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MULTIOBJECTIVE OPTIMIZATION OF CRANKSHAFT PIN GRINDING

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Abstract: The Crankshaft grinding is the most critical process in the manufacturing of crankshaft. After induction hardening the pins needs to be grind cylindrically using micromatic machine. Being the sensitive and very precise process chances of rejection and rework is high. So it is important to optimize the process. Every process has some input and some output, like wise here we have taken machine input parameter which are having great influence on quality of grinding they are Work Speed, Cutting Speed, Feed rate, Dressing feed rate and Dressing depth of cut. Similarly at output we have taken objectives to be optimized as- Surface Finish, Ovality and Chatter Marks. For Multiobjective Optimization technique Grey Relational Analysis is used.

Keywords-Work Speed, Cutting Speed, Feed rate, Dressing Feed rate, Dressing depth of cut, Surface finish, Ovality, Chatter Marks

I. INTRODUCTION

Grinding as defined by Webster's dictionary as "To reduce to small fragments by friction", but this type of material removal process is not small in a commercial sense, as it is a billion dollar growth industry that accounts for approximately 25% of all machining operations in manufacturing. Grinding has traditionally been one of the few manufacturing operations to be least understood, with production grinding problems being treated more like black magic, and relying on the experience of the operator, then using scientific principles. This is particularly in case for crankshaft pin grinding, where little research has been conducted to understand the process. There are many variables in the crankshaft pin grinding process that need to be studied as a complete system. Incorrect grinding can contribute to unsightly side effects, such as burn, poor quality surface finish and part sizing problems. The rejection rate of crankshafts directly associated with the grinding of the crankshaft pins at the manufacturer was approximately one out of every fifty crankshafts.

These problems, if left unsolved had been noted to cause engine seize up, high engine oil usage, vibrations and knocking sounds within the engine. Thus the crankshafts are usually unusable or required time and money to rectify the problem, and hence an experimental study into the variables that affects the end quality of the crankshaft pin grinding process was required to prevent these quality and other problems from occurring. In crankshaft manufacturing process, after induction hardening no other process is feasible to have close tolerances of pin and journal surfaces that are obtained. Grinding being one of the final operations in crankshaft manufacturing, with less tolerance zone within which the jobs must be produced. The defects found such as chatter marks, ovality, taper, radius dimensions, surface finish, geometric errors and surface burn, because of which jobs are mostly rejected during grinding. Once it is rejected we cannot rework it. So there is a huge loss of time, cost, man-hours, material, profit etc. Hence the process need to be studied and should be optimized so that the jobs produced will be within tolerance zone and can reduce the losses during manufacturing.

II. METHODOLOGY AND EXPERIMENTATION

A set of experiments were conducted on Micromatic Cylindrical Grinding Machine on 38MnVS6 steel material to determine effect of machining parameters namely work speed, cutting speed, feed rate, dressing feed rate and dressing depth of cut. For three levels and five factors L27 Orthogonal array is selected for carrying experiment using design of experiments (DOE) and relevant ranges of parameters are decided based on experience and specification
Specified of machine. Grinding wheel used for the present work is the aluminum oxide abrasive with vitrified bond with constant speed of 1350 RPM and water miscible coolant (Lavish) was supplied in all grinding experiments.

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The jobs have undergone turning and hardening processes before grinding. Hardening is done for better output response and the BHN is maintained at the range of 30-40 BHN.

Table1. For Process Parameter and their Levels-

S. No	Parameter	Units	Symbol	Low	Medium	High
1	Work speed	rpm	A	40	50	60
2	Cutting speed	m/min	B	35	40	45
3	Feed Rate	mm/Sec	C	0.01	0.15	0.30
4	Dressing Feed Rate	mm/Sec	D	0.120	0.150	0.180
5	Dressing Depth of Cut	mm	E	0.035	0.040	0.040

For Output-

1. These chatter marks are measured in terms of marks per unit inch area.
2. Ovality is measured by snap gauge with dial indicator manually and by air gauges (Etamic) systems in microns.
3. Surface roughness is measured by Taylor Hobson surface profiler& units in microns

Observation Table (Used L27 Array)

Step-I: Arranging an Orthogonal Array & Corresponding								
1	2	3	4	5	6	7	8	9
Exp No.	Input Parameters					Output Parameters		
	Work Speed (rpm)	Cutting Speed	Feed Rate	Dressing Feed Rate	Dressing Depth of Cut	Chatter Marks (mm/Inches)	Ovality (microns)	Surface Roughness in Microns (Ra)
1	40	35	0.1	0.12	0.03	7.5	9	0.2
2	40	35	0.1	0.12	0.04	7.5	9	0.2
3	40	35	0.1	0.12	0.04	6.5	9	0.3
4	40	40	0.15	0.15	0.03	6.5	8.5	0.3
5	40	40	0.15	0.15	0.04	8.5	8.5	0.3
6	40	40	0.15	0.15	0.04	7.5	8.5	0.4
7	40	45	0.3	0.18	0.03	8.5	9.5	0.3
8	40	45	0.3	0.18	0.04	7.5	9.5	0.3
9	40	45	0.3	0.18	0.04	8.5	9.5	0.3
10	50	35	0.15	0.18	0.03	15	5.5	0.3
11	50	35	0.15	0.18	0.04	14	4.5	0.4
12	50	35	0.15	0.18	0.04	15.5	5.5	0.3
13	50	40	0.3	0.12	0.03	13.5	5.5	0.4
14	50	40	0.3	0.12	0.04	14.5	5.5	0.4
15	50	40	0.3	0.12	0.04	14.5	4.5	0.4
16	50	45	0.1	0.15	0.03	15	4.5	0.5
17	50	45	0.1	0.15	0.04	14.5	4.5	0.5
18	50	45	0.1	0.15	0.04	15.5	3.5	0.6
19	60	35	0.3	0.15	0.03	8.5	11.5	0.7
20	60	35	0.3	0.15	0.04	7.5	10.5	0.7
21	60	35	0.3	0.15	0.04	7.5	10.5	0.7
22	60	40	0.1	0.18	0.03	7	11.5	0.8
23	60	40	0.1	0.18	0.04	7	12.5	0.8
24	60	40	0.1	0.18	0.04	8	11.5	0.7
25	60	45	0.15	0.12	0.03	5.5	11.5	0.7
26	60	45	0.15	0.12	0.04	7.5	11.5	0.8
27	60	45	0.15	0.12	0.04	7.5	11	0.8

In GRA, data pre-processing is required since the range and unit in one data sequence may differ from the others. Data pre-processing is also necessary when the sequence scatter range is too large, or when the directions of the target in the sequence are different.

III. INDENTATIONS AND EQUATIONS

Step -2 Pre- Processing Data For Analysis			
	Chatter Marks	Ovality	Surface Roughness
For Experiment No	7	8	9
Max Value	15.5	12.5	0.8
Min Value	5.5	4.5	0.2

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By considering Lower is Best and using the formula to calculate Maximum & Minimum value-

Formula Used-**x = (Max- Current Value)/Max- Min**

Table- Altered Values

1	2	3	4
Experiment No	Chatter Marks(mm/Inches)	Ovality (micron)	Surface Roughness in Microns (Ra)
1	0.8	0.4375	0.966667
2	0.8	0.4375	0.975
3	0.9	0.4375	0.85
4	0.9	0.5	0.9
5	0.7	0.5	0.825
6	0.8	0.5	0.716667
7	0.7	0.375	0.808333
8	0.8	0.375	0.816667
9	0.7	0.375	0.808333
10	0.05	0.875	0.791667
11	0.15	1	0.7
12	0	0.875	0.791667
13	0.2	0.875	0.666667
14	0.1	0.875	0.625
15	0.1	1	0.616667
16	0.05	1	0.525
17	0.1	1	0.516667
18	0	1.125	0.258333
19	0.7	0.125	0.158333
20	0.8	0.25	0.15
21	0.8	0.25	0.141667
22	0.85	0.125	0.05
23	0.85	0	0.025
24	0.75	0.125	0.158333
25	1	0.125	0.166667
26	0.8	0.125	0
27	0.8	0.1875	-0.00833

Step-3 As we are Giving Equal weighting for all output so considering 1 as a reference sequence

Table obtained after assigning reference sequence factor for each reading

1	2	3	4
Experiment No	Chatter Marks (mm/Inches)	Ovality (microns)	Surface Roughness in Microns (Ra)
Refe. Seq	1	1	1
1	0.2	0.5625	0.033333
2	0.2	0.5625	0.025
3	0.1	0.5625	0.15
4	0.1	0.5	0.1
5	0.3	0.5	0.175
6	0.2	0.5	0.283333
7	0.3	0.625	0.191667
8	0.2	0.625	0.183333
9	0.3	0.625	0.191667
10	0.95	0.125	0.208333
11	0.85	0	0.3
12	1	0.125	0.208333
13	0.8	0.125	0.333333
14	0.9	0.125	0.375
15	0.9	0	0.383333
16	0.95	0	0.475
17	0.9	0	0.483333
18	1	-0.125	0.741667
19	0.3	0.875	0.841667
20	0.2	0.75	0.85
21	0.2	0.75	0.858333
22	0.15	0.875	0.95
23	0.15	1	0.975
24	0.25	0.875	0.841667
25	0	0.875	0.833333
26	0.2	0.875	1
27	0.2	0.8125	1.008333

Step-4 Calculating Gray Coefficients $\zeta_i(k) = \frac{\Delta_{min} + \zeta \Delta_{max}}{\Delta_{0i} + \zeta \Delta_{max}}$

Table For Grey Relation Coefficient

1	2	3	4
Experiment No	Chatter Marks (mm/Inches)	Ovality (microns)	Surface Roughness in Microns (Ra)
1	0.714285714	0.4705882	0.9375



2	0.714285714	0.4705882	0.952381
3	0.833333333	0.4705882	0.769231
4	0.833333333	0.5	0.833333
5	0.625	0.5	0.740741
6	0.714285714	0.5	0.638298
7	0.625	0.4444444	0.722892
8	0.714285714	0.4444444	0.731707
9	0.625	0.4444444	0.722892
10	0.344827586	0.8	0.705882
11	0.37037037	1	0.625
12	0.333333333	0.8	0.705882
13	0.384615385	0.8	0.6
14	0.357142857	0.8	0.571429
15	0.357142857	1	0.566038
16	0.344827586	1	0.512821
17	0.357142857	1	0.508475
18	0.333333333	1.3333333	0.402685
19	0.625	0.3636364	0.372671
20	0.714285714	0.4	0.37037
21	0.714285714	0.4	0.368098
22	0.769230769	0.3636364	0.344828
23	0.769230769	0.3333333	0.338983
24	0.666666667	0.3636364	0.372671
25	1	0.3636364	0.375
26	0.714285714	0.3636364	0.333333
27	0.714285714	0.3809524	0.331492

Step-5 Calculating Grey Relational Grade

Formula=1/3(Values of Column (2+3+4)-By applying Gray Relation Analysis

1	2
Experiment No	Grey Relation Grade
1	0.707457983
2	0.712418301
3	0.691050779
4	0.722222222
5	0.62191358
6	0.617527862
7	0.597445337
8	0.630145825
9	0.597445337
10	0.616903313
11	0.665123457
12	0.613071895
13	0.594871795
14	0.576190476
15	0.641060198
16	0.619216033
17	0.621872478
18	0.689783743
19	0.453769057
20	0.494885362
21	0.494127958
22	0.492564906
23	0.480515718
24	0.467657946
25	0.579545455
26	0.47041847
27	0.475576603

Step-6 Observing Highest Value in Above Table & Assign Rank

1	2	3
Experiment No	Grey Relation Grade	Rank
1	0.707457983	3
2	0.712418301	2
4	0.722222222	1

We can observe that the Highest Value is obtained at Experiment 4 Hence we are getting optimum results for three output.

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1	2	3	4	5	6	7	8	9	
Experiment No	Level of Parameters					Chatter Marks (mm/Inches)	Ovality (microns)	Surface Roughness in Microns (Ra)	
	Work Speed (rpm)	Cutting Speed	Feed Rate	Dressing Feed Rate	Dressing Depth of Cut				
4	40	40	0.15	0.15	0.035	6.5	8.5	0.26	Calculated
Actual Obtained Values	40	40	0.15	0.15	0.035	6.23	8.01	0.27	From Trial Practical Values Obtained
						4.153846	5.764706	3.846154	% Error

IV. CONCLUSION

From above all calculations & results obtained we can conclude that, to optimize the multi objective of an experiment or trial the gray regression analysis is very useful method. In Crankshaft grinding optimization we got optimum results of chatter mark 6.5 mm/inches, ovality 8.5 microns & Surface roughness 0.26microns when if we used at input Work Speed 40 rpm, Cutting Speed 40, Feed rate 0.15, Dressing Feed rate 0.15 & Dressing depth of cut 0.035.

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