning operation is performed for three variables like that 243 experiments are conducted on this 41 work pieces. Surface finish is measured using TALYSURF for 243 experiments. Results are tabulated in table 2

Table-2
Surface roughness at various cutting speeds

S. No.	Rake angle (°)		Peed (rpm)	Feed (mm/rev)	Doc (mm)	Surface Roughness (µm)
	Back	Side				
1	8	12	250	0.1	0.5	2.835
2	8	12	250	0.1	1.0	3.190
3	8	12	250	0.1	1.5	3.510
4	8	12	250	0.3	0.5	3.810
5	8	12	250	0.3	1.0	3.405
6	8	12	250	0.3	1.5	4.390
7	8	12	250	0.5	0.5	4.270
8	8	12	250	0.5	1.0	4.210
9	8	12	250	0.5	1.5	4.410

S. No.	Rake angle (°)		Peed (rpm)	Feed (mm/rev)	Doc (mm)	Surface Roughness (µm)
10	8	12	350	0.1	0.5	2.265
11	8	12	350	0.1	1.0	2.545
12	8	12	350	0.1	1.5	2.475
13	8	12	350	0.3	0.5	3.200
14	8	12	350	0.3	1.0	3.160
15	8	12	350	0.3	1.5	3.720
16	8	12	350	0.5	0.5	4.345
17	8	12	350	0.5	1.0	3.890
18	8	12	350	0.5	1.5	4.600
19	8	12	550	0.1	0.5	2.200
20	8	12	550	0.1	1.0	1.665
21	8	12	550	0.1	1.5	2.080
22	8	12	550	0.3	0.5	2.940
23	8	12	550	0.3	1.0	2.410
24	8	12	550	0.3	1.5	2.885
25	8	12	550	0.5	0.5	3.765
26	8	12	550	0.5	1.0	3.735
27	8	12	550	0.5	1.5	4.170
28	8	15	250	0.1	0.5	3.050
29	8	15	250	0.1	1.0	2.750
30	8	15	250	0.1	1.5	3.150
31	8	15	250	0.3	0.5	3.605
32	8	15	250	0.3	1.0	3.710
33	8	15	250	0.3	1.5	3.830
34	8	15	250	0.5	0.5	4.125
35	8	15	250	0.5	1.0	4.230
36	8	15	250	0.5	1.5	5.030
37	8	15	350	0.1	0.5	2.485
38	8	15	350	0.1	1.0	2.570
39	8	15	350	0.1	1.5	2.800
40	8	15	350	0.3	0.5	3.385
41	8	15	350	0.3	1.0	2.920
42	8	15	350	0.3	1.5	3.430
43	8	15	350	0.5	0.5	3.960
44	8	15	350	0.5	1.0	4.155
45	8	15	350	0.5	1.5	4.230
46	8	15	550	0.1	0.5	2.145
47	8	15	550	0.1	1.0	2.060
48	8	15	550	0.1	1.5	2.425
49	8	15	550	0.3	0.5	2.600
50	8	15	550	0.3	1.0	2.670
51	8	15	550	0.3	1.5	3.160
52	8	15	550	0.5	0.5	3.870
53	8	15	550	0.5	1.0	3.580
54	8	15	550	0.5	1.5	4.150
55	8	18	250	0.1	0.5	2.905
56	8	18	250	0.1	1.0	2.605
57	8	18	250	0.1	1.5	3.195
58	8	18	250	0.3	0.5	3.380
59	8	18	250	0.3	1.0	3.225
60	8	18	250	0.3	1.5	3.740

S. No.	Rake angle (°)		Peed (rpm)	Feed (mm/rev)	Doc (mm)	Surface Roughness (µm)
61	8	18	250	0.5	0.5	4.320
62	8	18	250	0.5	1.0	4.445
63	8	18	250	0.5	1.5	5.110
64	8	18	350	0.1	0.5	2.415
65	8	18	350	0.1	1.0	2.200
66	8	18	350	0.1	1.5	2.510
67	8	18	350	0.3	0.5	3.080
68	8	18	350	0.3	1.0	2.550
69	8	18	350	0.3	1.5	3.210
70	8	18	350	0.5	0.5	4.120
71	8	18	350	0.5	1.0	3.730
72	8	18	350	0.5	1.5	3.925
73	8	18	550	0.1	0.5	2.115
74	8	18	550	0.1	1.0	1.795
75	8	18	550	0.1	1.5	2.255
76	8	18	550	0.3	0.5	2.800
77	8	18	550	0.3	1.0	2.640
78	8	18	550	0.3	1.5	3.440
79	8	18	550	0.5	0.5	3.825
80	8	18	550	0.5	1.0	3.480
81	8	18	550	0.5	1.5	4.105
82	11	12	250	0.1	0.5	2.840
83	11	12	250	0.1	1.0	2.805
84	11	12	250	0.1	1.5	3.190
85	11	12	250	0.3	0.5	3.615
86	11	12	250	0.3	1.0	3.590
87	11	12	250	0.3	1.5	3.725
88	11	12	250	0.5	0.5	4.450
89	11	12	250	0.5	1.0	4.075
90	11	12	250	0.5	1.5	5.065
91	11	12	350	0.1	0.5	2.230
92	11	12	350	0.1	1.0	1.795
93	11	12	350	0.1	1.5	2.570
94	11	12	350	0.3	0.5	2.760
95	11	12	350	0.3	1.0	2.830
96	11	12	350	0.3	1.5	3.360
97	11	12	350	0.5	0.5	3.960
98	11	12	350	0.5	1.0	3.355
99	11	12	350	0.5	1.5	4.340
100	11	12	550	0.1	0.5	2.110
101	11	12	550	0.1	1.0	2.035
102	11	12	550	0.1	1.5	2.440
103	11	12	550	0.3	0.5	2.840
104	11	12	550	0.3	1.0	2.635
105	11	12	550	0.3	1.5	3.375
106	11	12	550	0.5	0.5	3.590
107	11	12	550	0.5	1.0	3.725
108	11	12	550	0.5	1.5	3.980
109	11	15	250	0.1	0.5	2.335
110	11	15	250	0.1	1.0	2.290
111	11	15	250	0.1	1.5	3.040

S. No.	**Rake angle (°)**		**Peed (rpm)**	**Feed (mm/rev)**	**Doc (mm)**	**Surface Roughness (µm)**
112	11	15	250	0.3	0.5	3.480
113	11	15	250	0.3	1.0	3.405
114	11	15	250	0.3	1.5	3.780
115	11	15	250	0.5	0.5	4.725
116	11	15	250	0.5	1.0	4.410
117	11	15	250	0.5	1.5	4.850
118	11	15	350	0.1	0.5	2.145
119	11	15	350	0.1	1.0	1.925
120	11	15	350	0.1	1.5	2.480
121	11	15	350	0.3	0.5	3.210
122	11	15	350	0.3	1.0	2.940
123	11	15	350	0.3	1.5	3.220
124	11	15	350	0.5	0.5	3.795
125	11	15	350	0.5	1.0	3.640
126	11	15	350	0.5	1.5	4.440
127	11	15	550	0.1	0.5	2.040
128	11	15	550	0.1	1.0	2.110
129	11	15	550	0.1	1.5	2.260
130	11	15	550	0.3	0.5	3.040
131	11	15	550	0.3	1.0	2.560
132	11	15	550	0.3	1.5	3.080
133	11	15	550	0.5	0.5	3.220
134	11	15	550	0.5	1.0	3.375
135	11	15	550	0.5	1.5	3.900
136	11	18	250	0.1	0.5	2.815
137	11	18	250	0.1	1.0	2.600
138	11	18	250	0.1	1.5	3.275
139	11	18	250	0.3	0.5	3.440
140	11	18	250	0.3	1.0	3.250
141	11	18	250	0.3	1.5	3.870
142	11	18	250	0.5	0.5	4.465
143	11	18	250	0.5	1.0	4.210
144	11	18	250	0.5	1.5	4.700
145	11	18	350	0.1	0.5	2.350
146	11	18	350	0.1	1.0	2.475
147	11	18	350	0.1	1.5	2.580
148	11	18	350	0.3	0.5	3.345
149	11	18	350	0.3	1.0	2.580
150	11	18	350	0.3	1.5	3.555
151	11	18	350	0.5	0.5	3.750
152	11	18	350	0.5	1.0	3.740
153	11	18	350	0.5	1.5	3.825
154	11	18	550	0.1	0.5	2.040
155	11	18	550	0.1	1.0	1.880
156	11	18	550	0.1	1.5	2.280
157	11	18	550	0.3	0.5	3.170
158	11	18	550	0.3	1.0	2.205
159	11	18	550	0.3	1.5	3.215
160	11	18	550	0.5	0.5	3.425
161	11	18	550	0.5	1.0	3.440
162	11	18	550	0.5	1.5	3.815

S. No.	**Rake angle (°)**		**Peed (rpm)**	**Feed (mm/rev)**	**Doc (mm)**	**Surface Roughness (µm)**
163	14	12	250	0.1	0.5	2.195
164	14	12	250	0.1	1.0	2.320
165	14	12	250	0.1	1.5	3.120
166	14	12	250	0.3	0.5	3.120
167	14	12	250	0.3	1.0	3.150
168	14	12	250	0.3	1.5	3.340
169	14	12	250	0.5	0.5	4.170
170	14	12	250	0.5	1.0	3.710
171	14	12	250	0.5	1.5	4.320
172	14	12	350	0.1	0.5	2.250
173	14	12	350	0.1	1.0	1.780
174	14	12	350	0.1	1.5	2.360
175	14	12	350	0.3	0.5	2.670
176	14	12	350	0.3	1.0	2.480
177	14	12	350	0.3	1.5	3.115
178	14	12	350	0.5	0.5	3.560
179	14	12	350	0.5	1.0	3.345
180	14	12	350	0.5	1.5	3.915
181	14	12	550	0.1	0.5	1.890
182	14	12	550	0.1	1.0	1.580
183	14	12	550	0.1	1.5	1.970
184	14	12	550	0.3	0.5	2.740
185	14	12	550	0.3	1.0	2.400
186	14	12	550	0.3	1.5	2.665
187	14	12	550	0.5	0.5	3.175
188	14	12	550	0.5	1.0	2.885
189	14	12	550	0.5	1.5	3.400
190	14	15	250	0.1	0.5	2.465
191	14	15	250	0.1	1.0	2.560
192	14	15	250	0.1	1.5	2.435
193	14	15	250	0.3	0.5	3.335
194	14	15	250	0.3	1.0	2.920
195	14	15	250	0.3	1.5	3.045
196	14	15	250	0.5	0.5	3.920
197	14	15	250	0.5	1.0	3.400
198	14	15	250	0.5	1.5	4.120
199	14	15	350	0.1	0.5	1.460
200	14	15	350	0.1	1.0	1.370
201	14	15	350	0.1	1.5	2.060
202	14	15	350	0.3	0.5	2.275
202	14	15	350	0.3	1.0	2.420
204	14	15	350	0.3	1.5	2.800
205	14	15	350	0.5	0.5	3.385
206	14	15	350	0.5	1.0	3.205
207	14	15	350	0.5	1.5	3.640
208	14	15	550	0.1	0.5	1.700
209	14	15	550	0.1	1.0	1.605
210	14	15	550	0.1	1.5	1.925
211	14	15	550	0.3	0.5	2.460
212	14	15	550	0.3	1.0	2.555
213	14	15	550	0.3	1.5	2.420

S. No.	Rake angle (°)		Peed (rpm)	Feed (mm/rev)	Doc (mm)	Surface Roughness (µm)
214	14	15	550	0.5	0.5	2.970
215	14	15	550	0.5	1.0	2.720
216	14	15	550	0.5	1.5	3.050
217	14	18	250	0.1	0.5	2.310
218	14	18	250	0.1	1.0	2.090
219	14	18	250	0.1	1.5	2.669
220	14	18	250	0.3	0.5	2.760
221	14	18	250	0.3	1.0	3.075
222	14	18	250	0.3	1.5	3.570
223	14	18	250	0.5	0.5	3.545
224	14	18	250	0.5	1.0	3.715
225	14	18	250	0.5	1.5	4.200
226	14	18	350	0.1	0.5	1.920
227	14	18	350	0.1	1.0	1.285
228	14	18	350	0.1	1.5	2.085
229	14	18	350	0.3	0.5	2.540
230	14	18	350	0.3	1.0	2.640
231	14	18	350	0.3	1.5	3.120
232	14	18	350	0.5	0.5	3.775
233	14	18	350	0.5	1.0	3.375
234	14	18	350	0.5	1.5	3.720
235	14	18	550	0.1	0.5	1.630
236	14	18	550	0.1	1.0	1.465
237	14	18	550	0.1	1.5	2.225
238	14	18	550	0.3	0.5	2.725
239	14	18	550	0.3	1.0	2.380
240	14	18	550	0.3	1.5	2.570
241	14	18	550	0.5	0.5	3.200
242	14	18	550	0.5	1.0	3.060
243	14	18	550	0.5	1.5	3.390

Results

ANOVA analysis is carried out on the data shown in table1 using MINITAB Software for surface roughness and results are tabulated in table3

Table-3
Analysis of variance for surface roughness

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Back Rake	2	12.52	12.5	6.263	155.2	8.1
Side Rake	2	0.378	0.38	0.189	4.69	0.2
Speed	2	23.69	23.7	11.84	293.6	15.3
Feed	2	99.726	99.7	49.83	1236	64.3
DOC	2	9.355	9.35	4.677	115.9	6.05
Error	232	9.359	9.35	0.040		6.05
Total	242	155.03				

S = 0.200851 R-Sq = 93.96% R-Sq(adj) = 93.70%

Main effects plot and interaction plot are shown in figure .2 and figure-3

Conclusion

From figure-2it is observed that minimum surface roughness is obtained at a speed of 550 rpm, feed of 0.1 mm/rev, depth of cut of 1mm, side rake angle of 18º and back rake angle of 14º the surface finish is 1.465µm.

From table3 it is observed that feed is the significant parameter influencing surface roughness and side rake angle is having very less effect on surface roughness

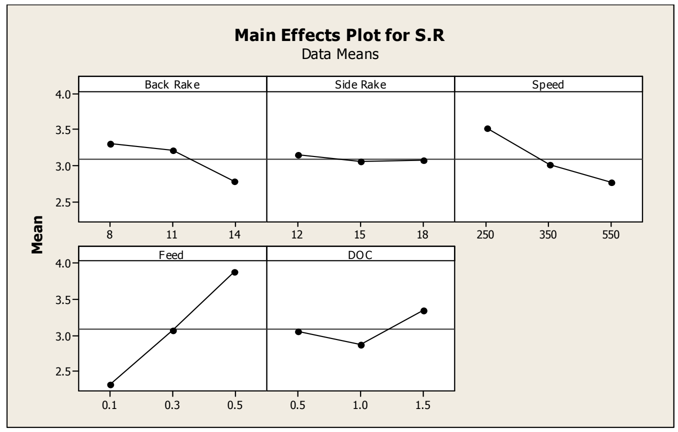

Figure-2
Main Effects Plot

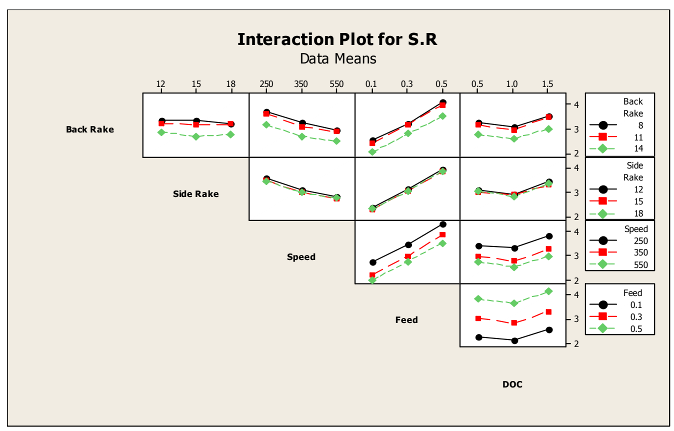

Figure-3
Interaction Plot

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