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Study of machining parameters while turning austenitic stainless steel AISI304

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Abstract
Stainless steels are hard materials and difficult to machine as seen in research work done until now. A machining industry which aims for higher quality and higher productivity at low cost, will definitely face problem with elevated temperatures at the metal cutting zone during the machining process, as the conventional cooling methods fail to reduce the heat at tool –chip interface thereby affecting the performance. This problem can be handled largely by reducing the cutting temperature. Hence, a cryogenic coolant is highly recommended for this purpose. Based on the results obtained from the experimental work done until now, it can be concluded that machining with the cryogenic CO2 cooling had a substantial benefit with respect to the cutting temperature, cutting forces, chip thickness and morphology, surface roughness, shear angle, and tool wear, when compared with the other conventional cooling methods. In this project, works on the various machining parameters affecting the effectiveness of turning AISI 304 are reviewed for improving surface finish. Process parameters such as cutting speed, feed rate, depth of cut mainly under conventional cooling and cryogenic cooling conditions are considered. Cryogenic cooling setup for supplying CO2 gas was developed. The work material Austenitic stainless steel AISI 304 is selected for performing various experimentations. The result is further confirmed by experiments. Finally output parameters like surface finish can be optimized for economical production.

Keywords: cutting speed, feed rate, depth of cut, cryogenic coolant co2, surface roughness, minitab software etc.

Introduction
In today's manufacturing industry the major variety of work material can be classified in following type of work materials Mild steel, Aluminum, Brass, Ferrous Alloys i.e., Alloy steel, Cast iron, Stainless steels. The machining of this austenitic stainless steel is very difficult since it contains a high amount of strength-enhancing elements such as chromium, nickel and molybdenum. One of the major problems is the heat generation at the cutting region during the machining of difficult-to-cut metals. The machining process requires more energy, so high temperatures occur throughout the deformation process and the friction at the tool-chip and tool-work piece interfaces. Recently, the machining technology has been quickly improved to increase the processing productivity and machining performance in the cases of difficult-to-cut steels. An increase in the productivity can be achieved by decreasing the temperature.

In this paper, an attempt has been made to use cryogenic carbon dioxide (CO2) as the cutting fluid. Based on the results obtained from the experimental work done until now, it can be concluded that machining with the cryogenic LN2 and CO2 cooling had a substantial benefit with respect to the cutting temperature, cutting forces, chip thickness and morphology, surface roughness, shear angle, and tool wear, when compared with the other conventional cooling methods. Further, the use of cryogenic coolants also reduces the adhesion and effect of friction at the chip-tool interface and work-tool interface, thereby reducing the tool wear, and improving the surface quality of the product.

In order to improve machining efficiency, reduce the machining cost, and improve the quality of machined parts, it is necessary to select the most appropriate machining conditions by optimization of parameters.

Taguchi designs provide a powerful and efficient method for designing products that operate consistently and optimally over a variety of conditions. Taguchi proposed several approaches to experimental designs that are sometimes called "Taguchi Methods." These methods utilize two, three, four, and five and mixed-level factorial designs. Taguchi refers to experimental design as "off-line quality control" because it is a method of ensuring good performance in the design stage of products or processes.

Smaller the better characteristics

$$S/N = -10\log\frac{1}{n}\left(\sum y^2\right) \quad \text{.................................. (A)}$$

Larger the better characteristics

$$S/N = -10\log\frac{1}{n}\left(\sum\frac{1}{y^2}\right) \quad \text{.................................. (B)}$$

Nominal the best characteristics

$$S/N = 10\log\frac{\bar{y}}{sy^2} \quad \text{.. (C)}$$

Literature survey
Dhar and Kamruzzaman 2007 [1] have carried out experimental investigation in the role of cryogenic cooling by applying LN2 jet on cutting temperature, tool wear, surface finish and the dimensional deviation in turning of AISI 4037

steel at industrial speed and feed combination by coated carbide insert. It was observed that the conventional coolant failed to show any significant improvement.

L.De Chiffre *et al*. 2007 [2] have carried out experimental investigations by comparing the efficiency of CO2 with the commercial water-based product as the coolant on threading and parting/grooving stainless steel. Tool life, cutting force, chip disposal and work piece surface finish were analyzed and concluded that the efficiency of CO2 was as high as 173% relative to water-based product in terms of the tool life. It was found that CO2 when applied at a rate of 6 g/s is an efficient coolant for threading and parting/grooving stainless steels.

Xavior and Adithan *et al*. (2009) [3] studied the influence of different cutting fluids on the tool wear and surface roughness during turning of AISI 304 steel. It was observed that coconut oil performed best. The optimization of cutting speed and feed in order to obtain favorable performance characteristics has also been reported recently.

Kaladhar *et al*. 2010 [4] aimed the present experimental investigation to evaluate the effects of the coating materials and determine the optimal levels of process parameters for optimizing the surface quality of AISI 304 austenitic stainless steel work piece by employing Taguchi's orthogonal array design and Analysis of Variance (ANOVA) using CVD and PVD coated tool on CNC lathe under dry environment. The AISI 304 austenitic stainless steel is the most widely used grade among all the grades of austenitic stainless steel. It is used for aerospace components and chemical processing equipment, for food, dairy, and beverage industries, for heat exchangers, and for the milder chemicals.

D. hilip selvaraj1, p. chandramohan 2,* *et al*. 2010 [5] the present work is concentrated with the dry turning of AISI 304 Austenitic Stainless Steel (ASS). This paper presents the influence of cutting parameters like cutting speed, feed rate and depth of cut on the surface roughness of austenitic stainless steel during dry turning. A plan of experiments based on Taguchi's technique has been used to acquire the data. An orthogonal array, the signal to noise (S/N) ratio and the analysis of variance (ANOVA) are employed to investigate the cutting characteristics of AISI 304 austenitic stainless steel bars using TiC and TiCN coated tungsten carbide cutting tool.

B. Dilip Jerold ∗, M. Pradeep Kumar *et al*.; 2011 [7], Experimental investigations are carried out by turning AISI 1045 steel in which the efficiency of cryogenic CO2 is compared to that of dry and wet machining with respect to cutting temperature, cutting forces, chip disposal and surface roughness. The experimental results show that the application of cryogenic CO2 as the cutting fluid is an efficient coolant for the turning operation as it reduced the cutting temperature by 5%–22% when compared with conventional machining. The major objective of this work is to study especially the effect of cryogenic CO2 as the cutting fluid in machining AISI 1045 steel and to compare the parameters like cutting temperature, cutting forces, chip thickness, shear angle and surface roughness with wet and dry machining. Cryogenic CO2 with high cooling potential was expected to remove ample heat from the cutting zone and this will also result in the improvement of mechanics of chip formation. Surface finish of the finished part is also improved in cryogenic condition to an appreciable amount on comparison with the other two environments.

Dilip Jerold and pradeep Kumar, 2012 [8] made experimental work and compare performance on cryogenic coolant such as LN2 and CO2 measures the cutting temperature, cutting force, tool wear, surface finish, and chip morphology using the work material as AISI 1045 Steel and used a cutting tool in multicoated carbide inserts the results says that when compared to the use of cryogenic LN2 coolant. Tool wear was found to be less on the application of CO2 compared to the wet and LN2 machining conditions.

Shokrani *et al*. (2012) [9] studied CNC end milling of the Inconel 718 nickel based alloy using TiAlN coated solid carbide tools. The experimental investigations told that cryogenic coolant i.e., CO2 has a significant potential to improve surface roughness of machined parts as compared to dry machining.

O. Pereiraa,b,*, A. Rodrígueza *et al*.; 2015 [13], In this Paper, CO2 cryogenic machining is presented as alternative to conventional hard turning. So, in the tests carried out in this research, dry and CO2 cryogenic hard turning with two types of inserts were compared. The variables measured were tool life, superficial roughness and the piece microstructure. The results show an increase of tool life over 60%, a similar superficial roughness and, when positive insert is used, the absence of the white layer. Carbon (CO2) cryogenic hard turning is presented as alternative to conventional hard turning processes. Tool life, superficial roughness and microstructure have been analyzed in the study.

Murat Sarýkaya *et al*.: 2015 [14] This paper presents the optimization of the surface roughness using the Taguchi technique to assess the machinability of the AISI 316Ti steel with PVD coated carbide inserts under different cooling conditions such as dry, conventional (wet) and cryogenic cooling with liquid nitrogen (LN2). Based on the Taguchi L9 (33) orthogonal-array design, the machinability tests were made utilizing a CNC lathe machine. Test parameters including the cutting speed, the cooling condition and the feed rate were taken and then the surface roughness (Ra) was measured to obtain the machinability indicator. An analysis of variance was performed to determine the importance of the input parameters for the surface roughness. The process parameters were optimized by taking the Taguchi technique into consideration.

Experimental procedure

In the present research work, the cryogenic cooling setup for supplying cryogenic CO2 coolant was developed, and turning operations were carried out for analyzing the performance of conventional and cryogenic coolants. The work material Austenitic stainless steel AISI 304 is selected for performing various experimentations. Table 1 shows the chemical composition of the raw material.

Taguchi method is used for analysis. Taguchi method based design involves selection of response variable, independent variable, their interactions and an orthogonal array. The standard L18 orthogonal array was selected. Table 2 shows the parameters and the corresponding levels chosen for the investigation.

Table 1: Chemical Composition of work Material

Elements	Composition %wt)
C	0.051
Si	0.412
Mn	1.351
Cr	18.275
Ni	8.473
Mo	0.301
Cu	0.318
Ti	0.005
V	0.049
W	0.003
Co	0.019
Nb	0.020
Fe	Balance

Table 2: Process parameters and their levels

	Factors		
Levels	**A**	**B**	**C**
(Mixed)	Cooling Condition	Speed (m/min)	Feed (mm/rev)
1	Wet	251	0.12
2	cryogenic	351	0.2
3		314	0.25

In this study, on the basis of the control factors and their levels from, the Taguchi L18 orthogonal array (OA) from the Minitab software was used, indicating the design of the experiments. It has 18 rows and 03 columns.
The surface roughness (Ra) was evaluated with an orthogonal array for each combination of the test parameters using the Taguchi technique and an optimization of the process parameters was achieved with signal-to-noise (S/N) ratios. In the last phase of the Taguchi method, a verification experiment has to be made to check the reliability of the optimization. The verification experiment was conducted at the optimum levels of the variables determined.

Design of Experiments

The process parameters considered in the present study are Speed, feed and cooling condition. The levels of these parameters are chosen based on the study of various research works. Experiments were designed using Taguchi method to use the experimental resources optimally. The cutting speed (V_c), the feed rate (f) and the cooling condition (C) were taken as the cutting parameters. The values of the cutting parameters were chosen from the plot experiments and the manufacturer's handbook the cutting parameters and their levels are given in Table 2.
Selection of Orthogonal Array: In this study, on the basis of the control factors and their levels from Table 2, the Taguchi L18 orthogonal array (OA) from the Minitab software was used, indicating the design of the experiments. It has 18 rows and 03 columns.

Machine Tool and Equipments Used In Experimentation

Machine Tool and Work piece:
Machine Tool: As the CNC Lathe is the best suitable machine, motor. All the turning tests are conducted using a machine tools, CNC lathe machine with the maximum spindle speed of 4800 r/min and a 15 kW drive.
Work piece Material: Austenitic stainless steels are widely used in springs, nuts, bolts and screws due to their high strength and high corrosion and oxidation resistance. AISI 304 stainless steel finds its application in air craft fittings, aerospace components such as bushings, shafts, valves, special screws, cryogenic vessels and components for severe chemical environments. It is also being used for welded constructions in aerospace structural components.

1. Raw material SS304 Ø40X1.0 mtr.
2. Cutting of bar at 50.0 mm- 18 no's minimum

Experimental Setup and Work-piece: Experiments were conducted using CNC turning center manufactured by machine tools. The cutting tool used is TNMG 16 04 08, TIN-TICN- AL2O3-TIN Coated insert. The work-piece used in the present work which is AISI304 having diameter 40 mm and length 50 mm. The experiments were carried out in wet and cryogenic cooling conditions.
Arrangement done for cooling:
For the cryogenic cooling, cryogenic coolant gas CO2 was delivered directly from the pressure tank to the tool holder at a pressure of 4 bar, it provides a connection between the tool holder and the liquid-CO2 container with the help of a hose and an adaptor. The CO2 gas in jet form is sprayed over insert of tool holder. It is to be released to the environment as a gas vapor, taking the heat from the insert.

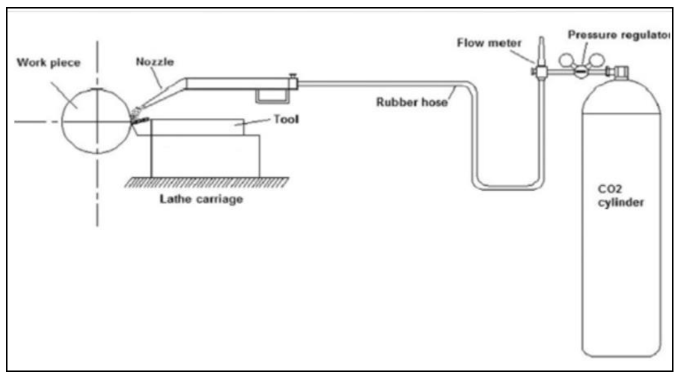

Fig 1: Cryogenic cooling setup-CO2

Surface Roughness Measuring Instrument: To measure surface roughness a Taylor Hobson surface roughness tester were used. The roughness parameter measured in this study, was Ra as it represents the characteristics of surface roughness for the turned components. Total three readings on each specimen have been taken. The averages of these readings are considered as final Ra value for each experimental run.

Results and Discussion

Analysis of the experimental results: Analysis done by using Minitab Software.
Data analysis: To obtain a reliable database, values were calculated. After all experiments are conducted, decisions must be made concerning which parameters affect the performance of a process and a mathematical model is

developed to predict output amounts close to the actual amounts. The Data analysis was done using MINITAB 14; following steps were taken for doing the analysis of machined components.

Signal-to-noise (S/N) analysis:

The surface roughness (Ra) was evaluated with an orthogonal array for each combination of the test parameters using the Taguchi technique and an optimization of the process parameters was achieved with signal-to noise (S/N) ratios. For the surface roughness with respect to the desired low Ra, The smaller-the-better approach is expressed as follows:

Smaller-the-better (minimize):

$$\frac{S}{N_{R_a}} = -10\log\left[\frac{1}{n}\sum_{r=1}^{n} o_i^2\right] \quad (1)$$

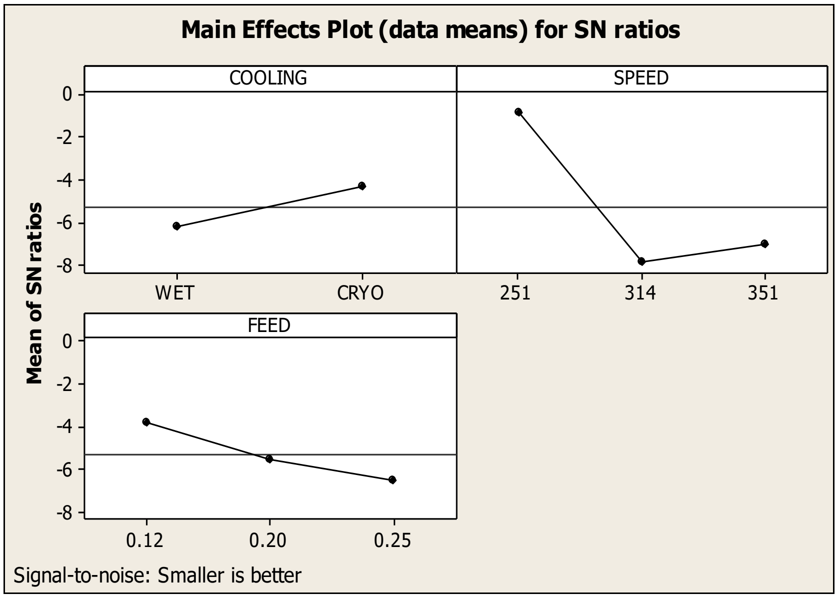

Fig 2

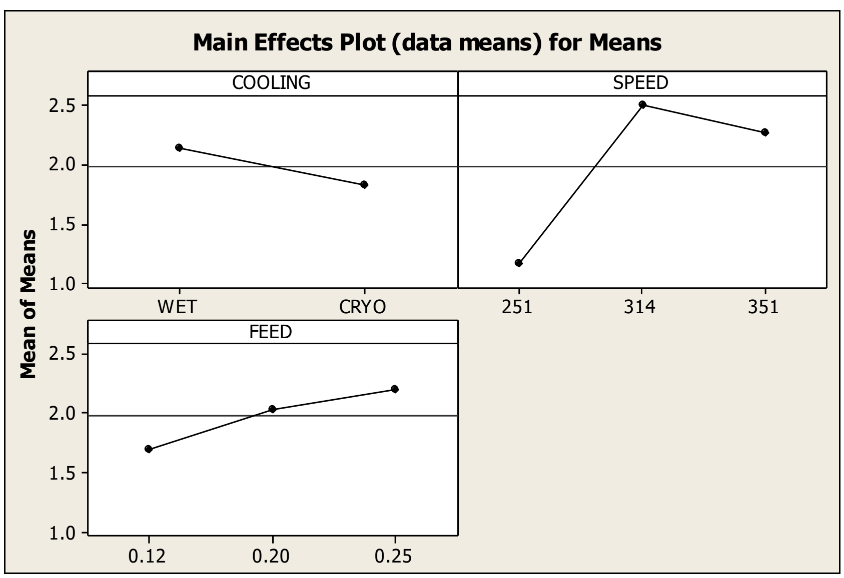

Fig 3: Main Effect Plot for S/N Ratio

Table 3: Experimental results and their S/N values

SR.NO	Cooling	Speed	feed	Ra (μm)	Snra1	Mean1
1	wet	251	0.12	1	0	1
2	wet	251	0.2	1.3	-2.27887	1.3
3	wet	251	0.25	1.8	-5.10545	1.8
4	wet	351	0.12	1.9	-5.57507	1.9
5	wet	351	0.2	2.5	-7.9588	2.5
6	wet	351	0.25	2.4	-7.60422	2.4

7	wet	314	0.12	2.5	-7.9588	2.5
8	wet	314	0.2	2.6	-8.29947	2.6
9	wet	314	0.25	3	-9.54243	3
10	cryo	251	0.12	0.65	4.43697	0.65
11	cryo	251	0.2	0.9	0.91515	0.9
12	cryo	251	0.25	1.2	-1.58362	1.2
13	cryo	351	0.12	2	-6.0206	2
14	cryo	351	0.2	2.4	-7.60422	2.4
15	cryo	351	0.25	2.4	-7.60422	2.4
16	cryo	314	0.12	2	-6.0206	2
17	cryo	314	0.2	2.5	-7.9588	2.5
18	cryo	314	0.25	2.4	-7.60422	2.4

Taguchi Analysis: Ra versus cooling, speed, feed

Table 4: Response Table for Signal to Noise Ratios Response Table for Means

Levels	**Control factors**			**Level**	**Control factors**		
	S/N ratios				**Means of means**		
	Cooling	**Speed**	**Feed**		**Cooling**	**Speed**	**Feed**
	A	**B**	**C**		**A**	**B**	**C**
1	-6.0359	-0.6026	-3.523	1	2.111	1.133	1.667
2	-4.3382	-7.8974	-5.5308	2	1.822	2.5	2.033
3		-7.0612	-6.5074	3		2.267	2.2
DELTA	1.6977	7.2947	2.9843	DELTA	0.289	1.367	0.533
RANK	3	1	2	RANK	3	1	2
	CRYO	251	0.12		CRYO	251	0.12

A2B1C1 A2B1C1

In Equation (1), o_i is the response of the output characteristic for the r^{th} test and n is the number of the outputs of the test. The experimental results and their S/N ratios were calculated using Equation (1) as given in Table 3. From this table, the mean surface roughness and the mean S/N ratio were calculated as 1.96 µm and –5.18 dB, respectively. The analysis of the process parameters like the cutting speed, feed rate and cooling condition was made using an S/N response table obtained with the Taguchi method as seen in Table 4 The S/N response table of the results gives the optimum points of the process parameters for the best surface roughness. Figure 2 was plotted to determine the optimum control factor of a machining parameter using the S/N response table. As seen in Figure 3, for the highest S/N ratio, the optimum parametric combination was found to be factor A (level 2, S/N = – 4.338 dB, mean: 1.822 µm), factor B (level 1, S/N = –0.6026 dB, mean: 1.133 µm) and factor C (level 1, S/N = –3.523 dB, mean: 1.667 µm).

Under cryogenic cooling, the cutting speed was 251m/min and the feed rate was 0.12 mm/r. We can also say that surface roughness depends on the speed, the surface roughness increases with speed up to a particular value of CS (speed) and again decreases. The results showed that with the increase in cutting speed there is slight increment in Ra value up to 314 m/min. Further, surface finish improves (decreases) with increasing cutting speed. The lowest surface roughness value obtained at 251 m/min. The results mean that for better surface finish lower values of feed can be more influential in affecting the Ra values.

ANOVA: Analysis of variance (also known as ANOVA) is statistical method and the significance of the machining parameters was identified with its help. The ANOVA analysis was performed with a 95 % confidence level and 5 % significance level. The F values of the control factors indicated the significance of the control factors determined with the ANOVA analysis. The percentage contribution of each parameter is shown in the last column of the ANOVA table. The column shows the effect rates of the input parameters on the outputs. In the present work, the ANOVA results are given in Table 5. The ANOVA results indicate that the cooling condition the cutting speed and the feed rate influenced the surface roughness by 4.6 %, 79.3 % and 11 %, respectively. Therefore, the cutting speed (factor B) is the most important factor affecting the surface roughness. According to Table 5, it can be said that the cooling condition, the feed rate and the cutting speed had a statistical and physical significance with regard to the surface roughness at the reliability level of 95 % because their P values are lower than 0.05.

Table 5: ANOVA analysis Table

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Contribution
cooliNg	1	0.3756	0.3756	0.3756	11.33	0.006	4.648515
speed	2	6.4133	6.4133	3.2067	96.74	0	79.37252
feed	2	0.8933	0.8933	0.4467	13.47	0.001	11.05569
Error	12	0.3978	0.3978	0.0331			4.923267
Total	17	8.08					100

Regression analysis: Ra versus cooling, Speed and Feed Regression Analysis

Regression analysis: Ra versus Cooling Condition, Speed, and Feed Regression analysis is performed to find out the relationship between factors and surface roughness. In conducting regression analysis, it is assumed that factors and the response are linearly related to each other. A multiple regression technique was used to formulate the Cooling Condition, Speed, and Feed to the Ra.

A mathematical model for the surface roughness with coded values can be written as,

Ra = 0.500 - 0.350A (cooling) + 0.630 B (speed) + 0.260 C (feed) ………………. (2)

R2 = 84.6 % the determination coefficient, expressed as R2, shows the reliability of the predicted model. It was recommended that R2 should be between 0.8 and 1.0. In this study, the value of the determination coefficient is R2 = 0.846 and it is high enough, demonstrating a significance of the predicted model. The residual plot of Ra is shown in Fig. This layout is useful to determine whether the model meets the assumptions of the analysis. The normal-probability plot of the residuals for the surface roughness showed that the residuals quite appropriately tended to a straight line, meaning that errors were normally delivered. This proved that Model was satisfactory and quite reliable.

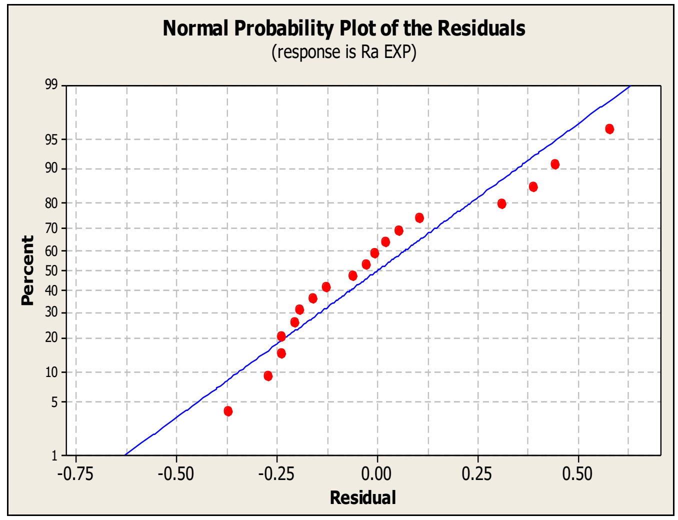

Fig 4: Normal-probability plot of the residuals

Experimental Vs Predicted Values

The prediction model was then validated with another set of data. Table 6 shows verification of the tests results for Surface roughness done by Comparison of the experimental results and the estimated results obtained with the Taguchi technique and mathematical model. The maximum prediction error was 9.09 % As a result; the prediction accuracy of the model appeared satisfactory

Table 6: Verification of the Test results for optimum and random levels

Part No.	A cooling	B speed	C feed	Ra Experimental	Ra Predicted	Difference	Percent
1	1	1	1	1	1.1	0.1	9.09
7	1	3	1	2.5	2.516	0.016	0.63
9	1	3	3	3	3.05	0.05	1
10	2	1	1	0.65	0.69	0.09	5.8
16	2	3	1	2	2.216	0.216	8

Determining the Optimum Surface Roughness

In the last phase of the Taguchi method, a verification experiment has to be made to check the reliability of the optimization. The verification experiment was conducted at the optimum levels of the variables determined. As seen from main affects plots for, (a) Mean Surface Roughness and (b) S/N ratios. A2-B1-C1 are the optimum levels for cooling condition, speed, and feed respectively. The values of the cutting parameters at the optimum levels were employed to calculate the estimated optimum surface roughness.

Table 7: Result of conformation Experiments

Details	Optimal Parameters of Ra					
	Prediction			Experimental		
Process parameters	**Cooling**	**Speed**	**Feed**	**Cooling**	**Speed**	**feed**
Level	2	1	1	2	1	1
Response Value	0.69			0.62		

The confirmation experiment was performed on CNC for finishing operation with Cooling A2, Speed B1., and Feed C1...Of parameters, it showed that the Ra decreased from 0.69 to 0.62 µm. They are A2: cryogenic cooling, B1: The cutting speed: 251m/min and C1:Feed rate 0.12 mm/r.

5. Conclusion

The experimental results show that the application of cryogenic CO2 as the cutting fluid is an efficient coolant for the turning operation when compared with conventional Coolant. It is also observed that the surface finish is improved to an appreciable amount in the finished work piece on the application of cryogenic CO2 gas. As seen from S/N Ratios response table and Means of Means response table the percentage improvement in surface finish is 13 %.

6. Future-scope

Future work may deal with analyzing the effects of some cooling/lubrication methods like the minimum quantity lubrication (MQL), high-pressure cooling with a coolant, high-pressure cooling with compressed air, and external cryogenic cooling with different coolants during the machining of the AISI 304 stainless steel.

7. References

1. Dhar NR, Kamruzzaman M. Cutting temperature, tool wear, surface roughness and dimensional deviation of turning AISI 4037 steel under cryogenic condition, International Journal of Machine Tools & Manufacture. 2007; 47:754-9.
2. De Chiffre L, Andreasen JL, Lagerberg S, Thesken IB. Performance testing of cryogenic CO 2 as cutting fluid in parting/grooving and threading austenitic stainless steel. CIRP Annals-Manufacturing Technology, 56(1):101-104.
3. Xavior, Adithan, *et al.* Determining the influence of cutting fluids on tool wear and surface roughness during turning of AISI 304 austenitic stainless steel, Journal of Materials Processing Technology. 2009; 209(2):900-909. doi:10.1016/j.jmatprotec.2008.02.068
4. Kaladhar M, Venkata Subbaiah K, Ch. Srinivasa Rao, Narayana Rao K. Optimization of Process Parameters in Turning of AISI202 austenitic stainless steel, ARPN Journal of Engineering and Applied Sciences, 5(9):79-87.
5. Philip Selvaraj D. Optimization of surface roughness of AISI 304 austenitic stainless steel in dry turning operation using Taguchi method, Journal of Engineering Science and Technology. 2010; 5(3):293-301, © School of Engineering, Taylor's University College
6. Umbrello PU, Caruso JC. Outeiro, The effects of Cryogenic Cooling on Surface Integrity in Hard Machining, Procedia Engineering. 2011; 19:371-376.
7. Dilip Jerold B, Pradeep Kumar M. Experimental investigation of turning AISI 1045 steel using cryogenic carbon dioxide as the cutting fluid, 'Journal of Manufacturing Processes. 2011; 13113-119.
8. Dilip Jerold, Pradeep Kumar M. Machining of AISI 316 Stainless Steel under Carbon-Di-Oxide is cooling, Materials and Manufacturing Processes. 2012; 27:1059-1065
9. Shokrani A, Dhokia V, Newman S. Environmentally conscious machining of difficult-to-machine materials with regard to cutting fluids, International Journal of Machine Tools and Manufacture. 2012; 57:83-101.
10. Pathade HP, Wakchaure VD. Experimental Investigation of Flank Wear in Coated Carbide Tipped tool for Machining AISI 304. International Journal of Mechanical and Production Engineering Research and Development (IJMPERD) ISSN 2249-6890. 2013; 3(2):63-86.
11. Patrick Mayera, Robert Skorupskib, Marek Smagab, Dietmar Eiflerb, Jan C Auricha. Deformation induced surface hardening when turning metastable austenitic steel AISI 347 with different cryogenic cooling strategies 6th CIRP International Conference on High Performance Cutting, HPC, 2014.
12. Shreemoy Kumar Nayak. Multi-Objective Optimization of Machining Parameters During Dry Turning of AISI 304 Austenitic Stainless Steel Using Grey Relational Analysis. 3rd International Conference on Materials Processing and Characterisation ICMPC, 2014.
13. Pereiraa OB, Rodrígueza A. Cryogenic Hard Turning of ASP23 steel using Carbon Dioxide The Manufacturing Engineering Society International Conference, MESIC, 2015
14. Sarýkaya M. optimization of the surface roughness by applying the taguchi technique for the turning of stainless steel under cooling conditions, MTAEC9. 2015; 49(6):941.
15. Bolewar AB, Shinde VB. Effect Of Cryogenic Cooling Environment Using Co2 On Cutting Temperature In Turning Process 'International Journal Of Innovations In Engineering Research And Technology'. [IJIERT], 2016, 3(6). ISSN: 2394-3696.
16. Ciftci, Machining of austenitic stainless steels using CVD multilayer coated cemented carbide tools, Tribology International. 2006; 39(6):565-569, doi:10.1016/j.triboint. 2005.05.005