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OPTIMIZATION OF TURNING PARAMETERS OF EN24 STEEL ALLOY USING RESPONSE SURFACE METHODOLOGY

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Abstract:

This work mainly focuses on the experimental optimization of cutting parameters primarily based on Surface roughness and material removal rate (MRR) and in this Experiment Central Composite Design is used to enhance surface roughness quality .Exclusive cutting parameters such as Cutting speed, Feed, and depth of cut,were examined by using covered Carbide equipment on CNC machines using EN24 (dry and wet machining) data, product Roughness, cutting quality and material removal rate were determined.After measuring the surface roughness on the Talysurf test device and obtaining the results, the results were analyzed in Minitab 17 software and the roughness of the EN24 (dry and wet processing) product was examined on the surface. The pathways and its contribution to decision-making ultimately indicate that it negatively affects the issue. All tests were carried out in dry and wet conditions; nine samples were produced under dry conditions and nine samples were produced under wet conditions. In this research the fundamental goal investigation of the various process(input) parameters and performed on a CNC turning machine since it is much improved in compression with different machines in context of accuracy and surface finish .The attention on the properties of the materials alongside the cutting condition of cutting tool and work piece has been made.It is found that the optimum results achieved at feed rate of 0.15 mm/rev 0.25 mm dept of cut and 2000 rpm speed.

KEYWORDS: EN24 steel alloy, RSM , Spindle speed, Feed rate, Depth of cut, Taguchi method, ANOVA,

1.INTRODUCTION:

Turning is a machining process where a lathe is used to rotate the metal at the same time as tool actions in a liner movement to removes steel along the diameter developing a cylindrical shape. Turning in machining can be done on various machines such as regular machine tools, special machine tools or CNC machine tools. CNC turning uses a computer to control the movement of the cutting tool. It allows complex parts to be created with high speed and precision. CNC turning is especially useful in making parts with complex radial features or where tight tolerances are required. There are many parameters that affect the turning process.

Understanding these can help improve the process and achieve the desired results. Some important parameters are Cutting Speed , Feed rate , and Depth of Cut. As shown in Fig 1.1

Fig 1.1 Turning of EN24 on CNC machine

Tanveer H. B.. (2014) Reaction surface. In the study of this method, data are cold,. Cutting speed, feed rate and depth of cut this analysis, it was determined that the biggest factor affecting the discomfort was the feed , speed.

S.ARizvi (2015) studied the study to improve the parting limit to achieve better position and different costs during turning using a CNC machine with EN24 steel bars (35 mm dimensions). Create areas such as functional information and synthetic materials. Flue gas deposition (CVD) involves carbide tips as the material. In this study, the boundary information is surface speed, feed velocity and depth of cut

Mohd.Arif. I (2016) has concentrated on a writing survey on different variables influencing turning activity. This paper manages the writing audit of different variables that influence the turning activity. In this paper different cycle boundaries like speed, profundity of cut, feed, nose range, and so forth are considered.

P.B.Patole(2017) Focused on the investigation and facilitation of cutting boundaries with various materials during MQL turning of AISI 4340 using nanofluids. This article turns to a simple method for limit cycling for minimum oil (MQL) return of AISI 4340 using nanofluids using Dim Social Investigation (GRA). Sixty initial surveys were carried out over the entire project network to refine the optimum level for CNC lathes. Research results for different reactions such as surface roughness and processing were analyzed using Dark Social Grade (GRG). The quality parameters obtained by way of GRA include spindle velocity (seventy five m/min), feed price (0.04 mm/hearth), and cutting depth (0.5 mm)

M. Mashrat (2018) Using the help vector regression strategy to build predictive models and the strategy of using genetics to create streamlined models, learned that state roughness boundaries (Ra) are concentrated nearby. Control measures to achieve these goals are spindle speed, feed and cutting depth, A.D. Pathak, R.S. Wargaan (S.U.) Deokar (2018) Controlling the development of machining parameters such as speed, feed, depth of cut and tool tip length in dry turning of AISI A2 material steel using tungsten carbide inserts.

Ibrahim et al , 2019 Box-Behnken's standard coating process was used to turn magnesium alloy material, and the nice running circumstance turned into carried out with a cutting speed of eighty mm/min, a feed price of 0.10 mm/fireplace and a drilling pace of forty five.7071. rpm. UA 31. Turning is done on the lower cutting edge; the lower part caused the tool to wear out and the tool reached the desired value of 0.27728 mm. Use of Compressed Air to Reduce the Temperature of the Work piece and Rotating Tools

Atlanta's et al., (2020) examined the surface roughness and wear trademark in miniature turning of compound Ti-6Ai-4V material, where they got a decent surface completing in miniature turning process utilizing the optimal cutting boundaries and multi objective advancement of miniature turning process through the utilization of reaction surface.

Lam Khanah and van Cuong, 2021 Studied the most useful input parameters for Turning En24 steel alloy. The objective was to research the impact of input factors on the surface roughness and MRR in the course of turning mnner. The analysis of the consequences decided the impact of input parameters on the surface roughness and elimination fee (MRR). But this research used SR for optimizing the input parameters.

Vikas and Marakini (2022) Analyzed the impact of face milling processes at the surface homes of AZ91 magnisium alloy using uncoated carbide inserts. The studies additionally explored cloth behaviour. In addition, a time area evaluation is performed to establish correlation between the machining vibration singles and floor integrity characteristics. This examine inves tigates the device behaviour in surface end.

Silveira et al. (2023) Analyzeed the floor integrity of annealed AISI H 13 steel regarding the effect of face milling parameters and tool grade. This take a look at located that the milling pressure components were in the main stimulated via the depth of reduce and feed in line with parameters. The EN24 steel with wc coated inserts is used on this reseasrch .

Chen et al., 2024): The focus of discourse is to the enhancement of machinability through the utilisation of coated inserts.Utilising tungsten carbide (WC)-coated inserts in the process of machining EN 24 steel is a strategic decision. WC-Coated inserts are chosen based on their exceptional hardness and resistance to wear.

2 EXPERIMENTATION:

Research objectives:

(a) To determine the amount of material to be removed and the Roughness of the Sample surface called Response Surface Methodology
(b) Material, Tool and Turning Parameters

2.1 Material:

Table 2.1 Chemical composition of EN24

COMPOUND	PERCENTAGE %
Carbon	.411
Silicon	.222
Manganese	.640
Phosphorus	.029
Sulphur	.033
Chromium	1.05
Molybdenum	.204
Nickle	1.36
Aluminum	.008

Boron	.0008
Cobalt	.009
Copper	.084
Lead	.000
Titanium	.004
Vanadium	.014
Tungsten	.000

2.2 Cutting Tool:

Carbide cutting devices, also known as established carbide cutting instruments or tungsten carbide cutting devices are a significant component of CNC machining. It offer high hardness, strength, and wear resistance. This trial uses solidified carbide and coated cutting bits for turning 18 work pieces.

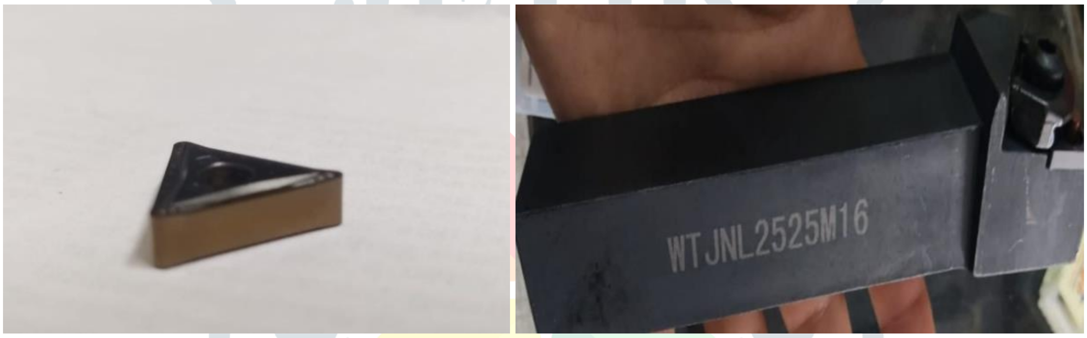

Fig. 2.1 carbide tool tip and cutting tool of CNC machine.

2.3 Trial and Final Run

The carbide cutting tool is used to complete the Trial**.** At low speed material removal rate is obtained very less as different trails are done and after that with the increase in speed as well as depth of cut, the material removal rate is achieved optimal

Table 4.3: Machining parameters and levels

S.No.	Parameters	Units	L1	L2	L3
1	Cutting speed	m/min	1500	1700	2000
2	Feed	mm/rev	0.05	0.1	0.15
3	Depth of cut	mm	0.25	0.4	0.6

3. Experimental Setup

Turning is a machining process where a lathe is used to rotate the metal at the same time as tool actions in a liner movement to removes steel along the diameter developing a cylindrical shape. Turning in machining can be done on various machines such as regular machine tools, special machine tools or CNC machine tools.

CNC turning uses a computer to control the movement of the cutting tool The sample size which is used in this Experiment was 42mm Diameter and 80mm Length.The experimental equipment is depicted in Fig 3.1. The levels of each process parameter/factor are shown in Table 5.1

Fig. 3.1 Pictorial view of CNC machine on which experiment is done

3.1 TURNED WORKPIECES

After machining of all Eighteen work pieces, Nine work pieces on dry machining and Nine work pieces on wet machining were collect the specimens and they are shown in fig 3.2 &3.3 below. Fig 3.2 indicates dry machining turned work pieces and Fig 3.3 indicates wet turned work pieces. The turned work pieces are now used to check the rate of material to be removed and weight loss. Measurement taken by using scale and the dimensions of length of work pieces is 50mm

Fig 3.2. Dry machining turned work pieces

Fig.3.3 Wet machining turned work pieces

4. Analysis Testing

4.1 SURFACE ROUGHNESS MEASUREMENT:

surface Roughness meter (stylus type surface roughness meter to measure the roughness of the sample. There are two main reasons for choosing this surface roughness meter, one is that it is Easy to obtain and the other is that it is Easy to use. The Surface Roughness meter used in this experiment is Talysurf.

Fig 4.1 Surface Roughness test

5. Results and Discussions:

5.1 Optimization of surface roughness:

Table 5.1 depicts the response surface roughness showing SN versus the individual level of each parameter. Figure 5.2 also shows the SN ratio at different levels.

Table 5.1: Roughness, signal-to-noise ratio, response table

LOWER IS BETTER			
POSITION	**SPINDLE SPEED**	**FEED**	**DEPTH OF CUT**
01	-4.884	-5.046	-6.169
02	-4.095	-5.355	-5.335
03	-6.238	-4.861	-3.759
Delta	2.188	0.494	2.410
Rank	2	3	1

Table 5.1 describes the average value obtained by the Minitab software. This clearly shows that spindle speed, is the most important factor in acquiring the optimal surface as compared to the Two Factors Feed and Depth of cut.

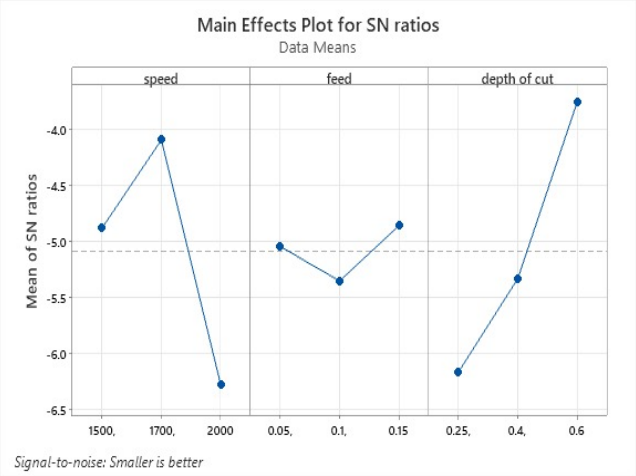

Fig.5.1 plot for surface roughness for dry Machining

According to the main results of the roughness map, the level with the highest signal-to-noise ratio from each parameter is selected as the best value of the parameter to minimize the Surface Roughness.

Table 5.2: Optimum values of parameters to reduce roughness

SPECIFICATION	CUTTING SPEED	FEED	DEPTH OF CUT
Unit	Rpm	mm/rev	Mm
POSITION	S2	F1	D3
QUANTITY	1700	0.05	o.6

The delta value and the order in the response display that amongst all parameters, spindle speed has the highest impact at the roughness of the turned work piece, accompanied via feed rate and spindle speed.

5.2 Optimization of MRR

Table 5.3: Signal-to-noise ratio response of MRR

LARGER IS BETTER			
POSITION	**CUTTING SPEED**	**FEED**	**DEPTH OF CUT**
1	1.847	1.889	2.178
2	1.640	1.947	1.951
3	2.216	1.866	1.573
Delta	0.576	0.082	0.604
Rank	2	3	1

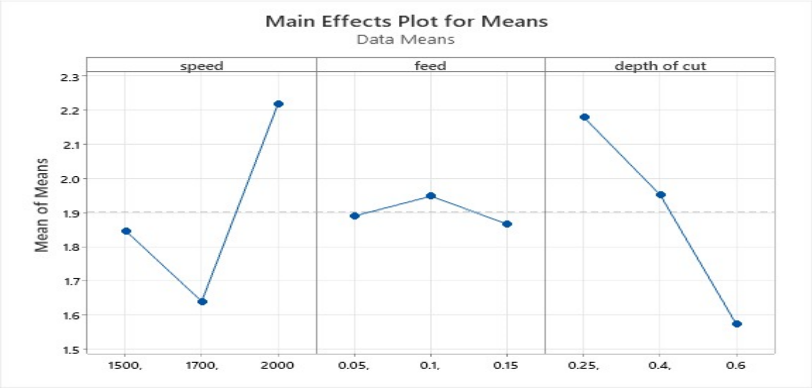

Figure 5.2: Main Representation of MRR signal-to-noise ratio

The Delta value and ranking in the response show that among all parameters, spindle speed has the largest impact on the roughness of turning the work piece, followed by feed rate and spindle speed.

Table 5.4: Best measures to increase MRR

SPECIFICATION	CUTTING SPEED	FEED	DEPTH OF CUT
UNIT	Rpm	mm/rev	mm
POSITION	S3	F2	D3
QUANTITY	2000	0.1	0.6

Response Surface Methodology (RSM):

The method used in this project called Response Surface Methodology (RSM), which is a statistical and numerical method for Statistical Analysis .Planning, interaction improvement, and product development. It is crucial in modern and manufacturing industries, where product quality and display standards are crucial. RSM aims to find the optimal response; identifying compromised ideals for specific Statistical Analysis. It's used for to research the relationship among response variables and capability variables, which include Surface Roughness regression in Minitab-17 software for Dry Machining of EN24 steel. Table 5.5: Estimated Regression for surface Roughness on the specimen for Dry Machining

Table 5.5: Surface Roughness obtained on Dry Machining of EN24

StdOrder	Run Order	P Type	Blocks	Speed	Feed	Depth of cut	SR
10	1	0	1	1500	0.05	0.250	2.661
11	2	0	1	1500	0.10	0.400	1.234
4	3	1	1	1500	0.15	0.600	1.645
3	4	1	1	1700	0.10	0.250	1.840
12	5	0	1	1700	0.15	0.400	1.908
7	6	1	1	1700	0.05	0.600	1.172
2	7	1	1	2000	0.15	0.255	1.167
5	8	1	1	2000	0.05	0.400	2.700
6	9	1	1	2000	0.10	0.600	2.790

Table 5.6 : Surface Roughness obtained on Wet Machining of EN24

StdOrder	RunOrder	PtType	Blocks	Speed	Feed	Depth of cut	SR

10	1	0	1	1500	0.05	0.250	1.501
11	2	0	1	1500	0.10	0.400	1.101
4	3	1	1	1500	0.15	0.600	1.098
3	4	1	1	1700	0.10	0.250	1.175
12	5	0	1	1700	0.15	0.400	1.382
7	6	1	1	1700	0.05	0.600	1.305
2	7	1	1	2000	0.15	0.255	0.999
5	8	1	1	2000	0.05	0.400	0.966
6	9	1	1	2000	0.10	0.600	0.561

Table 5.7: SR change analysis of dry processed samples

Terms	**Coeff**	**SE- coef**	**T- value**	**P- Value**	**VIF**
Constant v	1.925	0.425	4.53	0.046	---
Speed	0.656	0.368	1.78	0.049	1.39
Feed	0.215	0.368	0.58	0.007	1.50
Depth of cut	-0.064	0.368	-0.18	0.025	1.39
Speed*Speed	0.204	0.563	0.36	0.003	1.17
Speed*Speed	-0.089	0.368	-0.24	0.004	1.50
Feed*DOC	-0.067	0.368	-0.18	0.017	2.50

Table 5.8: ANOVA for SR on the specimens for Dry Machining

Source	**DOF**	**Adj SS**	**Adj MS**	**F-value**	**P-value**
Model	6	2.48770	0.41462	0.76	0.031
Linear	3	2.27655	0.75885	1.40	0.013
SPEED	1	1.72134	1.72134	3.17	0.017
FEED	1	0.18490	0.18490	0.34	0.018
DEPTH OF CUT	1	0.01664	0.01664	0.03	0.005
Square	1	0.07158	0.07158	0.13	0.010
SPEED*SPEED	1	0.07158	0.07158	0.13	0.059
2-way interaction	2	0.09734	0.04867	0.09	0.010
CUTTIN SPEED*FEED	1	0.03133	0.03133	0.06	0.033
FEED*DOC	1	0.01796	0.01796	0.03	0.057
Error	2	1.08533	0.54267		
Total	8	3.57303			

Here DOF stands for Degree of Freedom ; It is a measure of the information provided by your Data so as to calculate unknown variables.Here Seq SS represents the Sequential sum of square and Adj SS represents the adjusted sum of Square and Adj MS represents the adjusted mean square . F represents the f value , which is the ratio of the mean square. P represents the p value, indicating that the results obtained are significant.

Regression equation in encoded units

SR= 5.5 -0.0081 SPEED + 19.9 FEED + 0.40 DEPTH OF CUT + 0.000003 SPEED*SPEED-0.0071 SPEED*FEED – 7.7 FEED*DEPTH OF CUT

Table 5.9. CODED COFFICIENTS (WET MACHINING)

Terms	**Coef SE**	**Coef**	**T-value**	**P-value**	**VIF**
Constant	1.500	0.234	6.42	0.058	1.3
SPEED	-0.1481	0.0826	1.79	0.059	1.1
FEED	0.0716	0.0826	0.87	0.006	1.3
DEPTH OF CUT	0.0324	0.0826	0.39	0.035	1.2
SPEED*SPEED	-0.427	0.248	-1.72	0.003	1.3
SPEED*FEED	0.0904	0.0826	1.09	0.056	1.1
SPEED*DEPTH OF CUT	-0.0899	0.0826	-1.09	0.035	1.5
FEED*DEPTH OPF CUT	0.0629	0.0826	0.76	0.026	1.4

Table 5.10. ANOVA FOR WET MACHINING

Source	**DOF**	**Adj SS**	**Adj MS**	**F-value**	**P-value**
Model	7	0.548517	0.078360	1.43	0.013
Liner	3	0.224954	0.074985	1.37	0.044
SPEED	1	0.175528	0.175528	3.21	0.049
FEED	1	0.041041	0.041041	0.75	0.045
DEPTH OF CUT	1	0.008385	0.008385	0.15	0.049
Square	1	0.161975	0.161975	2.97	0.037
SPEED*SPEED	1	0.161975	0.161975	2.97	0.035
2-MANNER INTERACTION	3	0.161587	0.053862	0.99	0.012
SIPNDLE SPEED*SPEED	1	0.065341	0.065341	1.20	0.048
SPEED* DOC	1	0.064620	0.064620	1.18	0.043
FEED*DOC	1	0.031626	0.031626	0.58	0.049
Error	1	0.054615	0.054615		

Total	8	0.603132			

Regression equation in encoded units

SR= -18.6+0.0235 SPEED -14.3 FEED + 3.06 DEPTH OF CUT - 0.000007 SPEED*SPEED

+ 0.00723 SPEED *SPEED - 0.00205 SPEED*DOC + 7.19 FEED*DEPTH OF CUT

Main interaction Plot for CUTTING SPEED, FEED RATE, and DEPTH OF CUT

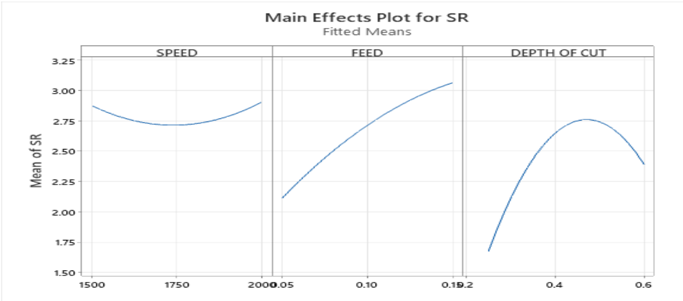

Fig. 5.3 primary information on Cutting speed, Feed and Depth of cut.

The effects show that when the speed increases, the roughness first decreases after which increases. As the feed Rate increases, the surface roughness decreases. It decreases as the intensity of cut increases after which step by step increases at certain points.

Counter Graph of SR verse FEED, SPEED

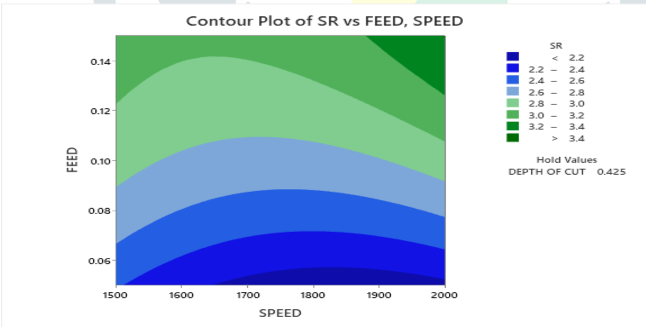

Figure 5.4. Comparison of SR with Spindle Speed, Feed rate, and Depth of cut :

Plot Graph of SR with feed rate and speed

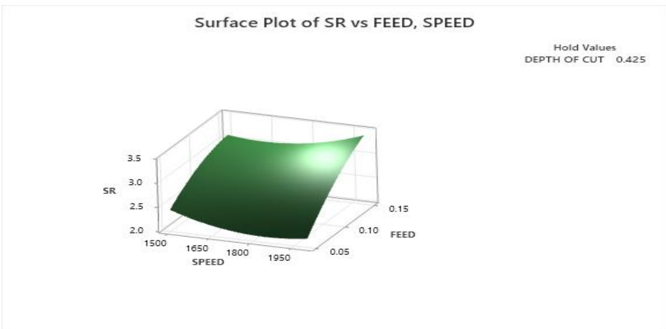

Figure 5.5. Famous plot of SR versus Speed, Feed rate and Dept of cut

Counter graph of SR

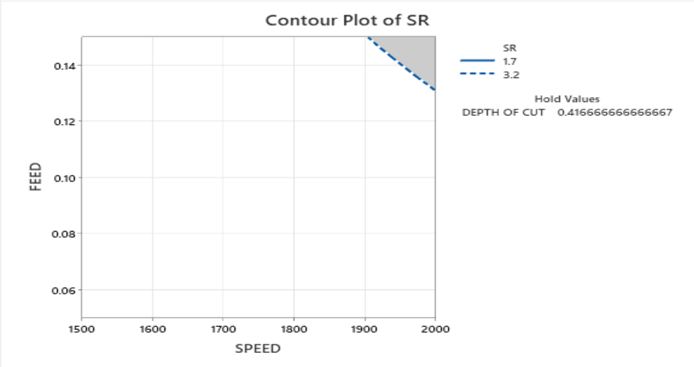

Fig. 5.6 Counter graph of SR

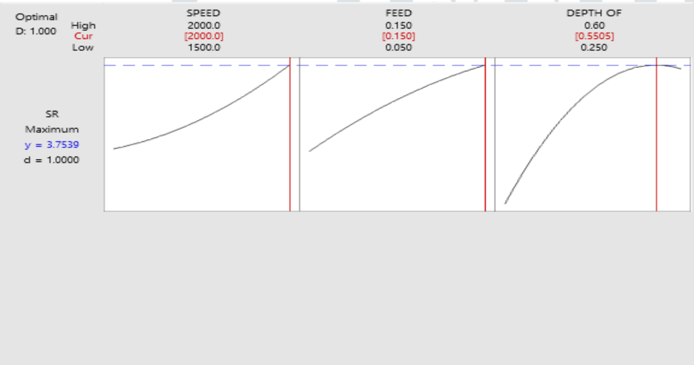

Figure 5.7 . Graph of Cutting Speed, Feed, Dept of Cut and SR.

Now same procedure is done on Minitab-17 Software for Wet Machining of EN24 and following data is obtained from the Minitab-17 Statistical Software and the Data is given below

Main displays of spindle speed, feed rate and Depth of cut

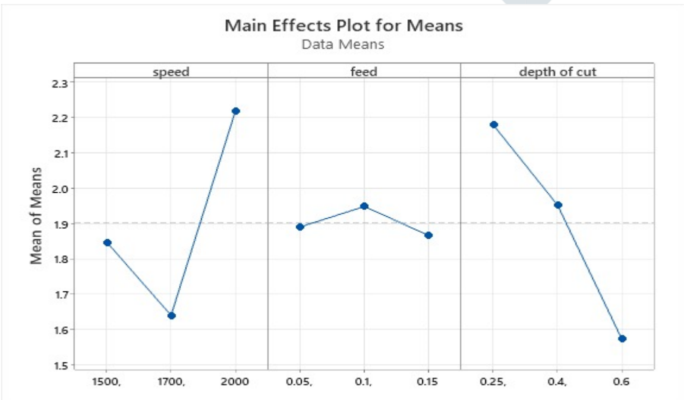

Fig 5.8 : Main interaction plot means for Speed, Feed, Depth of cut

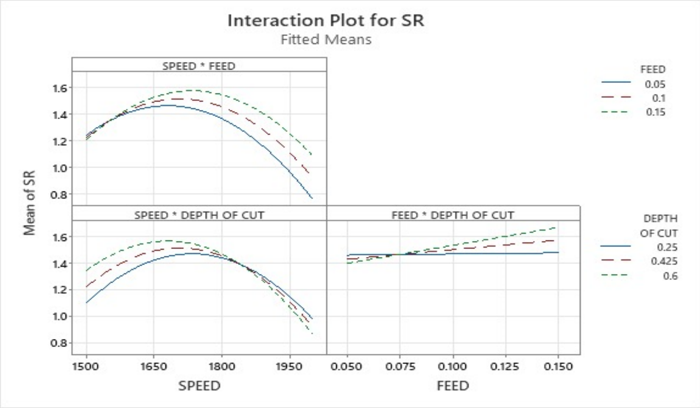

Fig 5.9 : Interaction graph of surface Roughness

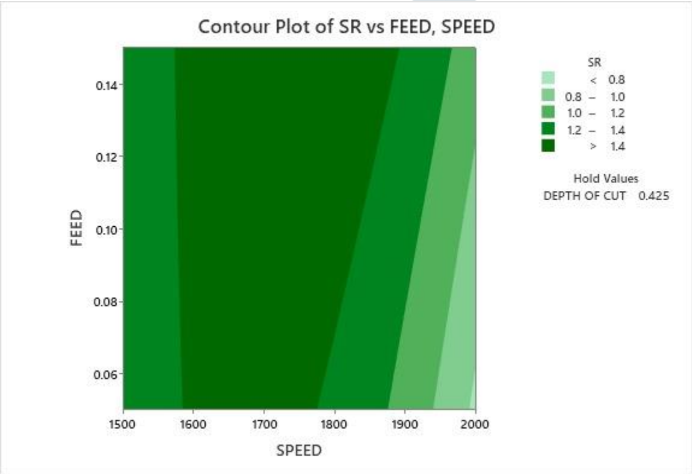

Fig 5.10 : Counter Graph for Cutting Speed. Feed and Depth of cut

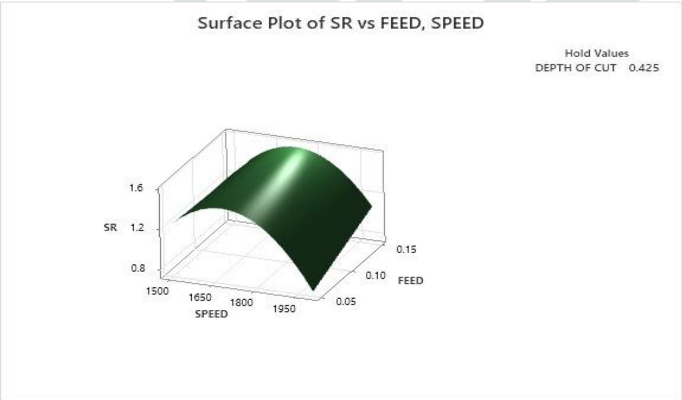

Fig 5.11 : Surface Roughness Graph for Speed, Feed and Depth of Cut

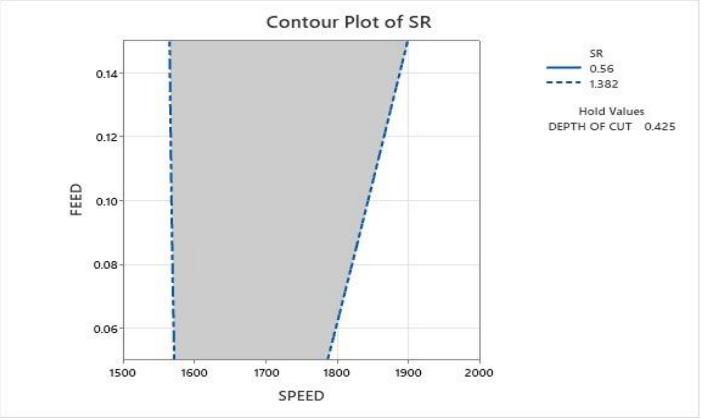

Fig 5.12. Counter Graph of SR

Fig 5.13 : Graph of Cutting Speed, Feed and Depth of Cut

6. Conclusion:

This manuscript is mainly focused on optimization of surface roughness (SR) and combination of different parameters that will produce better Surface Roughness under different conditions. Response Surface Modelling(RSM) is used for modelling of CNC Turning parameters in the Machining of EN24 steel alloy. In this research L18 orthogonal array is used, Nine workpieces for Dry Machining and Nine Workpieces For wet Machining. The results indicates that the model are effective in protecting multiple response in the turning compound

Based on results, Following conclusions are drawn:

- At Dry Machining of EN24, It has been found that Minimum surface Roughness is achieved at S1=1500 (S1=speed of rotation) , F1=0.15(F1=Feed rate) and D1=0.6 (D1=Depth of Cut) and Maximum surface Roughness is achieved at S2=1700, F2= 0.05 and D2= 0.6
- At Wet Machining of EN24, Minimum surface Roughness is achieved at S3=2000, F3=0.1 and D3=0.6 and Maximum surface Roughness is achieved at S1=1500, F1=0.05 and D3=0.25
- Material Removal Rate at Dry Machining: Maximum material removsal rate is achieved at S3 , F2 and D3 and Minimum Material Removal Rate is achieved at S3, F3 and D1
- Material removal Rate at Wet Machining : Maximum MRR is achieved at S1, F3 and D1 and Minimum MRR is achieved at S3, F1 and D2

From the above points it is found that material Removal rate increases as the spindle speed(S) increasses and Depth of cut (D) increases and vice versa

7. **Future Scope:**

- The following functions may be used in future work. The research can be extended to different mechanical devices using other variables, different tools and functional materials.
- In this study, RSM is used for optimization, but in the future, we can also use other statistical methods such as Taguchi, BDS, and FBD, which can be used for optimization. check out the impact of reducing fluid and geometry on surface roughness and metallic removal rate
- This study can be extended to consider many variables such as chip tool interface temperature, machining time, tool wear, different coolants, corner radius and tool geometry, among others.
- Studies can be based on optimizing various machining parameters for specific composite materials

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