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Research Article

PARAMETRIC OPTIMIZATION ON TURNING AISI 303 AUSTENITIC STAINLESS STEEL USING GREY RELATIONAL ANALYSIS

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ABSTRACT

Austenitic stainless steels are extensively used in numerous industries. Voluminous complications are testified during the machining of these steels. To remove these complications, optimization approaches plays a vibrant role for upgrading the eminence in product and for finding best cutting conditions. Moreover, awareness in enactment of coolant in machining is of acutesignificance to progress the efficiency of themachining. This effort boons an investigational study to afford least surface roughness with maximum metal removal rate by the Taguchi basedgrey relational technique. A PV7020 (TiAlN + TiN) coated cermet tool is used to machine AISI 303 stainless steel with ECO COOL 3015 as a standard coolant.

INTRODUCTION

Machining operations are accomplished to eradicate unwanted material from the surface of a work piece to attain preferred shape and size. Current industrial trend is to engineer a product at low cost with high quality in shorter duration (Sudhir, *et al.*, 2015). Turning, a prime machining and finishing process for making a component (Rony, *et al.*, 2014; Narayana and Ganti, 2014). Verdicting an optimality in machining parameters is anessential engineering task and it is obligatory to boost the productivity which is accomplished by taguchi's approach. It is a prevailing technique which uses statistical tool to estimate main effects using few experimental runs only (Nalbant, *et al.*, 2007; Muthuraman *et al.*, 2015). Coolants are liquids applied to tool and work piece to assist in cutting operation. Coolant helps to produce components with high accuracy and surface finish. Coolant reduces temperature in cutting region, decreases thermal distortion in work piece flushes out the chip easily from the cutting area (Nambi and Paulo, 2011; Anthony and Adithan, 2009).

Cermets are combination of ceramic hard and metal binding phase which are embedded in a matrix of metals (Arsath, *et al.*, 2015). Performance of coated inserts is better than the uncoated inserts (Kaladhar, *et al.*, 2011). PVD coatings provides excellent finishing, toughness and wear resistance (Prabakaran, *et al.*, 2014). Grey relational analysis, a multi quality optimization technique castoff to crackdifficult characteristics in to a simpler one. Characteristic are normalized, then grey relational coefficient based

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on normalized experimental data is calculated to signify the correlation among the desired and actual experimental and then grey relational grade is found out (Upinder and Deepak, 2013; Muthuraman, *et al.*, 2015). Thus the goal of this effort is to study the impact of machining parameters on Ra and MRR and to describe optimum process parameter setting of coated inserts on turning AISI 303 austenitic steel by using with and without coolant.

EXPERIMENTATION

Investigational study is conceded out on a CNC turning centre named super jobber LM Elite 500 manufactured by Ace Designers with maximum spindle rpm of 2625 and turning diameter of 200 mm as in (Fig. 1a). Inserts are distinct cutting tools with numerous points, and are fastened on tool shank with locking mechanism. A Kyocera PV 7020 coated (gold colour) Triangular insert made of Cermet is used for executing the turning process as in (Fig. 1b). Experimentations are conducted under the influence of with and without coolant named *ECO COOL 3015* a mineral oil based, water miscible cutting fluid which has low foaming, and high cutting performance ability manufactured by Fuchs Europe Schmiersoffe GMBH.

AISI 303 stainless steel which offers good strength, machinability and has a machinability index of 78 which is most broadly used in multiple industries and its chemical composition is shown in Table 1. Experiments were conducted on an 18 specimens of total length 65 mm, diameter 25 mm with turning length of 30 mm and for each run a new insert side was used and samples are turned as per ISO 3685 as in (Fig. 1c). Trialing of this work is centered on design of experiments by orthogonal array as in Table 2. Cutting Speed, Feed and depth of cut are the three process parameters and they are kept at three levels. L9 orthogonal array is used for the design of experiment layout as shown in Table 3.

ANOVA is made to study the influence of input factors on the responses and to govern which of the parameter unvaryingly affect the performance characteristics of machining. It shows the effect of process parameter on Surface Roughness and Metal Removal Rate and to obtain the significance of process parameter for both with and without coolant. Surface roughness was measured using the Mitutoyo SJ-210 surf tester following ISO 1997. Surface roughness were measured at two points on the samples and the mean was taken as final roughness value. For computing the MRR, digital weight scale SF-400 with capability of 1grams to 10,000 grams is used for measuring weight before and after turning. In addition, grey relational analysis allied with Taguchi's technique made the complicated optimization in to a simplex one with grey relational grade as an objective function.

RESULT AND DISCUSSION

The F-ratios in tables were related with standard F table. From tables F (0.05, 2, 2) =19. By forwarding ANOVA for the output responses it is identified as Depth of cut is the most significant, next to this feed was more significant factor at 95% confidence level for without coolant (Tables 4-6).

F-ratios in tables were related with standard F table. From tables F (0.05, 2, 2)=19. By forwarding ANOVA for output responses it is identified as feed is the most significant, next to this depth of cut was more significant factor at 95% confidence level for without coolant. Cutting speed is found to be insignificant for without coolant on machining for both MRR and Ra (Tables 7-10).

F-ratios in tables were related with standard F table.

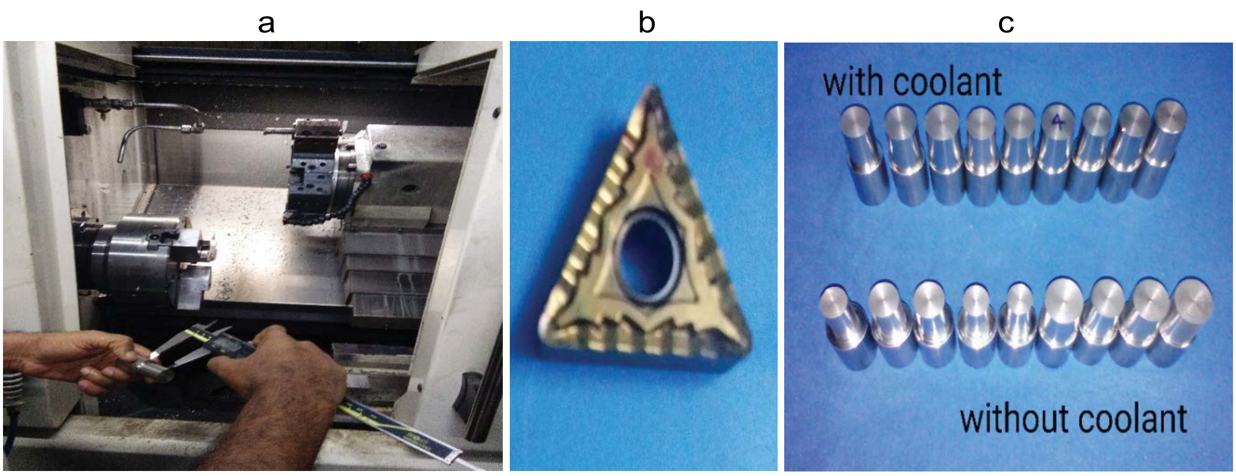

Fig. 1 (a-c) Shows experimental setup, cermet insert and machined component.

Table 1 AISI 303 stainless steel chemical composition

Grade		C	Mn	Si	P	S	Cr	Ni
303	Minimum	-	-	-	-	0.15	17.0	8.0
	Maximum	0.15	2.00	1.00	0.20	-	19.0	10.0
Actual		0.06	1.98	0.43	0.037	0.468	17.69	8.17

Table 2 Cutting parameters and their levels

S. No	Parameters	I^st Level	II^nd Level	III^rd Level
1	Cutting speed (rpm)	2100	2300	2500
2	Depth of cut (mm)	1.0	1.5	2
3	Feed rate (mm/rev)	0.1	0.15	0.2

Table 3 Orthogonal array L_9 of Taguchi experimental design

Trial	Cutting Speed (rpm)	Depth of Cut (mm)	Feed (mm/rev)
1	2100	1	0.1
2	2100	1.5	0.15
3	2100	2	0.2
4	2300	1	0.15
5	2300	1.5	0.2
6	2300	2	0.1
7	2500	1	0.2
8	2500	1.5	0.1
9	2500	2	0.15

Table 4 Experimental values of MRR and Ra without coolant

Exp	Cutting Speed (V)	Depth Of Cut (D)	Feed Rate (F)	Material Removal Rate (MRR)	Surface Roughness (Ra)
	rpm	mm	mm/rev	mm^3/sec	µm
1	2100	1	0.1	169.88	1.0925
2	2100	1.5	0.15	373.73	1.262
3	2100	2	0.2	498.31	1.542
4	2300	1	0.15	264.73	1.0955
5	2300	1.5	0.2	332.088	1.64
6	2300	2	0.1	323.78	1.138
7	2500	1	0.2	290.577	1.275
8	2500	1.5	0.1	273.97	1.1905
9	2500	2	0.15	462.55	1.144

Table 5 ANOVA – without coolant MRR

Source	SS	DOF	MS	F-Ratio	F-Tab	% Contr	Significant Status
Speed A	2920.09	2.00	1460.04	3.20	19.00	3.54	Insignificant
Depth B	52304.90	2.00	26152.45	57.38	19.00	63.47	Significant
Feed C	26265.95	2.00	13132.97	28.81	19.00	31.88	Significant
Error	911.56	2.00	455.78	--	--	1.11	--
Total	82402.49	8.00	--	--	--	100.00	--

Table 6 ANOVA –without coolant Ra

Source	SS	DOF	MS	F Ratio	F Tab	% Contr	Significant Status
Speed A	0.016955	2	0.008477	2.299366	19	5.43	Insignificant
Depth B	0.066520	2	0.033260	9.021277	19	21.30	Insignificant
Feed C	0.221417	2	0.110709	30.027899	19	70.91	Significant
Error	0.007374	2	0.003687	--	--	2.36	--
Total	0.312266	8	--	--	--	100.00	--

Table 7 Grey relational calculations for without coolant

S. No	GRGC		RSDC		GRCC		GRG
	MRR	RA	MRR	RA	MRR	RA	
X0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	
1	0	1	1.0000	0	0.333333	1	0.666667
2	0.62068	0.690410959	0.3793	0.30958904	0.568621	0.617597	0.593109
3	1	0.178995434	0.0000	0.82100457	1	0.3785	0.68925
4	0.2888	0.994520548	0.7112	0.00547945	0.412813	0.98916	0.700987
5	0.493889	0	0.5061	1	0.496963	0.333333	0.415148
6	0.468593	0.916894977	0.5314	0.08310502	0.484775	0.857478	0.671127
7	0.3675	0.666666667	0.6325	0.333333	0.4415	0.6124	0.52075
8	0.316932	0.821004566	0.6831	0.17899543	0.42263	0.736382	0.579506
9	0.891118	0.905936073	0.1089	0.09406393	0.821178	0.84166	0.831419

Table 8 Without coolant-response table for means of GRG

Variables	Level-1	Level-2	Level-3	Max-Min	Rank
Cutting speed-V	0.649675	0.595754	0.643892	0.053922	3
Depth of cut-D	0.629468	0.529255	0.730598	0.201344	1
Feed rate-F	0.6391	0.708505	0.541716	0.166789	2

Table 9 Experimental values of MRR and Ra with coolant

Exp	Cutting Speed (V)	Depth of Cut (D)	Feed Rate (F)	Material Removal Rate (MRR)	Surface Roughness (RA)
	rpm	mm	mm/rev	mm^3/sec	µm
1	2100	1	0.1	181.139	1.055
2	2100	1.5	0.15	373.599	1.1775
3	2100	2	0.2	601.909	1.48
4	2300	1	0.15	280.199	1.049
5	2300	1.5	0.2	498.13	1.6695
6	2300	2	0.1	398.505	1.127
7	2500	1	0.2	373.599	1.5075
8	2500	1.5	0.1	311.33	1.006
9	2500	2	0.15	569.29	1.129

Table 10 ANOVA – with coolant MRR

Source	SS	DOF	MS	F-Ratio	F-Tab	% Contr	Significant Status
Speed A	1768.47	2.00	884.24	1.00	19.00	1.17	Insignificant
Depth B	90062.87	2.00	45031.43	50.99	19.00	59.82	Significant
Feed C	56952.48	2.00	28476.24	32.24	19.00	37.83	Significant
Error	1766.26	2.00	883.13	--	--	1.17	--
Total	150550.08	8.00	--	--	--	100.00	--

From tables F (0.05, 2, 2) =19. By forwarding ANOVA for output responses it is identified as Depth of cut is the most significant, next to this feed was more significant factor at 95% confidence level for with coolant (Table 11).

F-ratios in tables were related with standard F table. From tables F (0.05, 2, 2)=19. By forwarding ANOVA the output responses it is identified as feed is the most significant, next to this depth of cut was more significant factor at 95% confidence level. Cutting speed is insignificant at 95% confidence level for the turning process for with coolant on machining (Table 12).

It is found that experiment No 9 machining parameter setting has highest GRG (0.797645), hence this is the optimal parameter setting for attaining multiple performances simultaneously among the nine experiments for using coolant (Tables 13 and 14).

TEST ON CONFIRMATION

A confirmatory test is made on the optimized parameters and the average of surface roughness

Table 11 ANOVA – With coolant Ra

Source	SS	DOF	MS	F-Ratio	F-Tab	% Contr	Significant Status
Speed A	0.007089	2	0.003544	0.354643	19	1.51	Insignificant
Depth B	0.009723	2	0.004862	0.486463	19	2.08	Insignificant
Feed C	0.431102	2	0.215551	21.567869	19	92.14	Significant
Error	0.019988	2	0.009994	--	--	4.27	--
Total	0.467903	8		--	--	100.00	--

Table 12 Grey relational calculations for with coolant

S. No	GRGC		RSDC		GRCC		GRG
	MRR	RA	MRR	RA	MRR	RA	
X0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	
1	0	0.926149209	1.0000	0.07385079	0.333333	0.871307	0.60232
2	0.4574	0.741522231	0.5426	0.25847777	0.47957	0.659215	0.569393
3	1	0.285606631	0.0000	0.71439337	1	0.411728	0.705864
4	0.2354	0.935192163	0.7646	0.06480784	0.39539	0.885257	0.640323
5	0.753359	0	0.2466	1	0.669666	0.333333	0.5015
6	0.516591	0.81763376	0.4834	0.18236624	0.508435	0.732744	0.62059
7	0.4574	0.24416	0.5426	0.75584	0.47957	0.39814	0.438855
8	0.309411	1	0.6906	0	0.41996	1	0.70998
9	0.922478	0.814619442	0.0775	0.18538056	0.865768	0.729522	0.797645

Table 13 With coolant-response table for means of GRG

Variables	Level-1	Level-2	Level-3	Max-Min	Rank
Cutting speed-V	0.625859	0.587471	0.648827	0.061356	3
Depth of cut-D	0.560499	0.593624	0.708033	0.147533	1
Feed rate-F	0.644297	0.66912	0.54874	0.120381	2

Table 14 Optimal levels for process parameters

S. No	Coolant condition	Optimal levels	Factor	Level	Values
1	Without Coolant	A1B3C2	Cutting Speed (A)	One	2100 rpm
			Depth of Cut (B)	Three	2 mm
			Feed Rate (C)	Two	0.15 mm/rev
2	With Coolant	A3B3C2	Cutting Speed (A)	Three	2500 rpm
			Depth of Cut (B)	Three	2 mm
			Feed Rate (C)	Two	0.15 mm/rev

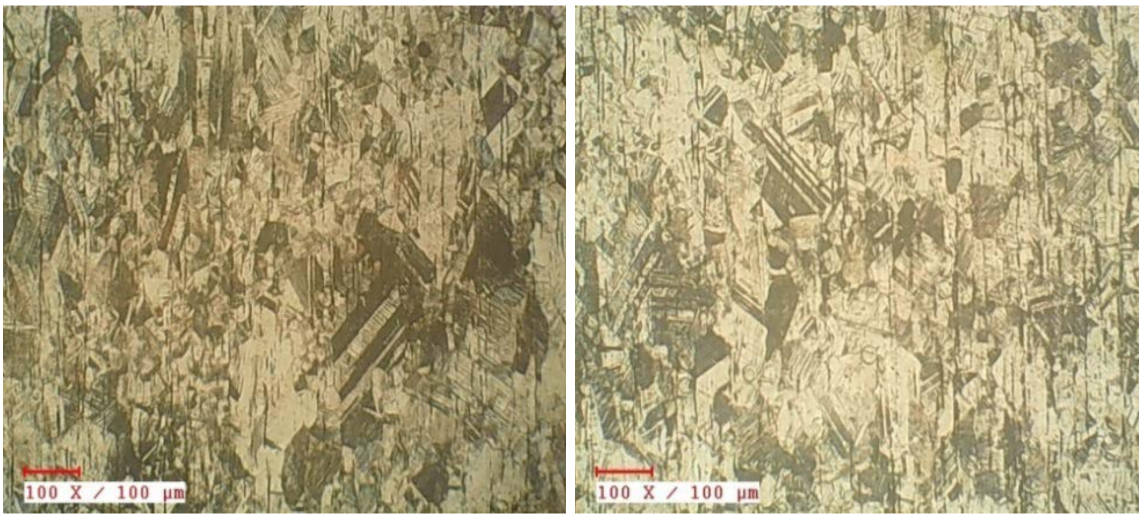

Fig. 2 (a and b) Shows metallurgical characterization of without and with coolant sample.

and MRR is found. The MRR for the without coolant parameters A1B3C2 is 482.80 mm^3/sec while the Ra is 1.306 µm. The MRR forwith coolant parameters A3B3C2 is 587.37 mm^3/sec while Ra is 1.124 µm.

A Micro structural investigation is made on both without and with coolant samples by Metallurgical Microscope-METSCOPE-1A. Glyceregia is used as an etchant. The samples are polished and grain size is measured as per ASTM chart by comparison method. From the microstructure it clearly shows the fine grains of austenite throughout the matrix, besides presence of delta ferrites are also observed as in (Fig. 2a and 2b). The grain size number is 4-5 as per ASTM chart for without coolant sample, while the grain size number is 5 as per ASTM chart by comparison method. There is a slight variation in its grain structure and size which is due to the use of coolant. Machining with coolant reduced the grain size to some extent.

CONCLUSION

This work presents a Taguchi based grey relational analysis for simple CNC turning process. Experiments comprising cermet insert and AISI 303 stainless steel material under the usage and non-usage of coolant were implemented. In this study outcome of coolant on machining is examined critically. Taguchi's robust design abridged the number of experiments at ease optimization in finding the cutting parameters namely cutting speed, feed, and depth of cut.

ANOVA is prepared to catch out the significance of the parameter convoluted in machining. From the results it is clear that feed is the most important significant factor for surface roughness and while depth of cut is most significant factor when considering metal removal rate for the "Coolant Off" and "Coolant On" conditions.

Cutting speed is the most insignificant factors for both surface roughness and MRR. Machining with coolant contributed good surface finish while paralleled with dry environments. The optimal parameters when "Coolant Off" is 2100 rpm, 2 mm, 0.15 mm/rev and "Coolant On" is 2500 rpm, 2 mm, 0.15 mm/rev. The increase in cutting speed, change in metal removal rate, decrease in grain size and change in micro structure is due to the use of coolant in CNC turning process.

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