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OPTIMIZATION OF CUTTING PARAMETERS OF MARTENSITIC STAINLESS STEEL GRADES AISI 410 AND AISI 420 DURING CNC DRY MILLING

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Abstract

An experiment was conducted for optimizing the CNC dry milling parameters for Martensitic Stainless steel (MSS) grades AISI 410 and AISI 420.Both of these grades are having lot of applications in bushings and nuts, screws, petroleum fractionating structures, bolts etc. But the machinability of AISI 410 and AISI 420 is very low as tough draggy chips are produced while machining. Hence the machinability study was carried out to understand the machining performance of these stainless steel grades. The experiments for finding the effect of spindle speed, depth of cut and feed on surface roughness and cutting force was designed by L27 orthogonal array using 3 levels of feed, spindle speeds and depth of cut. Optimization of cutting parameter is done by using Taguchi method (S/N ratio and ANOVA). Machining with optimum of machining parameter will improve the quality and productivity of the machined components. The impact of different parameters on cutting force, cutting temperature and Surface roughness were indicated by the rank obtained in Taguchi analysis. The analysis reveals that surface roughness and cutting force are most affected by spindle speed for both the MSS grades. The cutting temperature is most affected by depth of cut for both the MSS grades. Due to raised Chromium and Carbon content in MSS AISI 420 surface roughness and cutting force values become larger than MSS AISI 410.

Keywords: CNC dry milling, Cutting force, Martensitic stainless steel, Surface roughness, Taguchi method.

1. Introduction

MSS 410 (UNS S41000) and MSS 420(UNS S42000) contain chromium (11.5%-13.5%), iron, and other elements like carbon, manganese etc. Mechanical properties of MSS grade 410 can be improved by heat treatment. In both annealed and hardened conditions it is magnetic. It can be used for cases which need high strength and moderate corrosion resistance. Its corrosion resistance can be improved by tempering and hardening. After hot working (2000° F to 2200° F range), annealing, cold forming and welding can be done. Hence MSS 410 is called the general-purpose grade among MSS grades. MSS 420 is having more strength, hardness and similar corrosion properties to MSS 410. It is also a general-purpose grade with minimum of 12% chromium, which provides reasonable resistance to corrosion and can be improved further by polishing and hardening. Both grades have lots of applications in bushings and nuts, screws, petroleum fractionating structures, bolts etc.

Tool wear mechanism experiments were conducted by Correa et al. [1] for turning of S41426 (Super Martensitic) and S41000 (Martensitic) by using carbide tool with coating (TIC/TICN/TIN). Conclusion was, for S41426 grade; attrition and abrasion are the prominent factors for wear and for S41000 grade it is abrasion and diffusion. Experimental Investigation was done by Dirviyam et al. [2] for duplex stainless steel (DSS) grades 4A and 5A for milling operation (Dry). Findings show that surface roughness and cutting force are reduced when speed of spindle increased. Increase in feed cause larger surface roughness and cutting force. Optimization is done using Taguchi method. An optimization of cutting parameters was done by Sai and Bouzid [3] for the Austempered ductile iron hard turning employing ANOVA and signal to noise ratio. The cutting parameters selected were 3 levels of speed, feed and depth of cut. Cutting speed was the prominent factor affecting the surface roughness and tool wear.

Sahu and Choudhury [4] points out that machining of hard metals will be improved by using coated tools at small values of feed and larger values of speed. Taguchi methodology is used for optimization of surface finish and prediction of tool wear in hard turning. For this Multi-layer (TiN) coated and uncoated tools are used for high-speed turning of AISI 4340 to find the machining performance. Finished turning of AISI 420B is analyzed by Bruni et al. [5] for wet, dry and minimum quantity lubrication (MQL) and measured the tool wear and surface finish. It is concluded that MQL technique will produce the best results and the usage of concrete bed will produce improved surface finish and reduction in tool wear. Uysal et al. [6] conducted MQL experiments by using vegetable cutting fluid mixed with 1% Nano Molybdenum Disulphide for milling operation of AISI 420 MSS using tungsten carbide tool. It is found that MQL reduces the tool wear and improve the surface finish for milling operation. Ciftci [7] investigated the machining characteristics of austenitic stainless steel (ASS) by using CVD coated cutting tools. It is found that spindle speed was the prominent factor affecting the surface roughness. Optimization of end milling operation was done by Dirviyam et al. [8] for the 5A grade (DSS) to reduce surface roughness, cutting force and tool wear by employing Taguchi Technique. Philip et al. [9] optimized the surface finish of DSS using Box-Behnken design (BBD) Response surface method (RSM) in milling operation. It is found that optimal surface finish was achieved at higher speed, smaller feed and axial depth of cut. Romoli et al. [10] suggests that high surface finish with an average roughness less than 100 nm is obtained by layer removal in spiral trajectory since it helps a depth of cut in a controlled manner. It was suggested based on the experiments for micro- milling of MSS with the help of laser beam which was driven in spiral trajectories producing sub-pico second pulse duration. Taguchi technique was used by Zhang et al. [11] for optimizing the surface quality of AISI 304 ASS in CNC face milling operation. They employed feed, speed and depth of cut as control factors and operating chamber temperature as noise factor. Dodds et al. [12] compare how microstructure, hardness and wear resistance were influenced by Friction stir processing (FSP) with AISI 420 (conventionally hardened) and D2 tool steel. The results proved that FSP of AISI 420 produced better wear resistance and higher hardness than conventional method and even covering D2 tool steel in tribological performance and some areas of hardness.

Prieto et al. [13] evaluated the cryogenic treatment impact on microstructure and mechanical properties of AISI 420 MSS. Experiments demonstrate the precipitation of small carbide favored by cryogenic treatments which also shows homogeneity in size distribution. It is seen that mechanical properties of the material will be based on microstructural feature. Impact of various heat treatment methods was studied by Jahromi et al. [14] on the hardness of AISI 410 MSS to get different martensite microstructures like fine ferrite, fine and coarse ferrite. Results implicate a good conformity and laser surface treatment (LST) is a reliable method to improve hardness of the ferrite, despite martensite phase of coarse and fine structures. Wua et al. [15] did a research of AISI 420 MSS by deep plasma nitriding and rapid methods. It reveals that these methods improve the hardness of nitride layers, soften the profiles of microhardness and improve the wear resistance of specimen. Machining studies have been conducted by Kumar et al. [16] on hardened MSS (HRC 60) for analyzing the impact of tool life on wear of alumina ceramic cutting tools. Wears like flank, crater and notch are estimated and find that rate of wear is small for ceramic cutting tool. An investigation done by Isfahany et al. [17] regarding the impact on corrosion nature and mechanical properties of AISI 420 MSS by heat treatment. Experimental results showed that through optimized heat treatment, properties of AISI 420 MSS can be improved considerably.

It is confirmed from literature review that large number of studies was presented on turning operation of MSS. But for milling operation of MSS limited studies were presented. So in this study an initiative was made for optimizing the machining parameters in milling operation of AISI 410 and AISI 420 grade MSS by employing Taguchi approach.

2. Experimentation

2.1. Selection of work material

Materials selected for work are MSS grades AISI 420 and AISI 410. Table 1 shows chemical composition and Table 2 Mechanical properties of specimens.

Table 1. Chemical composition of MSS AISI 410 and AISI 420.

Alloy	Cr	Ni	C	Mn	Si	Mo	P	Fe
AISI 410	11.94	0.519	0.13	0.81	0.36	0.24	0.024	Balance
AISI 420	12.34	0.271	0.20	0.74	0.56	0.21	0.027	Balance

Table 2. Annealed mechanical properties of MSS AISI 410 and AISI 420.

	Tensile Strength (MPa)	Yield Strength (MPa)	Elongation %	Hardness (HRC)
AISI 410	510	290	34	38-45
AISI 420	586	310	29	53-57

Specimen dimension for work is of length 100 mm, width 80 mm and thickness 50 mm. The chemical composition tests for both the specimens were carried out at Metal test point, Coimbatore, Tamil Nadu India. The work piece materials were purchased at Jai Sree steels, Coimbatore, Tamil Nadu, India. The annealed mechanical properties are provided by the material suppliers.

2.2. Milling tests

CNC milling was done by BMV 40 T20 machine. The spindle motor is having 10 kW power rating and 60 to 6000 rpm speed range. TE90AP 216-16-09-L (Tagutec made) cutter with diameter 20 mm is used for experiment. Tungsten carbide inserts with TiCN coating is having specification APKT 09T308R-EM (Tagutec made). Force of cutting was measured with the aid of Kistler dynamometer (model 9257B). Surface roughness is tested with Mitutoyo (SJ210) surface roughness tester and temperature by Amprobe infrared thermometer (Model IR-750). CNC milling (dry type) operation was done for experiment. Experiment was done at Karunya Institute of Technology and Sciences, Coimbatore research centre. The setup of experiment and surface roughness measurement is shown in Figs. 1 and 2, respectively.

Dry machining eliminates the harmful effects of cutting fluid in the operator's health. It improves the environmental conditions of the workplace which leads to cleaner production and green manufacturing. It also eliminates the coolant and disposal costs. In order to eliminate the influence of tool wear during machining, for each and every trial a new insert was used.

Fig. 1. CNC milling.

Fig. 2. Surface roughness measurement.

2.3. Cutting parameter selection

Parameters of machining selected are spindle speed with a range 1000 to 2000 rpm, feed ranges from 30 to 90 mm/min and depth of cut with a range 0.3 to 0.6 mm. Three levels of Input parameters are used for experiment. Table 3 shows the list of parameters and their corresponding values at each level.

Table 3. Parameters and levels for the experimentation.

Input parameter	Level 1	Level 2	Level 3
Spindle speed (rpm)	1000	1500	2000
Feed (mm/min)	30	60	90
Depth of cut (mm)	0.3	0.6	0.9

2.4. Taguchi method

Taguchi method is a technique which produces an optimized design with the aid of process and product design. Taguchi developed this method mainly to reduce variability of process. The concept of quality loss function is introduced in this method. It can be used for design of parameters. S/N ratio can be done with 3 categories larger-the-better, nominal-the-best and smaller-the-better. Identifying the main function, noise factors, testing conditions, factors of control and levels, objective functions, selecting array (Orthogonal) experiment, conducting experiment (matrix), analysing the data, predicting the optimized levels and their performance.

3. Results and Discussion

The results of experiments done according to L27 OA are shown in the Table 4.

Table 4. Experimental results of 27 run experiment.

Sl.No.	Spindle speed *N* *rpm*	Feed Rate *f* *mm/min*	Depth of cut *d* *mm*	Temp, *T* (^0C)		Surface roughness, *Ra* (μm)		Cutting force, *Fc* (*N*)	
				AISI 410	AISI 420	AISI 410	AISI 420	AISI 410	AISI 420
1	1000	30	0.3	39.8	46.8	0.98	1.07	191.3	232.1
2	1000	30	0.6	48.4	53.4	1.06	1.13	222.7	255.0
3	1000	30	0.9	53.8	58.8	1.21	1.32	271.1	285.3
4	1000	60	0.3	41.6	46.6	1.11	1.18	226.2	244.2
5	1000	60	0.6	49.1	54.1	1.26	1.31	278.9	297.4
6	1000	60	0.9	55.7	60.7	1.35	1.48	332.6	359.5
7	1000	90	0.3	43.4	48.4	1.24	1.27	246.2	273.6
8	1000	90	0.6	52.1	57.1	1.38	1.59	294.2	332.8
9	1000	90	0.9	57.1	62.1	1.52	1.74	375.8	425.9
10	1500	30	0.3	43.8	47.8	0.62	0.66	163.9	204.6
11	1500	30	0.6	50.2	55.1	0.72	0.78	187.5	227.1
12	1500	30	0.9	55.6	60.6	0.81	0.86	228.6	264.7
13	1500	60	0.3	44.6	49.6	0.71	0.76	197.8	224.9
14	1500	60	0.6	51.2	56.2	0.79	0.82	235.4	265.3
15	1500	60	0.9	58.2	63.2	0.88	0.93	289.5	304.1
16	1500	90	0.3	46.1	50	0.78	0.84	231.2	256.3
17	1500	90	0.6	53.6	58.6	0.91	0.96	273.1	319.3
18	1500	90	0.9	61.3	66	1.03	1.12	344.6	396.3
19	2000	30	0.3	47.7	50.7	0.73	0.79	182.4	208.1
20	2000	30	0.6	55.8	60.8	0.81	0.87	201.2	242.3
21	2000	30	0.9	61.3	65.8	0.92	0.97	244.7	282.1
22	2000	60	0.3	49.8	54.8	0.81	0.85	192.6	215.7
23	2000	60	0.6	56.4	61.4	0.89	0.96	214.7	257.1
24	2000	60	0.9	69.9	71.6	1.04	1.15	288.9	312.2
25	2000	90	0.3	53.8	58.8	0.87	0.92	234.4	249.5
26	2000	90	0.6	65.2	70.2	1.24	1.31	279.1	321.7
27	2000	90	0.9	77.7	83	1.43	1.57	345.9	411.3

Results were analysed by Minitab 19 (statistical software) for getting optimum cutting parameters. The deviation of characteristics of quality from desired values was estimated with the aid of S/N ratio in Taguchi method. ANOVA analysis was employed to find the impact of spindle speed, feed and depth of cut on surface roughness, cutting force and temperature.

3.1. Machining parameters impact on Ra

Tables 5 and 6 represent the ratios of S/N response table of Ra for AISI 410 and AISI 420 MSS. Figures 3 and 4 show the main impact of signal to ratio plots of R_a and Tables 7 and 8 represents the ANOVA for R_a of MSS grades AISI 410 and AISI 420 grades respectively.

Table 5. Response table for S/N Ratios of R_a- MSS AISI 410.

Level	Spindle speed	Feed	Depth of cut
1	-1.7600	1.3486	1.3843
2	1.9654	0.3427	0.1503
3	0.4472	-1.0387	-0.8821
Delta	3.7254	2.3873	2.2664
Rank	1	2	3

Table 6. Response table for S/N Ratios of R_a- MSS AISI 420.

Level	Spindle speed	Feed	Depth of cut
1	-2.4627	0.7315	0.8432
2	1.4144	-0.2109	-0.4388
3	-0.1578	-1.7266	-1.6105
Delta	3.8771	2.4580	2.4537
Rank	1	2	3

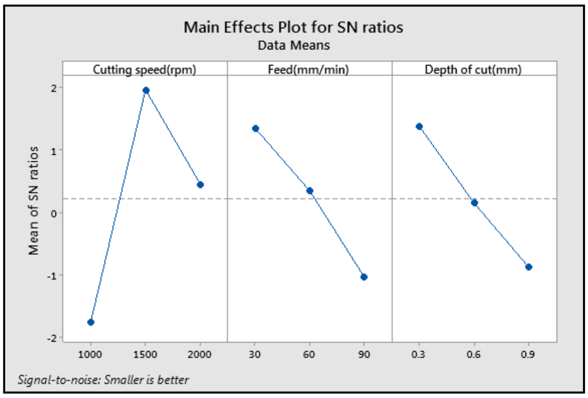

Fig. 3. Main effects plot for S/N ratios of R_a– MSS AISI 410.

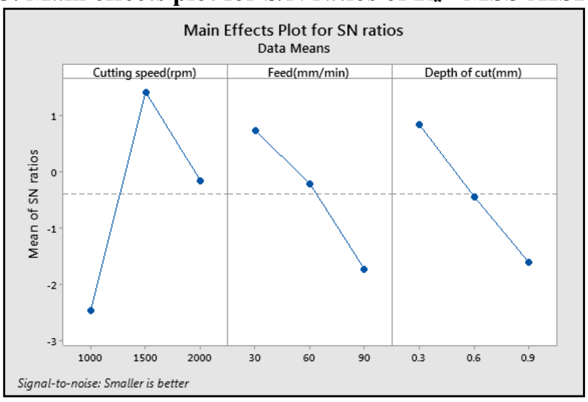

Fig.4. Main effects plot for S/N ratios of R_a- MSS AISI 420.

Table 7. Analysis of variance for R_a – MSS AISI 410.

Source	DF	Seq SS	Adj SS	Adj MS	F Value	Contribution
Spindle Speed	2	0.2137	0.2137	0.1068	140.73	54.12%
Feed	2	0.0860	0.0860	0.0430	56.66	21.79%
Depth of cut	2	0.0799	0.0799	0.0399	52.66	20.25%
Error	20	0.0151	0.0151	0.00075		3.85%
Total	26	0.3950				100.00%

Table 8. Analysis of variance for R_a- MSS AISI 420.

Source	DF	Seq. SS	Adj. SS	Adj. MS	F Value	Contribution
Spindle Speed	2	0.2143	0.2143	0.1071	152.94	53.89%
Feed	2	0.0841	0.0841	0.0420	60.08	21.17%
Depth of cut	2	0.0851	0.0851	0.0425	60.76	21.41%
Error	20	0.0140	0.0140	0.0007		3.52%
Total	26	0.3976				100.00%

Response plot of signal to noise values for R_a of MSS grade AISI 410 and AISI 420 are represented in Figs. 3 and 4. The larger values of ratios of S/N for R_a of grades (MSS) AISI 410 and AISI 420 are obtained at level 2 speed, level 1 feed and level 1 cutting depth. Hence optimal cutting parameters for R_a of AISI 410 and AISI 420 (MSS) grades are speed at 1500 rpm, rate of feed at 30 mm/min and cutting depth at 0.3 mm.

Tables 7 and 8 show output of R_a by ANOVA for grades of MSS AISI 410 and AISI 420. It was seen that values of R_a was affected in the order of spindle speed, feed and depth. ANOVA tables indicate that spindle speed, feed and cutting depth are contributing to the values of R_a of MSS AISI 410 by approximately 54.12%, 21.79% and 20.25% respectively and that of MSS AISI 420 are 53.89%, 21.17% and 21.41% respectively.

3.2. Machining parameters impact on FC

Tables 9 and 10 represents the ratios of S/N response table of F_c. Figures. 5 and 6 represents F_c values main effects plot for signal to noise ratios and Tables 11 and 12 represents the ANOVA for F_c of MSS grades AISI 410 and AISI 420 grades respectively.

Table 9. Response table for S/N Ratios of F_c- MSS AISI 410.

Level	Spindle speed	Feed	Depth of cut
1	-48.49	-46.36	-46.26
2	-47.36	-47.84	-47.61
3	-47.52	-49.17	-49.50
Delta	1.12	2.81	3.24
Rank	3	2	1

Table 10. Response table for S/N Ratios of F_c- MSS AISI 420.

Level	Spindle speed	Feed	Depth of cut
1	-49.41	-47.71	-47.36
2	-48.58	-48.70	-48.86
3	-48.69	-50.26	-50.45
Delta	0.83	2.55	3.09
Rank	3	2	1

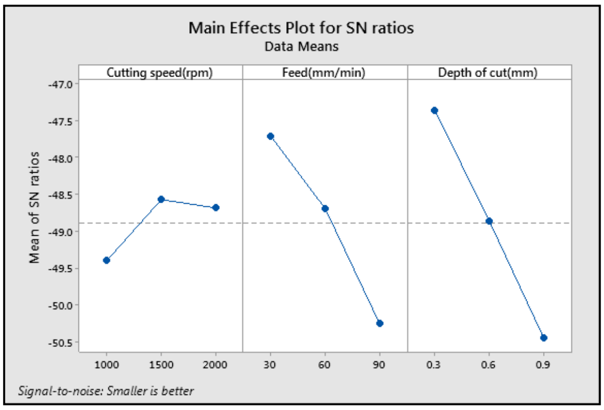

Fig. 5. Main effects plot for S/N ratios of F_c- MSS410.

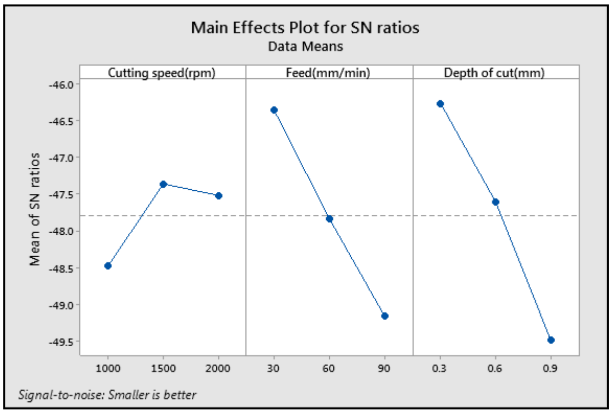

Fig. 6. Main effects plot for S/N ratios for F_c- MSS AISI 420.

Table 11. Analysis of variance for F_c- MSS AISI 410.

Source	DF	Seq SS	Adj SS	Adj MS	F Value	Contribution
Spindle Speed	2	0.0881	0.0881	0.04404	27.05	7.19%
Feed	2	0.4717	0.4717	0.23587	144.84	38.51%
Depth of cut	2	0.6325	0.6325	0.31627	194.21	51.64%
Error	20	0.0326	0.0326	0.0163		2.66%
Total	26	1.2249				100.00%

Table 12. Analysis of variance for F_c- MSS AISI 420.

Source	DF	Seq SS	Adj SS	Adj MS	F Valuee	Contribution
Spindle Speed	2	0.0662	0.0662	0.0331	18.70	5.11%
Feed	2	0.4741	0.4741	0..2371	133.86	36.57%
Depth of cut	2	0.7206	0.7206	0.3603	203.44	55.58%
Error	20	0.0354	0.0354	0.00177		2.73%
Total	26	1.296				100.00%

Grades of MSS AISI 410 and AISI 420 F_c response graph of S/N are shown in Figs. 5 and 6, the larger values of ratios of S/N for F_c of grades (MSS) AISI 410 and AISI 420 are obtained at level 2 speed, level 1 feed and level 1cutting depth. Hence optimal cutting parameters for F_c of AISI 410 and AISI 420 (MSS) grades are speed at 1500 rpm, feed at 30 mm/min and cutting depth at 0.3 mm. Tables 11 and 12 show output of F_c by ANOVA for grades of MSS AISI 410 and AISI 420. It was seen that values of F_c most affected by depth of cut followed by feed and spindle speed. ANOVA tables indicate that spindle speed, feed and cutting depth are contributing to the values of F_c of MSS AISI 410 by approximately 7.19%, 38.51% and 51.64% respectively and that of MSS AISI 420 are 5.11%, 36.57% and 55.58% respectively. Spindle speed is least important factor for affecting the values of F_c.

3.3. Machining parameters impact on temperature

Tables 13 and 14 represents the ratios of S/N response table of temperature. Figures. 7 and 8 represents temperature values main effects plot for signal to noise ratios and Tables 15 and 16 represent the ANOVA for both MSS grades AISI 410 and AISI 420 grades respectively for temperature.

Table 13. Response table for S/N Ratios of temperature – MSS AISI 410.

Level	Spindle speed	Feed	Depth of cut
1	-33.74	-34.03	-33.15
2	-34.20	-34.38	-34.54
3	-35.42	-34.95	-35.67
Delta	1.69	0.91	2.52
Rank	2	3	1

Table 14. Response table for S/N Ratios of temperature - MSS AISI 420.

Level	Spindle speed	Feed	Depth of cut
1	-34.64	-34.84	-34.02
2	-34.97	-35.14	-35.32
3	-36.05	-35.68	-36.31
Delta	1.42	0.84	2.29
Rank 2 3 1			

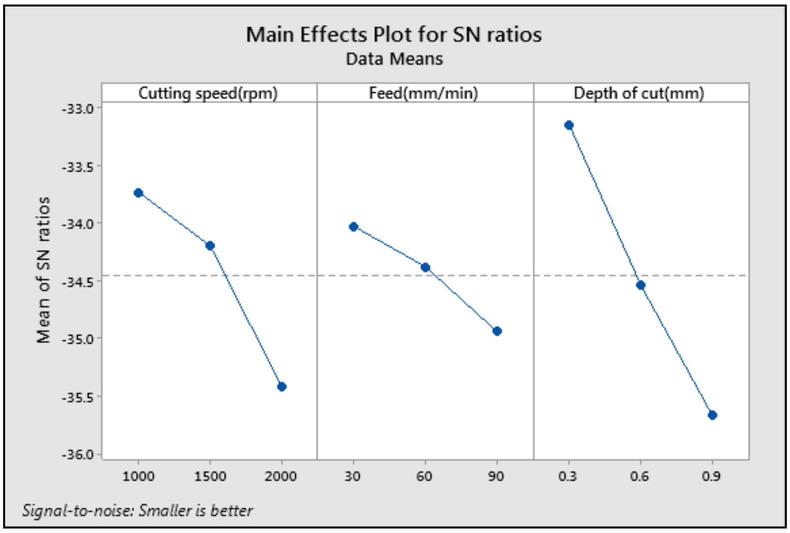

Fig. 7. Main effects plot for S/N ratios of temperature – MSS AISI 410.

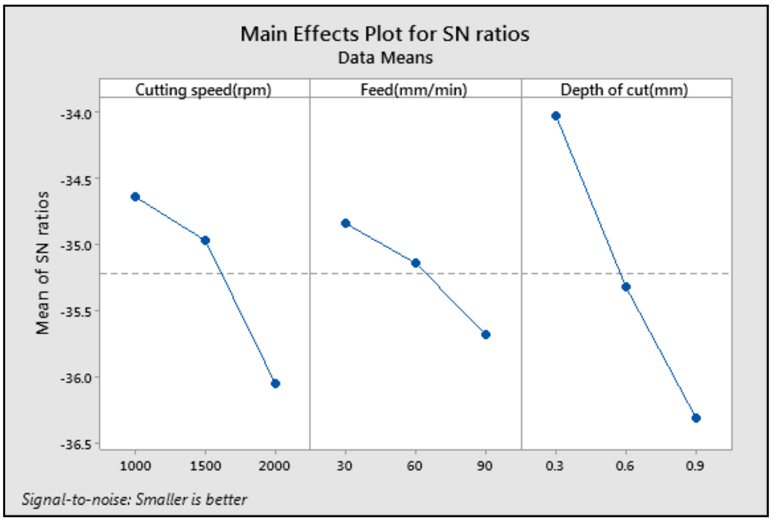

Fig. 8. Main effects plot for S/N ratios of temperature – MSS AISI 420.

Table 15. Analysis of variance for temperature – MSS AISI 410.

Source	DF	Seq. SS	Adj. SS	Adj. MS	F Value	Contribution
Spindle speed	2	0.000061	0.000061	0.000031	130.5	27.60%
Feed	2	0.000016	0.000016	0.000008	35.2	7.45%
Depth of cut	2	0.000139	0.000139	0.000069	297.1	62.84%
Error	20	0.000005	0.000005	0.00000025		2.12%
Total	26	0.000221				100.00%

Table 16. Analysis of variance for temperature - MSS AISI 420.

Source	DF	Seq. SS	Adj. SS	Adj. MS	F Value	Contribution
Spindle speed	2	0.000055	0.000055	0.000025	100.5	23.43%
Feed	2	0.000017	0.000017	0.0000085	30.4	7.10%
Depth of cut	2	0.000157	0.000157	0.000080	287.9	67.14%
Error	20	0.000006	0.000006	0.0000003		2.33%
Total	26	0.000235				100.00%

Grades of MSS AISI 410 and AISI 420 temperature response graph of S/N are shown in Figs. 7 and 8, the larger values of ratios of S/N for temperature of grades (MSS) AISI 410 and AISI 420 are obtained at level 1 speed, level 1 feed and level 1 cutting depth. Hence optimal cutting parameters for temperature of 410 and 420 (MSS) grades are speed at 1000 rpm, feed at 30 mm/min and cutting depth at 0.3 mm. Tables 15 and 16 show output of temperature by ANOVA for grades of MSS AISI 410 and AISI 420. It was seen that values of temperature most affected by depth of cut and next to it speed of spindle and then feed. ANOVA tables indicate that speed of spindle, rate of feed and cutting depth are contributing to the values of temperature of MSS AISI 410 by approximately 27.60%, 7.45% and 62.84% respectively and that of MSS AISI 420 are 23.43%, 7.10% and 67.14% respectively. Feed is least important factor for affecting the values of temperature.

In the present work, lower feed rates (30 to 90 mm/min), lower depth of cuts (0.3 mm to 0.9 mm) and lower spindle speeds (1000 to 2000 rpm) are employed in the end milling operation. So the cutting temperature values obtained are low. Karthik et al. (2019) conducted experiments in face milling operation for AISI 316 grade stainless steel. Higher feed rate (450 mm/min), higher depth of cut (1mm) and higher spindle speeds (1000 to 3000 rpm) were employed in the milling operation. So the cutting temperature values obtained are high.

3.4. Workpiece material impact on R_a and F_c

From Table 4, it is clear that values of R_a and F_c of MSS grade AISI 420 are greater than MSS grade AISI 410. The basic reason is chemical compositions variation in both grades. There is a remarkable variation of Cr and C presence in this case. C and Cr content in MSS grade AISI 420 are 0.201% and 12.34% comparing to 0.13% and 11.94% for MSS grade AISI 410. Stable metal carbides are produced by Chromium percentage increase which increases toughness, hardness, strength, and corrosion resistance. It is well known that carbon content increase distorts the crystal lattice. This distortion causes the same effect of work hardening. Voids present in the metal were entered by carbon and restrict the motion of atoms at lattice site. The result is increasing strength, hardness and decrease in ductility, forgeability and machinability. So for AISI MSS 420 due to the increased strength and hardness due to the raised C and Cr percentage the F_c and R_a values are higher. Both the grades were heat treated before the experiment.

Experimental results show that the optimum values of F_c and R_a values are obtained at spindle speed of 1500 rpm and feed rate of 30 mm/min and depth of cut of 0.3 mm for both MSS grades AISI 410 and AISI 420. For temperature the corresponding values are 1000 rpm, 30 mm/min and 0.3 mm. The results are shown in Tables 17 and 18.

Table 17. Optimized values of cutting parameters for R_a and F_c.

Spindle speed, *N* (rpm)	Feed rate, *f* (mm/min)	Depth of cut *d* (mm)	Surface roughness *Ra* (μm)		Cutting force *Fc* (N)	
			410 MSS	420 MSS	410 MSS	420 MSS
1500	30	0.3	0.62	0.66	163.865	204.63

Table 18. Optimized values of cutting parameters for temperature.

Spindle speed, *N*(rpm)	Feed rate, *f* (mm/min)	Depth of cut, *d* (mm)	Temperature *T* (°C)	
			410 MSS	420MSS
1000	30	0.3	39.8	46.8

4. Conclusions

CNC dry milling was done for optimizing cutting parameters for R_a, F_c and temperature of MSS grades AISI 410 and AISI 420 successfully using Taguchi method. The conclusions are given as below.

- The optimal cutting parameters for R_a and F_c of MSS grades AISI 410 and AISI 420 are spindle speed at 1500 rpm, feed at 30 mm/min and depth of cut at 0.3 mm. The optimum cutting parameters for tool temperature of MSS grades AISI 410 and AISI 420 are spindle speed at1000 rpm, feed at 30 mm/min and depth of cut at 0.3 mm.
- ANOVA result proves that values of R_a of both grades are most contributed by spindle speed followed by feed and cutting depth. ANOVA tables indicate that speed, feed and cutting depth are contributing to the values of R_a of MSS AISI 410 by approximately 54.12%, 21.79% and 20.25% respectively and that of MSS AISI 420 are 53.89%, 21.17% and 21.41% respectively.
- From the ANOVA results of F_c of both grades it was found that values of F_c prominently affected by depth of cut followed by feed and spindle speed. ANOVA tables indicate that spindle speed, feed and cutting depth are contributing to the values of F_c of MSS 410 by approximately 7.19%, 38.51% and 51.64% respectively and that of MSS 420 are 5.11%, 36.57% and 55.58% respectively.
- From the ANOVA results of Temperature of both grades shows values of temperature was most impacted by depth of cut followed by spindle speed and feed. ANOVA tables indicate that spindle speed, feed and cutting depth are contributing to the values of temperature of MSS AISI 410 by approximately 27.60%, 7.45% and 62.84% respectively and that of MSS AISI 420 are 23.43%, 7.10% and 67.14% respectively.
- MSS grade AISI 420 has larger Fc, R_a and temperature values than MSS grade AISI 410 due to difference in composition of chemicals and the raised C and Cr in MSS grade AISI 420.

Nomenclatures	
d	Depth of cut, mm
f	Feed rate, mm/min
F_c	Cutting force, N
N	Spindle speed, rpm
R_a	Surface roughness, μm
T	Temperature, 0C
d	Depth of cut, mm
Abbreviations	
ASS	Austenitic Stainless Steel
BBD	Box-Behnken Design
DSS	Duplex Stainless Steel
HRC	Hardness Rockwell C
LST	Laser Surface Treatment
RSM	Response Surface Methodology
TiCN	Titanium Carbo Nitride

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