Optimization of Cutting Parameters for Improvement of Surface Roughness and Tool Life on Low Carbon Steel Using Taguchi Method

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Abstract - *The test of present day machining businesses is mostly centered around the accomplishment of high calibre, regarding work piece dimensional precision, surface complete, high creation rate, less wear on the cutting apparatuses, economy of machining in terms of cost sparing and increment the execution of the item. In this way cutting parameters must be picked and upgraded in such a path, to the point that the surface quality and flank wear can be controlled. Dim taguchi technique is connected to streamlined multiresponse. In this review L27 orthogonal cluster used to upgraded turning parameters i.e. cutting rate, bolster, profundity of cut and corner range. The coefficient and grades as indicated by Gray social examination are assessed utilizing standardized trial after effects of the execution attributes. The Analyses Of Fluctuation (ANOVA) are led to recognize the most huge calculate influencing the turning execution. The got comes about show that cutting velocity is best parameter that effect on surface unpleasantness and flank wear along these lines took after by profundity of cut, nourish rate and corner range.*

Key Words: ASTM A36, cutting parameters, coated carbide tool, corner radius, flank wear, grey taguchi method, surface roughness.

1. INTRODUCTION

There are two principle functional issues that specialists confront in an assembling procedure. The first is to decide the estimations of the procedure parameters that will yield the coveted item quality and the second is to expand fabricating framework execution utilizing the accessible assets. What's more, another primary issue is to limiting item cost. The choices made by assembling designers are based not just on their experience and mastery additionally on traditions with respect to marvels that happen amid preparing. In the machining field, a hefty portion of these marvels are profoundly complex and associate with an expansive number of components, hence keeping high process execution from being accomplished. To beat these issues, the analysts propose models that attempt to reenact the conditions amid machining and build up circumstances and end results connections between different components and sought item attributes. Moreover, the innovative propels in the field, for example the regularly developing utilization of PC controlled machine devices, have raised new issues to manage, which additionally underscore the requirement for additional exact prescient models [9].

Surface unpleasantness is a generally utilized record of item quality furthermore, by and large a specialized prerequisite for mechanical items. For development of hardware life the flank wear is exceptionally critical reaction to limit. Analyst limiting flank wear and accomplishing the coveted surface quality is of incredible significance for the practical conduct of a section. The most normal procedure includes the determination of traditionalist handle parameters, which neither ensures the accomplishment of the coveted surface complete nor accomplishes high wear.

2. LITERATURE SURVEY

Nalbant et al. used the Taguchi method to find the optimal cutting parameters for surface roughness in turning. The orthogonal array, the signal-to-noise ratio, and analysis of variance are employed to study the performance characteristics in turning operations of AISI 1030 steel bars using TiN coated tools. Three cutting parameters namely, insert radius, feed rate, and depth of cut, are optimized with considerations of surface roughness. Experimental results are provided to illustrate the effectiveness of this approach. **Aslan et al.** carried out an experimental study toOptimal cutting parameters by employing Taguchi techniques. They also combined effects of three cutting parameters, namely cutting speed, feed rate and depth of cut on two performance measures, flank wear (VB) and surface roughness (Ra), were investigated employing an orthogonal array and the analysis of variance (ANOVA). Optimal cutting parameters for each performance measure were obtained; also the relationship between the parameters and the performance measures were determined using multiple linear regression. Al_2O_3-based ceramics material are used because it is one of the most suitable cutting tool materials for machining hardened steels. However, their high degree of brittleness usually leads to inconsistent results and sudden catastrophic failures.

Motorcu investigated the surface roughness in the turning of AISI 8660 hardened alloy steels by ceramic based cutting tools in terms of main cutting parameters such as cutting speed, feed rate, depth of cut in addition to tool's nose radius, using a statistical approach. Machining tests were carried out with PVD coated ceramic cutting tools under different conditions. An orthogonal design, signal-to-noise ratio and analysis of variance were employed to find out the effective cutting parameters and nose radius on the surface roughness. This researcher obtained results indicate that the feed rate was found to be the dominant factor among controllable factors on the surface roughness, followed by depth of cut and tool's nose radius. However, the cutting speed showed an insignificant effect. Furthermore, the interaction of feed rate/depth of cut was found to be significant on the surface finish due to surface hardening of steel. Optimal testing parameters for surface roughness could be calculated. Moreover, the second order regression model also shows that the predicted values were very close to the experimental one for surface roughness.

Davis et al. carried out experimental study to optimize the cutting parameters like depth of cut, feed rate and spindle speed in turning EN24 steel. In this study, the turning operation are carried out on EN24 steel by carbide P-30 cutting tool in dry condition and the combination of the optimal levels of the parameters are obtained. In order to study the performance characteristics in turning operation the Signal-to-Noise ratio and Analysis of Variance are employed. As a result of the analysis none of the factor are found to be significant. Taguchi method has shown that feed rate followed by Spindle speed and depth of cut are the combination of the optimal levels of factors while turning EN24 steel by carbide cutting tool in dry cutting condition.

Makadia and Nanavati used Design of experiments to study the effect of the main turning parameters such as feed rate, tool nose radius, cutting speed and depth of cut on the surface roughness of AISI 410 steel. A mathematical prediction model of the surface roughness has been developed in terms of above parameters. The effect of these parameters on the surface roughness has been investigated by using Response Surface Methodology (RSM). Response surface contours were constructed for determining the optimum conditions for a required surface roughness. The developed prediction equation shows that the feed rate is the main factor followed by tool nose radius influences the surface roughness. The surface roughness was found to increase with the increase in the feed and it decreased with increase in the tool nose radius. The verification experiment is carried out to check the validity of the developed model that predicted surface roughness within 6% error.

Verma et al. carried out the analysis of optimum cutting conditions to get lowest surface roughness in turning ASTM A242 Type-1 Alloys Steel by Taguchi method. Experiment was designed using Taguchi method and 9 experiments were conducted by this process. The results are analysed using analysis of variance (ANOVA) method. Taguchi method has shown that the cutting speed has significant role to play in producing lower surface roughness about 57.47% followed by feed rate about 16.27%. The Depth of Cut has lesser role on surface roughness from the tests. The results obtained by this method will be useful to other researches for similar type of study and may be eye opening for further research on tool vibrations, cutting forces etc.

Ramya et.al. In this experimental work turning parameters on EN-8 steel with different parameters such as Cutting speed, feed and depth of cut are greatly influenced by response parameters. The experimental design was formed based on Taguchi's Technique. An orthogonal array and Analysis of Variance (ANOVA) are employed to investigate the Turning conditions and machining was done using coated tool insert.

3. SYSTEM ARCHITECTURE

3.1 Objectives

1. Literature reviews of turning process parameters.
2. Identify the performance characteristics and select process parameters to be evaluated
3. Determine the number of levels for the process parameters and possible interactions between the process parameters.
4. Select the appropriate orthogonal array and assignment of process parameters to the orthogonal array.
5. Conduct the experiments based on the arrangement of the orthogonal array.
6. Optimization of process parameters using Design of Experiments (DOE).
7. Analyze the experimental results using the S/N ratio and ANOVA.
8. Verify the optimal process parameters through the confirmation experiment.

3.2 Method

3.2.1. Taguchi method

The Taguchi method developed by Genichi Taguchi (1990) was the most important statistical tool for the optimization of the single output parameter. It considers a set of different number of input parameters, may it be an L27 orthogonal array or an L9 orthogonal array depending upon the degree of accuracy needed. Taguchi is a set of methodologies by different properties of material and machining process has been taken into account of design shape [9].

Step of Taguchi method follows as:

1. Selection of the factors to be evaluated.
2. Selection of the number of levels.
3. Selection of the appropriate orthogonal array.
4. Assignment of factors to the columns.
5. Conduct the experiment.
6. Analyze the result, predict the optimum level.
7. Perform the verification experiment and plan the future action.

Table -3.1: Machining parameters

Parameters	Level 1	Level 2	Level 3	Units
Cutting speed *(Vc)*	175	250	325	m/min
Feed *(F)*	0.05	0.1	0.2	mm/rev
Depth of cut *(Dc)*	0.25	0.5	1.0	mm
Corner radius *(R)*	0.4	0.8	1.2	mm

Taguchi's methodology involves use of specially constructed tables called "Orthogonal Array" (OA) which requires very less number of experimental runs in designing which are consistent and very easy.

Table -3.2: Layout using an L27 orthogonal array

Test No.	Vc	F	Dc	R
1	1	1	1	1
2	1	1	2	2
3	1	1	3	3
4	1	2	1	2
5	1	2	2	3
6	1	2	3	1
7	1	3	1	3
8	1	3	2	1
9	1	3	3	2
10	2	1	1	1
11	2	1	2	2
12	2	1	3	3
13	2	2	1	2
14	2	2	2	3
15	2	2	3	1
16	2	3	1	3
17	2	3	2	1
18	2	3	3	2
19	3	1	1	1
20	3	1	2	2
21	3	1	3	3
22	3	2	1	2
23	3	2	2	3
24	3	2	3	1
25	3	3	1	3
26	3	3	2	1
27	3	3	3	2

Table -3.3: Experimental layout for ASTM A-36 steel using an L27 orthogonal array

Test No.	Cutting Speed (Vc)	Feed (F)	Depth of cut (Dc)	Corner radius (R)
1	175	0.05	0.25	0.4
2	175	0.05	0.5	0.8
3	175	0.05	1	1.2
4	175	0.1	0.25	0.8
5	175	0.1	0.5	1.2
6	175	0.1	1	0.4
7	175	0.2	0.25	1.2
8	175	0.2	0.5	0.4
9	175	0.2	1	0.8
10	250	0.05	0.25	0.4
11	250	0.05	0.5	0.8
12	250	0.05	1	1.2
13	250	0.1	0.25	0.8
14	250	0.1	0.5	1.2
15	250	0.1	1	0.4
16	250	0.2	0.25	1.2
17	250	0.2	0.5	0.4
18	250	0.2	1	0.8
19	325	0.05	0.25	0.4
20	325	0.05	0.5	0.8
21	325	0.05	1	1.2
22	325	0.1	0.25	0.8
23	325	0.1	0.5	1.2
24	325	0.1	1	0.4
25	325	0.2	0.25	1.2
26	325	0.2	0.5	0.4
27	325	0.2	1	0.8

3.2.2 Grey Taguchi Approach

The Grey Taguchi Approach is an advanced form of the Taguchi method, which emphasizes on the optimization of more than one output parameters, rather than optimizing a single output parameter as in case of the Taguchi method. It considers a set of different number of input parameters, depending upon the degree of accuracy needed. The number of experiments chosen in this study is an L27 orthogonal array comprising the input parameters are cutting speed *(Vc),* feed *(F),* Depth of cut (*Dc*) and corner radius (*R*).

Two-output parameters of the surface roughness and flank wear, namely Ra and VB are considered and converted into a single output parameter, called the Grade. The calculation of the grade requires the calculation of the normalized, Δ and Grey relational coefficient (ξ) values for each of the output parameters of the surface roughness and flank wear. The average of the grey relational coefficient (ξ) values for output parameters gives the value of the grade of the entire output parameters. Based on the grade calculated, the corresponding S/N ratio is obtained through the following formula [13].

4. EXPERIMENTATION

The goal of this experimental work is to investigate the effects of cutting parameters on surface roughness and tool wear, and to establish a correlation between them. In order for this, cutting speed, feed rate, depth of cut and corner nose radius was chosen as process parameters.

To choose a fitting orthogonal cluster for tests, the aggregate degrees of opportunity should be processed. The degrees of opportunity are characterized as the quantity of examinations between process parameters that should be made to figure out which level is better and particularly how much better it is. For instance, a three-level process parameter means two degrees of flexibility. The degrees of opportunity related with cooperation between two process parameters are given by the result of the degrees of flexibility for the two procedure parameters. In the present review, the connection between the cutting parameters is ignored. In this manner, there are six degrees of opportunity attributable to the three cutting parameters in turning operations. Once the degrees of flexibility required are known, the Next stride is to choose a proper orthogonal cluster to fit the particular undertaking. Fundamentally, the degrees of opportunity for the orthogonal cluster ought to be more noteworthy than or if nothing else equivalent to those for the procedure parameters. In this review, L27 orthogonal exhibits were utilized.

Fig -4.1: Pressure cup

Table -4.1: Chemical composition (Wt. %) of ASTM A-36 steel

C	Si	Mn	S	P	Cu	Fe
0.26	0.28	1.03	0.05	0.04	0.20	98.0

Table -4.2: Mechanical properties of ASTM A-36 steel

Mechanical property	Value
Hardness	159 HB
% Elongation	20
% Reduction of Area	50
Tensile Strength	550 MPa
Yield Strength	225 MPa

4.1 CUTTING TOOL:

The different cutting tool inserts used for experimentation with coated carbide their specifications shown in table.

Fig -4.1.1: Cutting insert

Table -4.1.1: Insert specification.

ISO Catalogue no.	Nose radius (mm)	Nose angle (deg.)	Flank face (mm)
TNMG 160404 SH	0.4	15°	0.2
TNMG 160408 MA	0.8	22°	0.23
TNMG 160412 MH	1.2	16°	0.25

5. RESULTS AND DISCUSSION

After machining the work piece surface are measured on Surftest SJ-210 and insert wear measured on optical microscope their results are shown in table.

Table -5.1: Results of flank wear and surface roughness

Ex no.	Cutting speed (Vc)	Feed (F)	Depth of cut (Dc)	Corner radius (R)	Flank wear (Vb) (mm)	Surface roughness (Ra)
1	175	0.05	0.25	0.4	0.05	3.6
2	175	0.05	0.5	0.8	0.06	1.98
3	175	0.05	1	1.2	0.07	1.56
4	175	0.1	0.25	0.8	0.2	2.3
5	175	0.1	0.5	1.2	0.26	2.955
6	175	0.1	1	0.4	0.1	3.92
7	175	0.2	0.25	1.2	0.22	3.13
8	175	0.2	0.5	0.4	0.29	3.28
9	175	0.2	1	0.8	0.5	3.98
10	250	0.05	0.25	0.4	0.05	0.735
11	250	0.05	0.5	0.8	0.19	0.845
12	250	0.05	1	1.2	0.2	1.44
13	250	0.1	0.25	0.8	0.06	0.55
14	250	0.1	0.5	1.2	0.07	1.405
15	250	0.1	1	0.4	0.22	1.33
16	250	0.2	0.25	1.2	0.21	1.73
17	250	0.2	0.5	0.4	0.03	2.005
18	250	0.2	1	0.8	0.23	2.23
19	325	0.05	0.25	0.4	0.08	0.9298
20	325	0.05	0.5	0.8	0.07	0.9466
21	325	0.05	1	1.2	0.09	0.692
22	325	0.1	0.25	0.8	0.12	1.08
23	325	0.1	0.5	1.2	0.11	0.8485
24	325	0.1	1	0.4	0.12	1.835
25	325	0.2	0.25	1.2	0.19	1.5068
26	325	0.2	0.5	0.4	0.06	1.7363
27	325	0.2	1	0.8	0.05	1.7777

5.1 Tool life:

Tool life generally indicates the amount of satisfactory performance or service rendered by a fresh tool or a cutting point till it is declared failed. Wear and tool life of any tool for any work material is governed mainly by the level of the machining parameters i.e., cutting velocity, (VC), feed, (F) and depth of cut (Dc). Its formula is shown below.

$$T = \frac{C}{Vc^{n} F^{n1} Dc^{n2}} \tag{5.1}$$

Where;
T= Tool life
V= Cutting speed and
n and c = depend on feed, depth of cut, work material and, tooling material
Tool material is coated carbide so values of c, n, n1 and n2 are shown below:
C = 500
n = 0.27
n1 = 0.42
n2 = 0.15
Results of tool life calculation is shown in table

Table -5.1.1: Results of tool life calculation

Ex no.	Cutting speed (Vc)	Feed (F)	Depth of cut (Dc)	Corner radius (R)	Vb (mm)	Ra(um)	Tool life (hours)
1	175	0.05	0.25	0.4	0.05	3.6	8.952412
2	175	0.05	0.5	0.8	0.06	1.98	8.068366
3	175	0.05	1	1.2	0.07	1.56	7.271618
4	175	0.1	0.25	0.8	0.2	2.3	6.691253
5	175	0.1	0.5	1.2	0.26	2.955	6.030495
6	175	0.1	1	0.4	0.1	3.92	5.434987
7	175	0.2	0.25	1.2	0.22	3.13	5.001208
8	175	0.2	0.5	0.4	0.29	3.28	4.507341
9	175	0.2	1	0.8	0.5	3.98	4.062243
10	250	0.05	0.25	0.4	0.05	0.735	8.130487
11	250	0.05	0.5	0.8	0.19	0.845	7.327605
12	250	0.05	1	1.2	0.2	1.44	6.604007
13	250	0.1	0.25	0.8	0.06	0.55	6.076926
14	250	0.1	0.5	1.2	0.07	1.405	5.476832
15	250	0.1	1	0.4	0.22	1.33	4.935998
16	250	0.2	0.25	1.2	0.21	1.73	4.542044
17	250	0.2	0.5	0.4	0.03	2.005	4.093519
18	250	0.2	1	0.8	0.23	2.23	3.689286
19	325	0.05	0.25	0.4	0.08	0.9298	7.574463
20	325	0.05	0.5	0.8	0.07	0.9466	6.826488
21	325	0.05	1	1.2	0.09	0.692	6.152376
22	325	0.1	0.25	0.8	0.12	1.08	5.66134
23	325	0.1	0.5	1.2	0.11	0.8485	5.102285
24	325	0.1	1	0.4	0.12	1.835	4.598437
25	325	0.2	0.25	1.2	0.19	1.5068	4.231425
26	325	0.2	0.5	0.4	0.06	1.7363	3.813574
27	325	0.2	1	0.8	0.05	1.7777	3.436985

Table -5.1.2: Normalized value and grey relational coefficient

Ex No	Flank wear	Surface roughness	Normalized value for Flank Wear	Normalized value for Ra	Grey coefficient Wear	Grey coefficient Ra
1	0.05	3.6	0.957447	0.11079	0.92157	0.35992
2	0.06	1.98	0.93617	0.58309	0.88679	0.54531
3	0.07	1.56	0.914894	0.70554	0.85455	0.62936
4	0.2	2.3	0.638298	0.4898	0.58025	0.49495
5	0.26	2.955	0.510638	0.29883	0.50538	0.41626
6	0.1	3.92	0.851064	0.01749	0.77049	0.33727
7	0.22	3.13	0.595745	0.24781	0.55294	0.3993
8	0.29	3.28	0.446809	0.20408	0.47475	0.38583
9	0.5	3.98	0	0	0.33333	0.33333
10	0.05	0.735	0.957447	0.94606	0.92157	0.90263
11	0.19	0.845	0.659574	0.91399	0.59494	0.85323
12	0.2	1.44	0.638298	0.74052	0.58025	0.65835
13	0.06	0.55	0.93617	1	0.88679	1
14	0.07	1.405	0.914894	0.75073	0.85455	0.66732
15	0.22	1.33	0.595745	0.77259	0.55294	0.68737
16	0.21	1.73	0.617021	0.65598	0.56627	0.5924
17	0.03	2.005	1	0.5758	1	0.54101
18	0.23	2.23	0.574468	0.5102	0.54023	0.50515
19	0.08	0.9298	0.893617	0.88927	0.82456	0.81869
20	0.07	0.9466	0.914894	0.88437	0.85455	0.81218
21	0.09	0.692	0.87234	0.9586	0.79661	0.92353
22	0.12	1.08	0.808511	0.84548	0.72308	0.76392
23	0.11	0.8485	0.829787	0.91297	0.74603	0.85175
24	0.12	1.835	0.808511	0.62536	0.72308	0.57167
25	0.19	1.5068	0.659574	0.72105	0.59494	0.64189
26	0.06	1.7363	0.93617	0.65414	0.88679	0.59111
27	0.05	1.7777	0.957447	0.64207	0.92157	0.5828

Table -5.1.3: Grey relational grade and its order

Exp No.	Grey relational grade	Order
1	0.64074	16
2	0.71605	14
3	0.74195	11
4	0.5376	22
5	0.46082	25
6	0.55388	21
7	0.47612	24
8	0.43029	26
9	0.33333	27
10	0.9121	2
11	0.72409	13
12	0.6193	18
13	0.9434	1
14	0.76093	8
15	0.62016	17
16	0.57933	20
17	0.7705	7
18	0.52269	23
19	0.82163	5
20	0.83336	4
21	0.86007	3
22	0.7435	10
23	0.79889	6
24	0.64737	15
25	0.61841	19
26	0.73895	12
27	0.75218	9

Table -5.1.4: Grey relation grade response

Level	Cutting Speed (Vc)	Feed (F)	Depth of cut (Dc)	Corner radius (R)
1	0.54342	0.763255	0.696981	0.681736
2	0.716944	0.67406	0.67406	0.678467
3	0.757153	0.580202	0.580202	0.657314
Delta	0.213732	0.183052	0.116779	0.024422
Rank	1	2	3	4

From the rank it is observed that the cutting speed is the most significant factor for grey relational grade. After that sliding distance followed by feed and depth of cut. The effect from response table is plotted in chart 5.1.

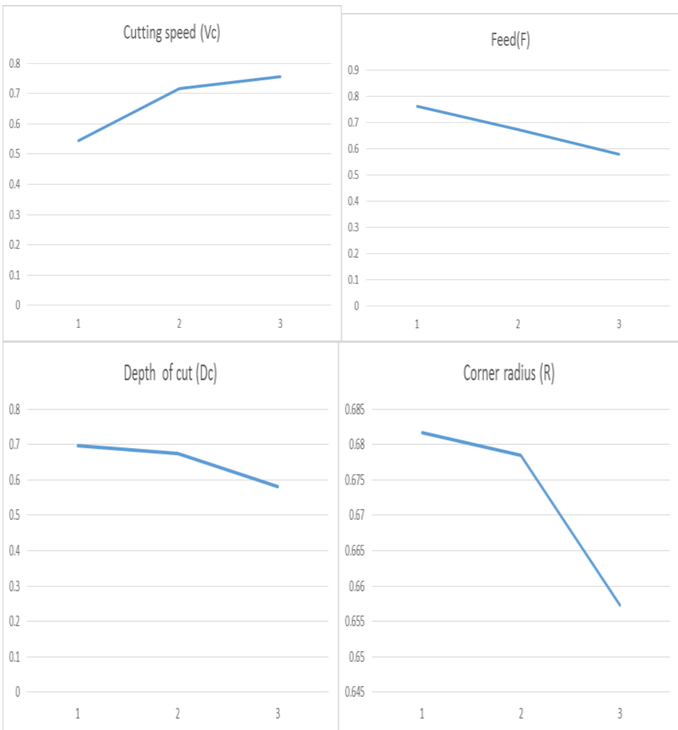

Chart -5.1: Grey relational grade response plot

Now, in order to understand contribution of the cutting speed, feed depth of cut and corner radius on the experimental results analysis of variance is carried out. The results of ANOVA for grey relational grade are shown in Table 5.1.5

Table -5.1.5: ANOVA table for grey relational grade

	DOF	Sum of square	Mean square	F value	%contribution
Vc	2	0.232226	0.116113	15.48403	38.49384
F	2	0.150819	0.075409	10.05609	24.9998
Dc	2	0.082092	0.041046	5.473634	13.60764
R	2	0.003164	0.001582	0.210938	0.524399
error	18	0.13498	0.007499	--	22.37431
total	26	0.603281	0.241649	--	100

It is observed from the table that cutting speed (Vc) has most significant effect on grey relational grade followed by Feed (F), Depth of cut (D) and Corner radius (R) for this analysis. Now, confirmation test is carried out to verify the accuracy of the analysis using Eq. (6). The confirmation test results for the analysis are shown in Table 5.1.5.

Table -5.1.5: Confirmation test

	Initial parameter	Optimal parameter	
		Theoretical	Experimental
Level	Vc3F3Dc1R3	Vc3F1Dc1R1	Vc3F1Dc1R1
Flank wear	0.19	--	0.08
Surface roughness	1.5068	--	0.9298
Grey grade	0.672506	0.881606	0.871405

6. CONCLUSION

The following conclusions can be drawn based on the results of experimental study:

1. The machining parameters to be specific cutting pace, bolster rate, profundity of cut, corner span is upgraded to meet the targets. The outcomes uncover that the essential element influencing the surface harshness and flank wear is speed therefore took after by profundity of cut, sustain and corner range.
2. The cutting pace is most huge variable which limiting surface unpleasantness and enhancing instrument life is 38.49 % along these lines took after by profundity of cut which contributes 24.99 %, sustain rate 12.60 % and corner sweep has minimum critical component contributes 0.524%.
3. The upgraded calculate for extraordinary surface complete and low flank wear is cutting pace Vc3=325m/min, sustain F1= 0.05 mm/rev, profundity of cut Dc1=0.25 mm, and corner span R1=0.4 mm.
4. The optimized factor for great surface finish and low flank wear is cutting speed Vc3=325m/min, feed F1= 0.05 mm/rev, depth of cut Dc1=0.25 mm, and corner radius R1=0.4 mm.

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