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A Method to Optimize Process Parameters of Turning

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***Abstract*-It is well known that the relation between different input process parameters and surface roughness in all machining operations. The same things happen in turning operation also. In turning operation, the input parameters speed, feed, depth of cut etc. affect the surface finish. Many engineer and researchers have tried to do optimize of this. But still, there is a gap in determining of the exact contribution of speed, feed and depth of cut (S, F&D) to get optimum surface finish.**

Keyword:-ANOVA, Taguchi, surface finish, S/N ratio, orthogonal array, Grey.

I. INTRODUCTION

A common process to manufacture parts to a precise dimension has the removal of excess material by machining operation with the help of cutting tool. Turning process is the one of the methods to remove material from cylindrical and non-cylindrical parts. Taguchi method is a dominant tool for the design of high quality systems. It offers simple, effective and methodical tactic to optimize design for performance, quality and cost. Taguchi method is efficient method for designing process that operates consistently and optimally over a variety of conditions. Taguchi approach to design the of experiments easy to adopt and apply for users with limited knowledge of statics, hence grew wide popularity in the engineering and scientific community.

II. PHYSICAL DESCRIPTION OF THE PROBLEM

Equipment's used in the Machining Process: High Speed Precision Lathe NH22
Cutting Tool Used: Tungsten Carbide Tip Tool
Work Piece Used: Mild steel bars of diameter 32mm and length 200 mm.
Roughness Measurement: Surface Profile Roughness measurement has been done using a portable stylus-type profilometer,
Process variables and their limits for L27

Taguchi method is efficient method for designing process that operates consistently and optimally over a variety of conditions. Taguchi approach to design of experiments easy to adopt and apply for users with limited knowledge of statics, hence gained wide popularity in the engineering and scientific community. The desired cutting parameters determined by handbook. Cutting parameter are reflected on surface roughness.

Levels	Speed (RPM)	Feed (mm/rev)	Depth of Cut (mm)
1	740	0.09	0.15
2	580	0.07	0.10
3	450	0.05	0.05

TABLE 1.

I. EXPERIMENTATION

Design of experiment techniques, i.e. Taguchi's technique has been used to accomplish the objective. L27 orthogonal array used for conducting the experiments. ANOVA and factorial design technique is employed to analyse the PC and influence of Process Parameters.

I. RESULTS AND DISCUSSION

The results and discussion of the present work mainly consists of the following;

i. Percentages contribution of input variables on surface finish using Grey Relational Analysis technique.
ii. Percentages contribution of input variables on Ra, MMR&PC using Grey Relational Analysis technique.
iii. Percentages contribution of input variables on Ra, MMR&PC using Weighted Signal to Noise Ratio (WSNR) technique.
iv. Percentages contribution of input variables on Ra, MMR&PC using Multi-Response Signal-to-Noise Ratio (MRSN) technique.

3.1. Percentages contribution of input variables on multi response using Taguchi using Gray relational analysis (GRA)

The data obtained from the experiments (L_{27}) have been used to get the PC of the input variables.
Experimental Results For L_{27}

Sl. No.	Z_{ij}			ξ_{ij}			γ_i
	R_a(μm)	MRR(mm^3/min)	PC(KW)	R_a	MRR	PC	
1	0.70644	1.00000	0.198281	0.63008	1	0.384107	0.671394
2	0.30662	0.69516	0	0.41898	0.621243	0.333333	0.457851
3	0.71501	0.51074	0.108704	0.63695	0.505429	0.359377	0.500586
4	0.61730	0.72395	0.095206	0.56645	0.644286	0.355924	0.522219
5	0.29025	0.94381	0.255436	0.41331	0.898968	0.401747	0.571342
6	0.31961	0.81745	0.361378	0.42359	0.73255	0.439127	0.531755
7	0.21973	0.87470	0.215109	0.39054	0.799616	0.389138	0.526432
8	0.40813	0.75819	0.369379	0.45793	0.674026	0.442235	0.52473
9	0.44697	0.81745	0.685388	0.47482	0.73255	0.613789	0.607054
10	0.73855	0.99975	0.413324	0.65664	0.999501	0.460119	0.70542
11	0.13817	0.76707	0.719954	0.36715	0.682193	0.640988	0.563445
12	0.69568	0.79291	0.557281	0.62164	0.707124	0.530381	0.619715
13	0.29043	0.92153	0.348929	0.41337	0.864352	0.434378	0.5707
14	0.38896	0.86648	0.482876	0.45003	0.789247	0.491582	0.576952
15	0.49041	0.76575	0.253217	0.49525	0.680971	0.401032	0.525751
16	0.00000	0.91777	0.666428	0.33333	0.85877	0.599828	0.597311
17	0.36256	0.91530	0.860369	0.43958	0.855134	0.7817	0.692139
18	0.44697	0.60586	0.71848	0.47482	0.559196	0.639779	0.557932
19	0.54211	0.76707	0.358845	0.52198	0.682193	0.438152	0.547442
20	0.49013	0.27615	0.745995	0.49512	0.408545	0.663126	0.522262
21	1.00000	0.62115	0.40817	1.00000	0.568928	0.457947	0.675625
22	0.19379	0.77983	0.983072	0.38279	0.69428	0.967252	0.68144
23	0.43708	0.92275	0.821088	0.47040	0.866183	0.736472	0.691018
24	0.80314	0.10682	0.677427	0.71751	0.358892	0.607849	0.561416
25	0.22455	0.84091	0.522656	0.39202	0.758625	0.511591	0.554078
26	0.77257	0.00000	0.639089	0.68735	0.333333	0.58078	0.533822
27	0.70097	0.11026	1	0.62576	0.359779	1	0.661847

TABLE 2.

Figure 1: variation of Gray relational grade

Level of parameters	Speed (S)	Feed (F)	Depth of cut (D)
1	0.545929	0.58486	0.597382
2	0.601041	0.581399	0.570396
3	0.603217	0.583927	0.582409
Delta(Max-Min)	0.057288	0.003461	0.026986
Rank	1	3	2

TABLE 3.(ANOVA Results for Gray relational analysis)

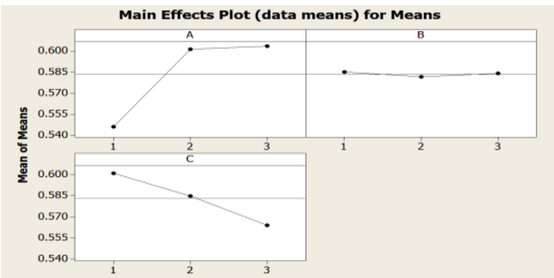
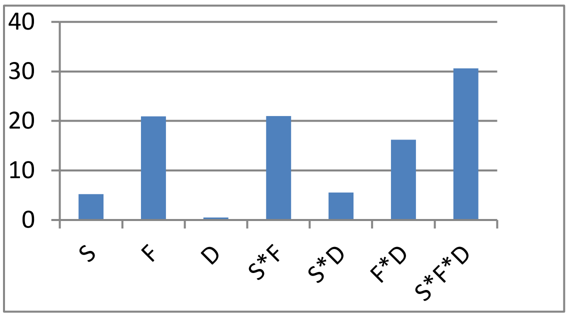


Figure 2: variation of level average of parameters

Factors(Fa)	Sum of Square (SS)	Degree of Freedom (DOF)	Mean Square(MS)	PC
S	0.0063677	2	0.003184	5.234443
F	0.0254408	2	0.01272	20.91311
D	0.0006262	2	0.000313	0.514755
S*F	0.0255374	4	0.006384	20.99252
S*D	0.0067377	4	0.001684	5.538594
F*D	0.0196906	4	0.004923	16.18627
S*F*D	0.0372494	8	0.004656	30.62014
Error	---------	0	-----------	------------
Total	0.1216498	26	----------	100

TABLE 4.



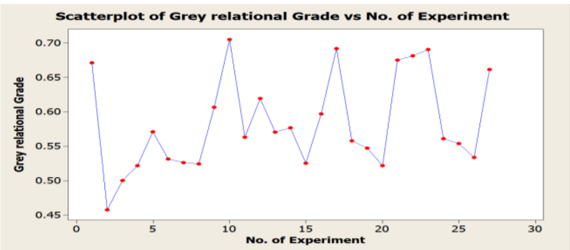


Figure 3: PC of factors

It is observed from above (L_{27}-GRA) analysis that S3-F1-D1 is the optimal combination for getting best output results and corresponding Gray relational grade is 0.547442. The best output results mean the combination of all output parameters, these are surface finish, MRR and power consumption with equal weightage. The PC of speed is 5.23 %, of feed is 20.91 % and of depth of cut is 0.52 %. Similarly, the PC of speed and feed is 20.99%, of speed and depth of cut is 5.53%, of feed and depth of cut is 16.18%, and the combination of S, F&Dof cut is 30.62%. It indicates that, for the above ranges of input levels, the feed is most (single) effective parameters and as a combination, S-F-D is most effective.

Percentages contribution of input variables on surface finish using weighted signal-to-noise ratio technique.

Using the data obtained from the table (Table 5.7), the weighted signal-to-noise ratio (WSN) of input variables have been calculated.

Table 3.4: weighted S/N ratio for L27

S.N.	S/N ratio (η_{ij})			Scaled S/N ratio (Y_{ij})			WSN
	Ra	MRR	PC	Ra	MRR	PC	
1	-8.73025	-2.61537	-19.3056	0.70644	0.993339	0.19828	0.632688
2	-13.2667	-8.29756	-21.3227	0.30661	0.695336	0	0.333983
3	-8.63306	-11.8149	-20.2168	0.71501	0.510868	0.108709	0.444863
4	-9.74164	-7.74856	-20.3542	0.61730	0.724128	0.095203	0.478878
5	-13.4523	-3.55533	-18.7242	0.29025	0.944043	0.255431	0.496576
6	-13.1193	-5.96519	-17.6464	0.31960	0.817657	0.361378	0.499547
7	-14.2525	-4.87336	-19.1344	0.21973	0.874918	0.215109	0.436585
8	-12.1149	-7.09549	-17.565	0.40813	0.758378	0.36938	0.511963
9	-11.6742	-5.96519	-14.3502	0.44697	0.817657	0.685393	0.650007
10	-8.36603	-2.48836	-17.118	0.73855	1	0.41332	0.717289
11	-15.1778	-6.92610	-13.9986	0.13817	0.767262	0.719955	0.541797
12	-8.85242	-6.43328	-15.6535	0.69568	0.793108	0.557279	0.682021
13	-13.4503	-3.98016	-17.773	0.29043	0.921762	0.348933	0.520376
14	-12.3325	-5.03004	-16.4104	0.38895	0.866701	0.482876	0.57951
15	-11.1814	-6.95121	-18.7467	0.49041	0.765945	0.253219	0.50319
16	-16.7455	-4.05188	-14.5431	0.00000	0.918001	0.666431	0.528144
17	-12.6319	-4.09909	-12.5702	0.36256	0.915525	0.860366	0.712818
18	-11.6742	-10.0008	-14.0136	0.44697	0.606009	0.71848	0.590487
19	-10.5948	-6.92610	-17.6722	0.54211	0.767262	0.358842	0.556071
20	-11.1845	-16.2892	-13.7337	0.49013	0.276213	0.745994	0.504113
21	-5.39959	-9.70904	-17.1704	1.00000	0.62131	0.408169	0.676493
22	-14.54	-6.68	-11.3	0.19379	0.780025	0.983073	0.652295

	68	275	219				
23	-11.7865	-3.95684	-12.9698	0.43707	0.922985	0.821085	0.727048
24	-7.63313	-19.5185	-14.4312	0.80314	0.106852	0.67743	0.529141
25	-14.1978	-5.51776	-16.0057	0.22455	0.841123	0.522658	0.529443
26	-7.97997	-21.5559	-14.8213	0.77257	0	0.639084	0.470552
27	-8.79234	-19.4530	-11.1497	0.70097	0.110287	1	0.603753

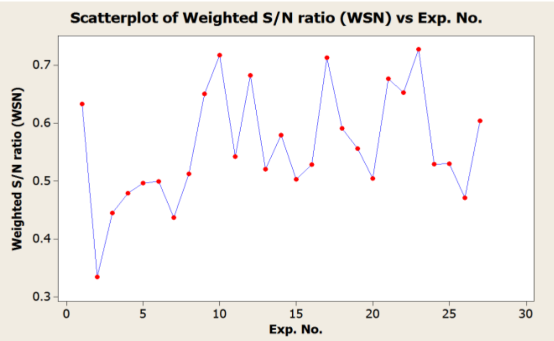


Figure3.4: Variation of WSN

Table 3.5: Level Average for WSN

Level	Speed (S)	Feed(F)	Depth of Cut
1	0.498343	0.56548	0.561307
2	0.597292	0.554062	0.54204
3	0.583212	0.559306	0.57550
Delta (Max-Min)	0.098949	0.011418	0.03346
Rank	1	3	2

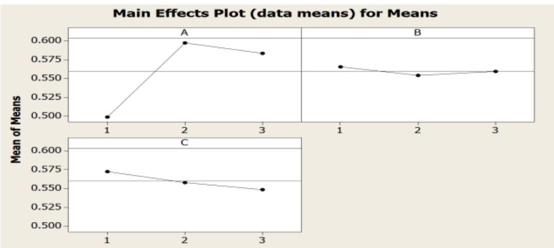


Figure 3.5: Variation of level average of parameter

Table 3.6: ANOVA for WSN:

Fa	SS	DOF	MS	PC
S	0.004096	2	0.0020478	1.672439
F	0.017957	2	0.0089788	7.332784
D	0.01138	2	0.0056848	4.646902
S*F	0.080264	4	0.0200659	32.77565
S*D	0.028104	4	0.0070261	11.47643
F*D	0.050021	4	0.0125052	20.42596
S*F*D	0.053067	8	0.0066334	21.66987
Error	-----------	0	------------	------------
Total	0.2448879	26	-----------	100

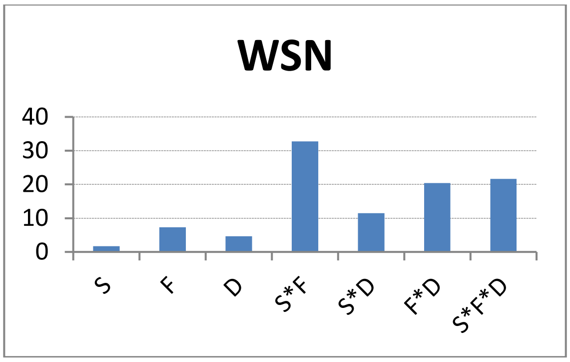


Figure 3.6: PC of input parameters

It is observed from above (L_{27}-WSN) analysis that S2-F1-D3 is the optimal combination for getting best output results and corresponding weighted signal-to-noise ratio is 0.619715. The best output results mean the combination of all output parameters, these are surface finish, MRR and power consumption with equal weightage. The PC of speed is 1.67 %, of feed is 7.33 %, and of depth of cut is 4.64 %. Similarly, the PC of speed and feed is 32.77%, of speed and depth of cut is 11.48%, of feed and depth of cut is 20.43%, and the combination of S, F&Dis 21.67%. It indicates that, for the above ranges of input levels, the feed is most (single) effective parameters and as a combination S-F is most effective.

Percentages contribution of input variables on surface finish using Multi-response signal-to-noise ratio technique.

Using the data obtained from the table (Table5.7), the multi-response signal-to-noise ratio (MRSN) of input variables have been calculated.

Table 3.7: Multi-response signal-to-noise ratio

Sl. No	Quality loss(L_{ij})			Normalised loss (S_{ij})			Total quality loss(T_{ij})	MRSN
	Ra	MRR	PC	Ra	MRR	PC		
1	7.4649	1.8261	85.2233	0.45456	0.10419	1.67265	0.74380	1.28542
2	21.2161	6.7570	135.603	1.29192	0.38551	2.66144	1.44629	-1.6025
3	7.29972	15.187	105.119	0.44450	0.866513	2.06315	1.12472	-0.5104
4	9.42244	5.9546	108.496	0.57376	0.339738	2.12943	1.01431	-0.0617
5	22.1426	2.2674	74.5444	1.34834	0.12936	1.46306	0.98025	0.0866
6	20.508	3.9492	58.1621	1.24881	0.22532	1.14153	0.87189	0.59538
7	26.62	3.0714	81.9293	1.62113	0.175237	1.60800	1.13479	-0.5

	25							491
8	16.2739	5.1232	57.0822	0.99097	0.292305	1.12033	0.80120	0.96255
9	14.7033	3.9492	27.2285	0.89534	0.22532	0.53440	0.55169	2.58304
10	6.864	1.7735	51.4985	0.41799	0.10118	1.01074	0.50997	2.92449
11	32.9441	4.9273	25.1108	2.00608	0.281124	0.49284	0.92668	0.33068
12	7.67788	4.3987	36.7576	0.46753	0.25096	0.72143	0.47997	3.18779
13	22.1323	2.5004	59.8831	1.34771	0.142661	1.17530	0.88856	0.51312
14	17.1098	3.1842	43.7562	1.04187	0.181674	0.85879	0.69411	1.58569
15	13.1261	4.9558	74.9329	0.79929	0.282754	1.47068	0.85091	0.70115
16	47.2656	2.5420	28.4651	2.87816	0.145036	0.55867	1.19396	-0.7699
17	18.3312	2.5698	18.0724	1.11625	0.146621	0.35470	0.53919	2.68256
18	14.7033	10.001	25.1976	0.89534	0.570643	0.49454	0.65351	1.84747
19	11.4677	4.9273	58.5082	0.69830	0.281124	1.14832	0.70925	1.49199
20	13.1355	42.551	23.6248	0.79986	2.42775	0.46367	1.23043	-0.9005
21	3.46704	9.352	52.1240	0.21112	0.533572	1.02302	0.58923	2.29708
22	28.4889	4.6588	13.5578	1.73478	0.265805	0.26609	0.75556	1.21729
23	15.0885	2.4870	19.8142	0.91879	0.141897	0.38888	0.48319	3.15879
24	5.79846	89.505	27.7410	0.35308	5.106675	0.54446	2.00141	-3.0133
25	26.2892	3.5626	39.8631	1.60084	0.203266	0.78238	0.86216	0.64410
26	6.28053	143.08	30.3476	0.38244	8.163486	0.59562	3.04718	-4.8389
27	7.57240	88.165	13.0308	0.46111	5.030243	0.25575	1.91570	-2.8232

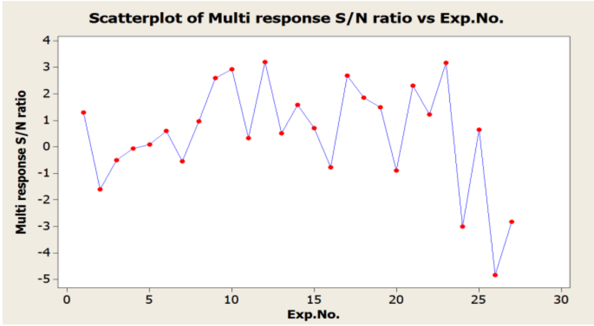


Figure 3.7: variation of MRSN

Table 3.8: Level average of MRSN

Level	Speed (S)	Feed (F)	Depth of Cut (D)
1	0.309898	0.944874	0.743962
2	1.444788	0.53144	0.16275
3	-0.30744	-0.02906	0.540537
Delta (max-min)	1.752228	0.973934	0.581212
Rank	1	2	3

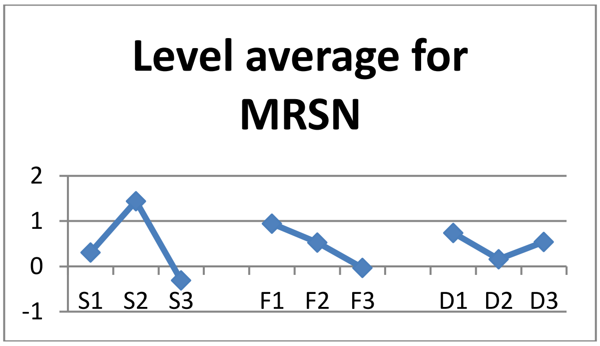


Figure 3.8: variation of MRSN of input parameters

Table 3.9: ANOVA for multi-response S/N ratio:

Fa	SS	DOF	MS	PC
S	3.4258	2	1.7129	3.41181
F	15.4770	2	7.7385	15.4138
D	7.2379	2	3.61895	7.20834
S*F	16.2841	4	4.07102	16.2176
S*D	3.8167	4	0.954175	3.8011
F*D	12.9914	4	3.24785	12.9383
S*F*D	41.1786	8	5.147325	41.0018
Error	-----------	--------	------------	-----------
Total	100.4115	26	------------	100

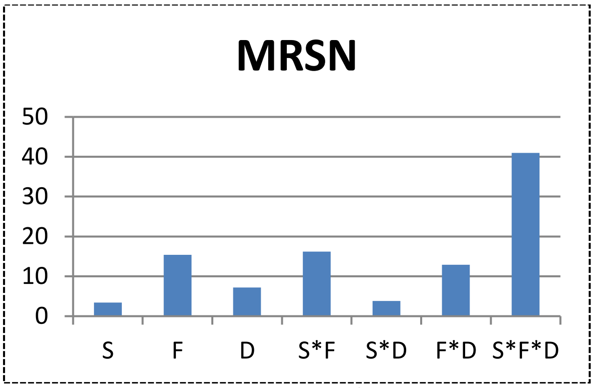


Figure 3.9: contribution of parameters

It is observed from above (L_{27}-MRSN) analysis that S2-F1-D1 is the optimal combination for getting best output results and corresponding multi-response signal-to-noise ratio is 0.924494. The PC of speed is 3.41 %, of feed is 15.41 %, and of depth of cut is 7.20 %. Similarly, the PC of speed and feed is 16.21%, of speed and depth of cut is 3.80%, of feed and depth of cut is 12.93% and the combination of speed, feed, and depth of cut is 41.00%. It indicates that, for the above ranges of input levels, the feed is most (single) effective parameters and as a combination S-F-D is most effective.

Table 3.10: compression of different optimise results

Optimization method	Performance characteristics	Optimized setting	SN ratio
GRA(m)	GRG(m)	S3F1D1	0.547442
WSN(m)	WSN ratio	S2F1D3	0.619715
MRSN(m)	MRSN ratio	S2F1D1	0.924494

From the above table, it is observed that for single response, combination S1-F1-D1 is the best for getting best surface finish. Also it is observed that combinations of input parameters for multi response optimization are different when the different techniques used. Since the SN ratio is highest in MRSN technique, so S2-F1-D1 combination can be chosen for getting best multi response output.

IV. CONCLUSIONS

In present work, turning operation has been optimised and PC of parameters calculated with different optimisation techniques. On the basis of results, the following conclusions can be drawn.

1. In the multi response optimization, feed is effective (single) parameter, which is evaluated by all the three techniques (GRA, WSN, and MRSN).
2. For multi response, optimal parametric settings for GRA, WSN, and MRSN, are S3-F1-D1, S2-F1-D3, and S2-F2-D1 respectively. Hence, there has been considerable difference among the optimal settings yielded by the methods investigated.
3. On the basis of computations performed, MRSN method yielded highest magnitude of S/N response (0.924494dB) and therefore, its outcomes S2-F2-D1 can be recommended for getting best output results.

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