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EXPERIMENTAL ANALYSIS OF TURNING OPERATION USING COATED TOOL AND AISI 1020 STEEL

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ABSTRACT

Due to their exceptional characteristics, AISI 1020 tool steel are suitable for die and mould making applications. Due to their high hardness and low elastic modulus, which result in significant cutting forces and tool wear, these alloys are challenging to process. In turning AISI 1020 steel with coated and uncoated carbide inserts, this paper describes an optimization strategy for surface roughness and cutting force using Taguchi design of experiment. Cutting velocity, feed, and depth of cut, three turning process controllable parameters, were each examined at four levels. The trials were carried out using an L_{16} Orthogonal array. Using Taguchi's parameter design, the best parameter settings to reduce cutting force and surface roughness have been discovered. The outcomes of the experiments show that the ideal factor settings for every response. Therefore. All of the performance factors are taken into account simultaneously when optimizing the process parameters. The most significant turning parameters were determined using the analysis of variance techniques.

Keywords: Aisi 1020 Steel; Cutting Force; Dynamometer; Orthogonal Array; Surface Roughness; Taguchi Design.

I. INTRODUCTION

The Due to high demand of tool steel material in mould making and die making industries and their practical application required to make lathe machine in turning operation. AISI 1020 tool steel is a low carbon steel that is commonly used in a variety of applications. When machining AISI 1020 tool steel on a lathe, there are a few important things to keep in mind [1]. it is important to use the appropriate cutting speed, feed rate, and depth of cut for the specific operation being performed. Various tool material is used for machining and carbide tool insert is used with coated and uncoated tool [2].

It is not a novel idea to use coating materials to improve the performance of cutting instruments. Since its introduction in 1969, coated hard metals have significantly increased productivity, which has had a direct impact on the metal cutting sectors. [3]. Carbide-cutting tools are utilised more frequently than high-speed steel ones in the production sector today because of their noticeably higher toughness. The ideal alternative for the majority of turning operations can be found in coated and uncoated carbides, which are widely utilised in the metalworking sector. [4]. Cemented carbides can be employed in extremely hot applications due to their heat endurance, and any sort of PVD and CVD technique can be used to deposit coatings on them [5]. Important coating features including wear resistance, abrasion resistance, and adhesion strength are determined by the combined substrate-coating properties. A hard and tough substrate is necessary to complement a hardwear resistant coating's performance [6]. As a result, a hard coating that is applied on a soft substrate has inadequate properties. [7]. Vapour-deposited coatings that are both physically and chemically deposited provide a strong option today for enhancing the cutting performance of cutting materials.

The majority of cutting instruments in use today have hard coatings created by chemical or physical vapour deposition. [8]. These coatings' high hardness, wear resistance, and chemical stability have been shown to improve tool life and machining efficiency. [9].

Nearly all of the products used in modern society are made either directly or indirectly using the metal cutting process, which is the foundation of the engineering sector. [10], [11]. In order to maximise the effectiveness of any metal cutting process, the cutting tool is one of the crucial components. [12].

In above the literature, we can find that various type of tool material is used for turning operation in lathe machine [13]. And combination of tool insert is used for coating and without coating for machining operation [14]. The goal of the current study is to determine the ideal machining parameter setting for a better surface finish and the minimum force is required for machining. So that this paper studies the with and without Tin

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coated insert as a tool material used in lathe machines with AISI 1020 tool steel as a workpiece. And find the optimum setting of machining parameters with responses are cutting force and surface roughness.

II. EXPERIMENTATION AND METHOD

The current project focuses on turning hard materials like AISI 1020 steel. It is a crucial technical component used in the production of parts for the automotive and aerospace industries. High speed dry machining, which is currently popular in the industrial sector, was used to assess how coated tools performed in common manufacturing procedures.

The experimental work was divided into two groups: the first group, machining of AISI 1020 steel was carried out with uncoated tools and in the second group, machining of same workpiece with the TiN coated carbide tool was carried out. This presents work used multiple responses (surface roughness and cutting force) in turning using Taguchi design of experiment. In both cases, continuous dry turning tests were performed. Solid bars of AISI 1020 steel with 37mm diameter, 160mm long and of 45 HRC were used as workpiece and coated and uncoated tool are shown in Fig.1. The photographic view of the experimental setup is shown in Fig. 2

Figure :1 Workpiece and tool (Coated and Uncoated

Figure :2 Tool workpiece setup

Four different cutting speeds, feed rates, and depths of cut were used in the turning trials. Three controllable factors of the turning process were studied at four levels each. Machining parameter with their different ranges are presented in Table 1. Taguchi design of experiment for L16 Orthogonal array was used for conducting the experiments. Experiment data for surface roughness, and cutting force with coated and uncoated value are represented in Table 2.

Table 1: Machining Parameters and their levels

Machining parameter	Symbol	Unit	Levels			
			Level 1	Level 2	Level 3	Level 4
Speed	(V)	RPM	82	105	130	160
Feed	(f)	mm/rev	0.06	0.09	0.125	0.180
Depth of cut	(d)	mm	0.20	0.30	0.40	0.50

Table 2: Experimental data for surface roughness, and cutting force (With Coated and Uncoated tool)

Sr. No.	Speed (RPM)	Feed (mm/rev)	Depth of Cut (mm)	Surface Roughness		Force (Fx, Fy and Fz)					
				Coated	Uncoated	Coated			Uncoated		
				Ra (μm)	Ra (μm)	Fx (N)	Fy (N)	Fz (N)	Fx (N)	Fy (N)	Fz (N)
1	82	0.060	0.2	1.50	1.75	66.22	71.39	76.22	86.22	89.22	95.89
2	82	0.090	0.3	1.94	2.03	67.89	72.85	77.89	87.89	90.89	96.79
3	82	0.125	0.4	2.24	2.43	85.69	90.79	95.69	105.56	108.69	114.35

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4	82	0.180	0.5	2.44	2.57	108.36	105.56	100.36	128.26	131.36	137.36
5	105	0.060	0.3	1.41	1.46	96.38	101.23	106.38	116.38	119.38	125.38
6	105	0.090	0.2	1.82	1.93	100.56	105.26	110.56	120.53	123.56	129.23
7	105	0.125	0.5	1.93	2.05	105.30	110.52	115.30	125.21	128.31	134.3
8	105	0.180	0.4	2.21	2.31	105.36	110.56	115.36	125.26	128.36	134.87
9	130	0.060	0.4	1.37	1.43	130.36	135.36	140.52	150.89	153.36	159.82
10	130	0.090	0.5	1.72	1.81	165.36	170.36	175.89	185.95	188.36	194.46
11	130	0.125	0.2	1.81	1.93	166.36	171.58	176.36	186.36	189.36	195.52
12	130	0.180	0.3	2.10	2.20	170.36	165.36	153.56	190.36	193.36	199.53
13	160	0.060	0.5	1.22	1.28	130.36	135.26	140.41	150.36	153.36	159.78
14	160	0.090	0.4	1.60	1.65	150.36	155.24	160.62	170.86	173.36	179.24
15	160	0.125	0.3	1.72	1.80	170.30	175.78	180.20	190.56	193.30	199.45
16	160	0.180	0.2	2.06	2.16	185.36	190.92	195.78	205.26	208.36	214.46

III. MODELING FLOW CHART OF EXPERIMENT

All the step-by-step experiment procedures are described in the flow chat. In this flow chat given input parameters are workpiece and tool material, second step given the experimentation in this experimentation is shown machining parameters. The next step is the experiment technique chosen as Taguchi design of experiment after those responses are calculated such as force and surface roughness.

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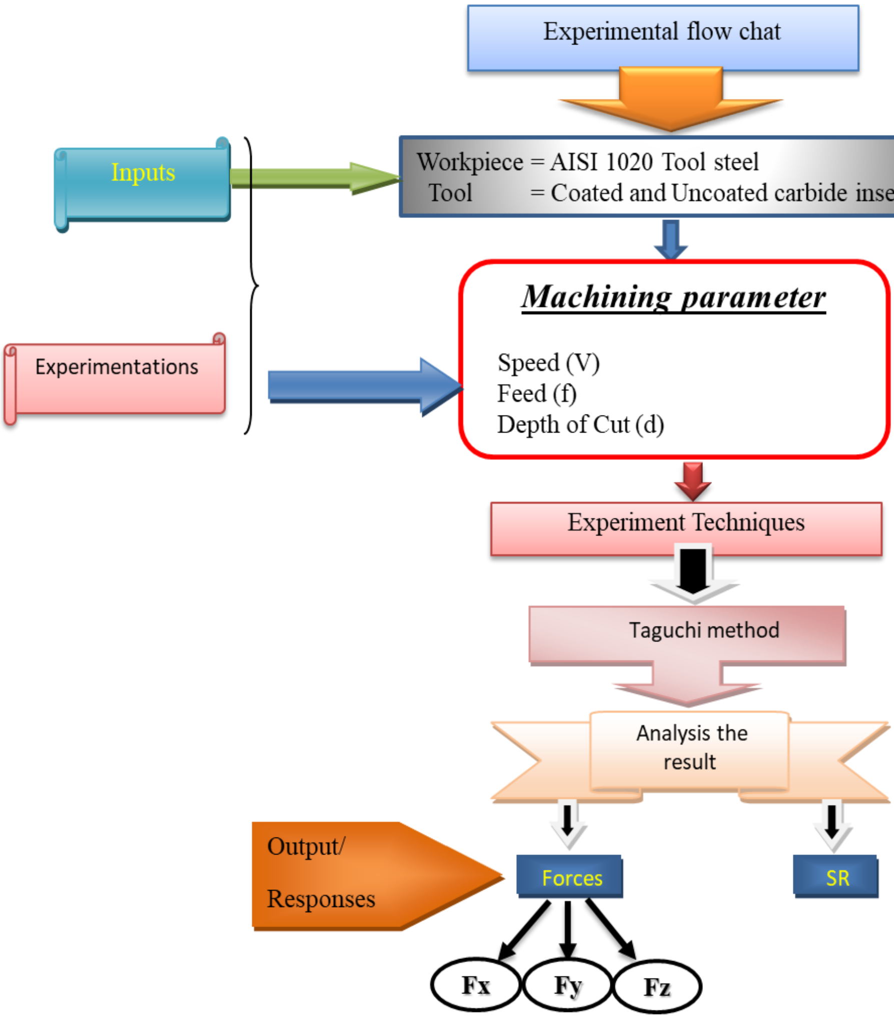

Figure 3 Experiment flow chat

IV. FORCE MEASUREMENT (WITH UNCOATED TOOL)

Figures 4 to 6 exhibit graphs representing the results of cutting tests that illustrate the variance of various forces with different cutting speed and feed for the uncoated tool. Main effect plot for force Fx, Fy and Fz. Analysis of variance for forces is showing table 3.

The three machining force components have been seen to decrease as cutting speed is raised. The fluctuation in friction caused by the temperature increase in the secondary-shear zone area, which reduced the restricted force, may be responsible for this decrease in forces. [5], [15]. The cutting forces for the coated tools are lower for all of the evaluated tools. This limit value of the minimum cutting force for the uncoated tool is reached at a cutting speed of around 160 m/min.

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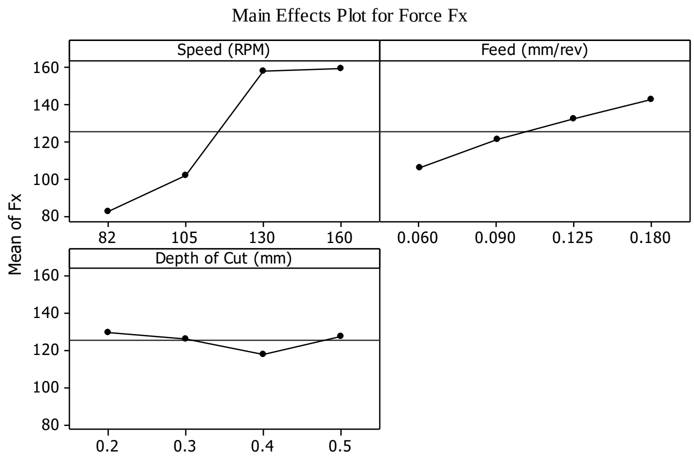

Figure 4: Main effect plot for thrust/feed force (Fx) with uncoated tool

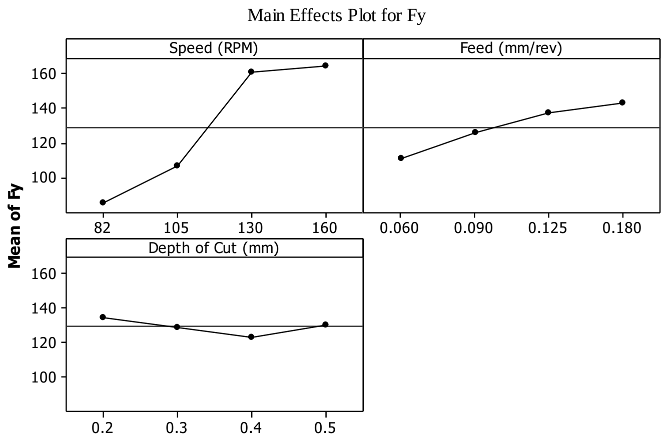

Figure 5: Main effect plot for Redial force (Fy) with uncoated tool

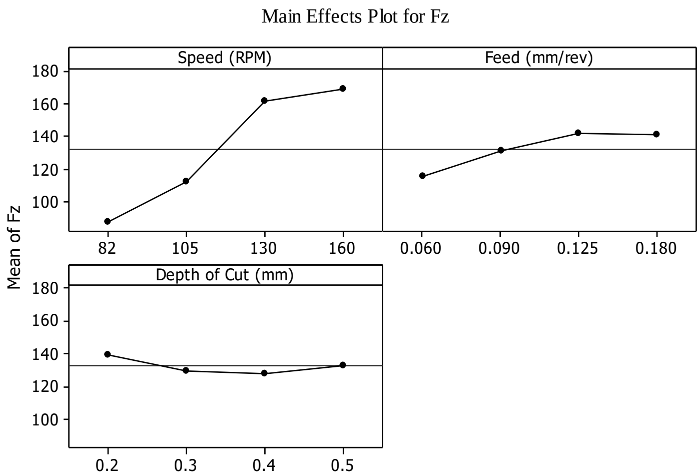

Figure 6: Main effect plot for Cutting force (Fz) with uncoated tool

Analysis of Variance (ANOVA) is a statistical technique used to analyse the variation between different groups or factors in a dataset. In the case of forces (Fx, Fy and Fz) data, ANOVA can be used to determine if there are significant differences in the average force values between different groups or factors, such as different machining conditions, tool geometries, or workpiece materials.

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Table 3: Abridged ANOVA for Forces (Fx, Fy and Fz) with Uncoated tool

Source	DF	Fx		Fy		Fz	
		F	P	F	P	F	P
Speed (RPM)	3	50.75	0.000	48.14	0.000	34.61	0.000
Feed (mm/rev)	3	8.01	0.016	6.14	0.029	3.30	0.099
Depth of Cut (mm)	3	0.85	0.51 4	0.73	0.573	0.61	0.635
Residual Error	6						
Total	15						

V. FORCE MEASUREMENT (WITH COATED TOOL)

The result for TiN coated tool has given in Fig 7 to 9. The findings show how cutting forces varied at various feed rates, including 0.06, 0.09, 0.125, and 0.18 mm/rev, as well as cutting speeds ranging from 82,105,130 to 160 m/min. The forces diminish as the cutting speed rises for the 0.06 mm/rev feed rate and the coated tool. This demonstrates how coatings have a positive impact on cutting forces. The cutting force values are in the same range at greater feed rates regardless of the tested tool, but the cutting tool determines how the cutting force curves look. At lower medium cutting speeds, tool morphology or process variation may be responsible for the variation in forces for the feed rate of 0.18 mm/rev.

In fact, it is usually expected that the main cutting force Fz should be the highest and the radial force Fy and thrust force (Fx) should be the lowest in magnitude. Due to the creation of high temperatures at the cutting zone, the cutting force typically decreases with increasing cutting speed. This outcome is mostly attributable to the coating's excellent adhesion, ultrafine crystallinity, and great oxidation resistance. Thermal conductivity and the coefficient of friction are also impacted by the coating material. The average surface roughness of the machining material is reduced by lowering the coefficient of friction and heat conductivity of the cutting tool.

When cutting speed is high and feed rates are low, low cutting forces are given. Higher thrust components caused by larger chip cross sections are what cause the higher forces at higher feed rates. However, under similar cutting feeds, coated tools' cutting forces are lower than those of uncoated tools.

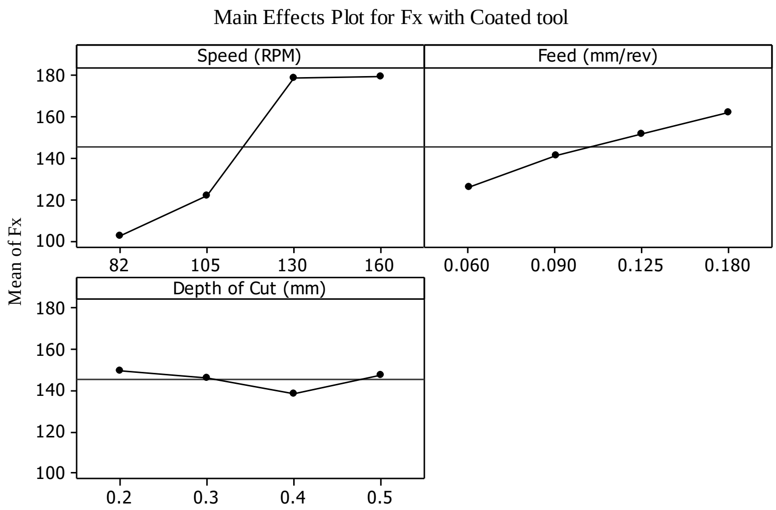

Figure 7: Main effect plot for Feed force Fx with coated tool

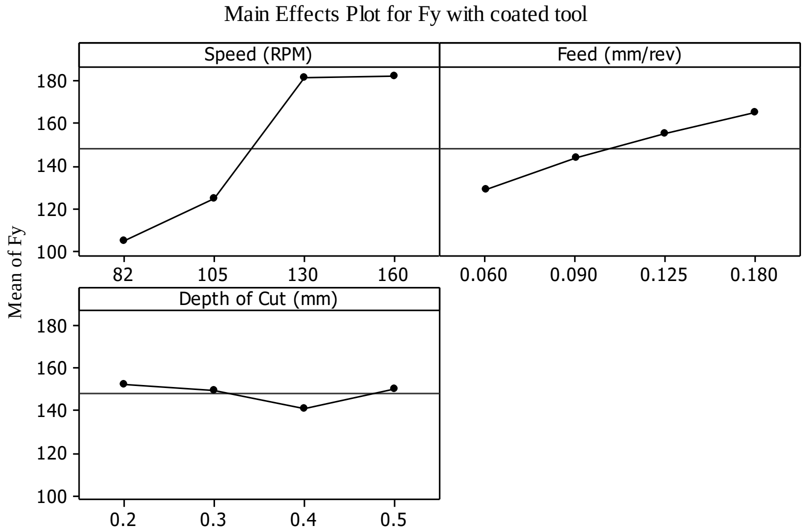

Figure 8: Main effect plot for Redial force Fy with coated tool

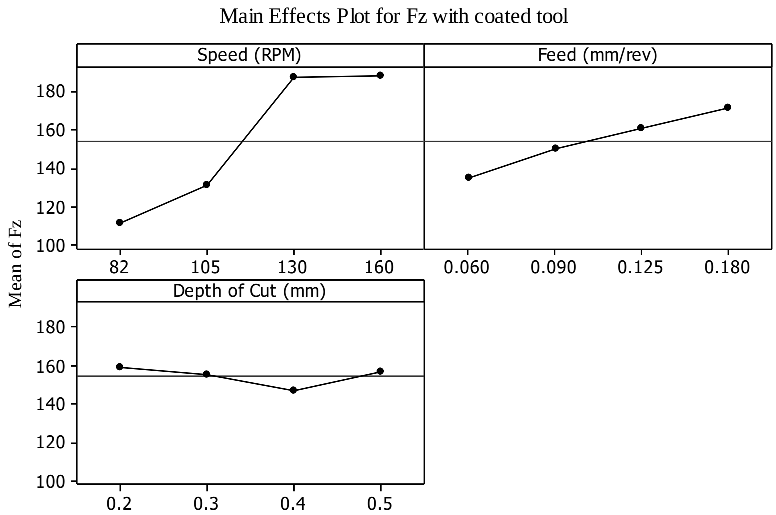

Figure 9: Main effect plot for Cutting force Fz with coated tool

Table 4: Abridged ANOVA for Forces (Fx, Fy and Fz) with Coated tool

Source	DF	Fx		Fy		Fz	
		F	P	F	P	F	P
Speed (RPM)	3	50.21	0.000	50.76	0.000	52.12	0.000
Feed (mm/rev)	3	7.76	0.017	8.01	0.016	8.11	0.016
Depth of Cut (mm)	3	0.81	0.534	0.85	0.514	0.87	0.505
Residual Error	6						
Total	15						

VI. SURFACE ROUGHNESS MEASUREMENT

It has been discovered that a variety of parameters, including cutting speed, feed rate, and depth of cut, have an impact on surface finish in turning. The numerous simple surface roughness parameters, including average roughness (Ra), root mean square RMS, and maximum peak to valley, are employed in the various industries. Ra is the theoretically calculated average surface roughness where f is the feed rate (mm/rev) and R is the tool nose radius (mm). It implies that surface roughness of the work piece increases with increasing feed rate and decreases with a large tool nose radius.

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Graphs are used to illustrate the results of tests to measure surface roughness. Graphs of cutting speed, feed rate, and depth of cut vs surface roughness are shown in Figures 10 and 11 for speeds of 80, 105, 130, and 160 m/min, respectively, with feed rates of 0.06, 0.08, 0.12, and 0.16 mm/rev and depths of cut of 0.2, 0.3, 0.4, and 0.5 mm. The surface roughness major effect plot for coated and uncoated tools.

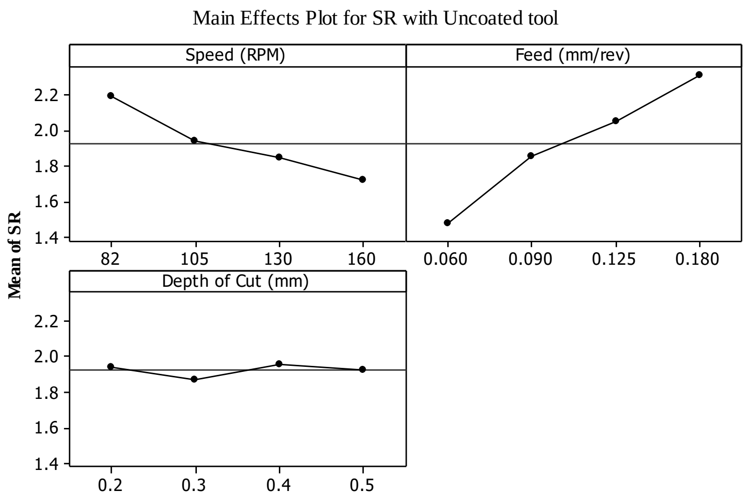

Figure 10: Main effect plot for Surface Roughness with Uncoated tool

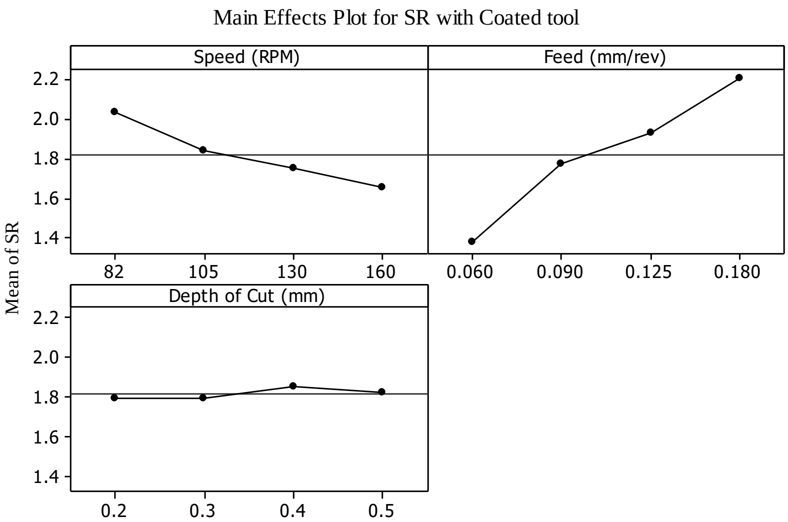

Figure 11: Main effect plot for surface roughness with coated tool

Analysis of variance of SR with coated tools are presented in Table 5 and 6. Determine the significance level: Determine the significance level for the F-ratio using a statistical table or software (Minitab@16). If the significance level is less than the chosen alpha level (usually 0.05), then there is a significant difference between the groups or factors. If there is a significant difference between the groups or factors, then further analysis can be performed to determine which groups or factors have significantly different force values from one another.

Table 5: Analysis of Variance for SR Uncoated

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Speed (RPM)	3	0.48347	0.48347	0.161156	47.78	0.000
Feed (mm/rev)	3	1.46962	1.46962	0.489873	145.24	0.000
Depth of Cut (mm)	3	0.01587	0.01587	0.005290	1.57	0.292
Residual Error	6	0.02024	0.02024	0.003373		

Total	15	1.98919				
S = 0.05808 R-Sq = 99.0% R-Sq(adj) = 97.5%						

Table 6: Analysis of Variance for SR Coated

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Speed (RPM)	3	0.31357	0.31357	0.104523	28.78	0.001
Feed (mm/rev)	3	1.43137	1.43137	0.477123	131.39	0.000
Depth of Cut (mm)	3	0.01012	0.01012	0.003373	0.93	0.482
Residual Error	6	0.02179	0.02179	0.003631		
Total	15	1.77684				
S = 0.06026 R-Sq = 98.8% R-Sq(adj) = 96.9%						

VII. CONCLUSION

The following inferences on the impact of cutting speed and feed on the functionality of uncoated and TiN coated carbide tools for turning AISI 1020 steel can be made based on the experimental data provided and discussed:

• In terms of cutting forces, coated carbide tools outperform uncoated carbide tools. Because under experimental conditions, the average magnitudes of forces obtained with uncoated carbide tools were higher than those obtained with coated carbide tools.

• At all cutting speeds, the main cutting force (Fz), feed force (Fx), and radial force (Fy) produced by TiN coated carbide tools are lower than those produced by uncoated carbide tools, indicating that turning with the former tools is more energy and power efficient than turning with the latter.

• Cutting forces in the experimental range have been optimised at a cutting speed of 160 m/min. Cutting force is directly impacted by cutting feed. The cutting forces directly rise as the feed rate does.

• The results indicate that utilising coated tools improves the cutting of hard materials at greater speeds. According to the results of the experimental inquiry, coated tools perform better when turning than uncoated tools.

• According to this study, TiN coating on carbide tools results in better surface roughness at high speeds and low feed rates. The depth of cut, however, only slightly affects surface roughness.

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