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# Experimental Analysis of Cutting Parameters on Tool Wear and Work Piece Surface Temperature in Turning of Titanium Grade -5

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**Abstract -** *Now-a-days increasing in the productivity and the quality of the machined parts are the main challenges of metal cutting industry during turning processes. Optimization methods in turning processes, considered being a vital role for continual improvement of output quality in product and processes include modeling of input-output and process parameters relationship and determination of optimal cutting conditions. This paper presents an optimization method of the cutting parameters (cutting speed, depth of cut and feed) in dry turning of Titanium Grade -5 alloy and carbide tool to achieve minimum tool wear and low work piece surface temperature. In the improvement of output quality of the product, the optimization technique like Taguchi's method is a very good tool and effective method to improve performance and quality of manufacturing industries. To achieve minimum tool, wear the surface temperature of the workpiece should be low. The experiment design or design of experiment based on the Taguchi's L9 orthogonal array technique was performed to identify the effect of cutting parameters on the different response variables. The results of the turning machining experiments of titanium-grade-5 characterize the main factors affecting the surface roughness by analysis of variance (ANOVA) method. The minimum tool wear was found at a lower speed and the feed rate was found to be the most significant parameters to influence the surface roughness of grade -5 materials in turning process*

***Key Words***: Titanium, Taguchi optimization technique; Turning; Cutting force; Temperature

## 1. INTRODUCTION

Titanium grade-5 is one of the alloy which is more application in medical and aerospace application. The titanium grade-5 alloys are offering the reasonable weldbility, good corrosion and high strength. The titanium alloys have major applications in marine, aerospace, medical, biomedical and automobile industry because titanium grade-5 have very good in fatigue strength, high corrosion resistance properties but the major drawback of the alloys is low thermal expansion and very hard, difficulty to machining. The specific weight of the titanium alloys is more than the steel and 50 to 60% higher than the aluminum. The titanium alloy strength greater than any other alloys, alloys steel and steel. Titanium have very high strength to weight ratio. In titanium alloys(Ti-6Al-4V)-Titanium grade-5 is th major alloys it is used more application. The titanium grade-5 alloys an alpha and beat alloy which contains vanadium 4% Weight and 6% aluminum by Weight. In machining of the titanium grade-5 is the major problem to machining because it is very hard to machining. The major machining problem of titanium alloys is due to high chemical reaction and low thermal conductivity. Whatever the heat which is generated by cutting operation on tool is cannot dissipate the quickly. Tool wear is the biggest problem in the machining of the Ti-6Al-4V (titanium grade-5) alloy due to its cutting temperature. In this research work, the turning of titanium grade-5 alloy was conducted at the moderate speed by using ceramic types of CVD coated inserts. The results give the cutting force are highly significantly at different speed. The tool temperature is almost nearer value for different cutting speed and feed conditions. The main aim of this research work is to identify the effect of different machining parameters on the Titanium grade-5(Ti-6Al-4V) works specimen surface roughness and tool inserts flank wear and tip temperature of the CVD inserts by the optimize technique like Taguchi's method. The L9 orthogonal array is to use to identify the cutting condition test and optimize the predicting values in linear values, finally tested by the confirmation test.

## 2. LITERATURE REVIEW

The present study shows that many of the researchers has been used the taguchi's technique to optimize the machining parameters, the turning is carried out on the titanium grade-5 in lathe machine by using CVD coated ceramic tool inserts by applying the taguchi's techniques to get the output response likes cutting force and surface roughness.[1]et al are major contribution to find the flank wear by using the ultrasonic vibrating cutting signals and made the comparison with and without cutting fluids. They use to optimize the cutting condition by using the liner regression equations. [2]

## 3. EXPERIMENTAL DETAILS

3.1 Workpiece Materials

Titanium grade-5(Ti-6Al-4V) is specimen for experimental test, which consists of 60mm in diameter bar and length of the specimen is 150mm. Titanium grade-5 is the one of the commercial alloy. The grade-5 titanium alloy which have wide range of application in aerospace and medical field but titanium grade-5 (Ti-6Al-4V) alloy is also well balanced in ductility, strength, creep, weldbility, facture toughness and workability. This alloy mainly used for manufacturing of airframe and aircraft engine parts. The chemical properties, physical properties and mechanical properties of titanium grade-5 as shown in below table.

TABLE 1 chemical composition of Titanium grade-5 work piece in percentage by weight

| O | N | C | H | Fe | Al | V | RESIDUALS |
|---|---|---|---|---|---|---|---|
| 0.2 | 0.05 | 0.08 | 0.015 | 0.4 | 5.5-6.75 | 3.5-4.5 | 0.4 |

The titanium alloy which consists of ultimate strength of 998Mpa and having the hardness about 45 brinell hardness number. Some of the mechanical properties are listed below in the table.

TABLE 2 Mechanical Properties of Titanium grade-5 at Room Temperature

| **Properties** | **Minimum values** | **Typical Values** |
|---|---|---|
| Yield Strength | 830MPa | 910MPA |
| Ultimate Strength | 900MPa | 998Mpa |
| Elongation | 12% | 16% |
| Reduction in Area | 18% | |
| Hardness | | 35-45BHN |
| Modulus of Elasticity | | 119GPa |
| Impact | | 25-30 |

TABLE 3 Physical properties of the Titanium grade-5 alloy

| | |
|---|---|
| Melting point | 1650 oC |
| Density | 4.43g/cm3 |
| Beta transus | 995oC |
| Thermal Expansion(0-100oC) | 9*10-6 k-1 |
| Thermal Expansion (0-300oC | 9.5*10-6 K-1 |
| Therml Conductivity | 7.5 W/mK |
| Specific heat at room temperature | 0.57J/gK |
| Electrical Resistivity at room temperature | 171W*cm |
| poisson's ratio | 0.32-0.35 |

### 3.2Cutting Inserts

With the help of L9 array, the turning of machining operation experiment is conducted with help of CVD coated ceramic inserts having 80o diamond shaped insert having without chip breaker.ISO-CNMG120408 cutting insert which is screwed to the right hand turning tool holder.

FIGURE.1 CNMG120408 insert (PVD) with Tool holder PCLNR 2525 M12

### 3.3 Surface Roughness Measurements

The surface roughness of the titanium alloy is measured by the help of surface tester which measures the surface at the different position of the material at the angle of 1200 at the circumference of the 60mm round bar immediately after the turning for every operation.

FIGURE.2 Surface roughness measurements

### 3.4 Experimental Procedure

The turning of titanium is called hard turning, the experiments was conducted on titanium grade-5 alloy with the help of CVD coated ceramic inserts. the test was conducted with the help of lathe machine having speed in the range of 30rpm to 1600rpm under the dry condition to find the flank wear of the tool and to find the temperature which carried by the tool tip.

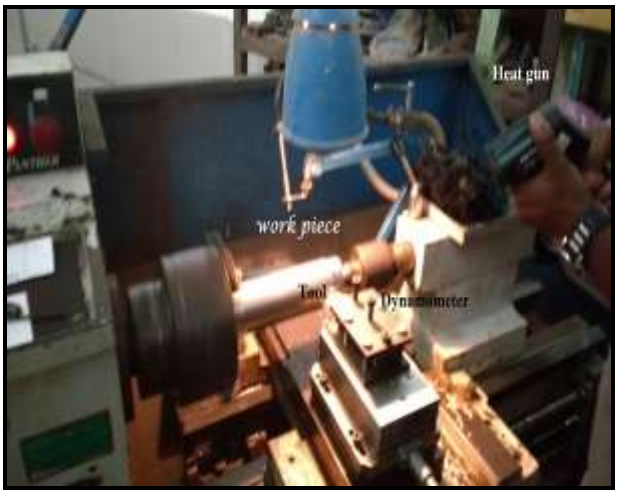


FIGURE 3 Experimental setup

## 4. ResultS and discussions

The experimental machining work was conducted with help of Taguchi's orthogonal array of L9 and analyzed with the Minitab soft wear system. The below table shows the cutting inputs for machining of titanium alloy like grade-5 material with help CVD coated ceramics tool inserts. After the turning operations of titanium grade-5 alloy is tabulated in table with related S/N ratio.

TABLE 4 Independent variables and their levels

| Levels | Cutting Speed | Feed Rate | Depth of cut |
|---|---|---|---|
| | $V_c$ (m/min) | f (mm/rev) | $a_p$ (mm) |
| 1 | 60 | 0.015 | 0.25 |
| 2 | 70 | 0.030 | 0.30 |
| 3 | 80 | 0.045 | 0.35 |

**TABLE 5 Input Parameters**

| SL No | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| $V_c$ | 60 | 60 | 60 | 70 | 70 | 70 | 80 | 80 | 80 |
| $a_p$ | 0.25 | 0.30 | 0.35 | 0.25 | 0.30 | 0.35 | 0.25 | 0.30 | 0.35 |
| f | 0.015 | 0.030 | 0.045 | 0.030 | 0.045 | 0.015 | 0.045 | 0.015 | 0.030 |

### 4.1 Analysis of S/N ratio

In a mechanical engineering system signal to noise ratio is measured to compare the desired level of signal to noise ratio. The taguchi's is the one the best technique is used to measure the optimum solutions for different input values and signal to noise raito is to use for different values. There will be three characteristics in experiment like cutting speed, temperature and surface roughness. To get good quality of work piece and charterstics by using smaller the better in taguchi's orthogonal array system.

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

Where the n measure the experiments numbers and Y is measuring values. And the number of experiment was conducted for different input machining parameters to get high signal to noise ratio for least variance and quality of work.

### 4.2 Analysis of Variance (ANOVA)

The ANOVA practice is the unique of the best optimize in the taguchi's technique. This process is to decide the process parameters of turning parameters. taguchi's technique cannot trust for govern the effect of specific progression parameters will be in proportion contribution and some of the factors impact the design model. The ANOVA table is consisting of mean square(MS), sum squares (SS), degree of freedom (DOF), F-value, P-value and percentage contribution.

TABLE 6 Output Response and S/N ratio for CVD Coated Ceramic Cutting Tool Insert

| | Input | | | output | | | | S/N Ratios | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sl No | Vc | Ap | f | T | Fy | Ra | Vb | T | Fy | Ra |
| 1 | 60 | 0.25 | 0.015 | 58.8 | 167.45 | 6.03 | 0.22 | -35.39 | -44.48 | -44.48 |
| 2 | 60 | 0.3 | 0.03 | 73.6 | 186.18 | 6.78 | 0.36 | -37.34 | -45.40 | -45.40 |
| 3 | 60 | 0.35 | 0.045 | 108.7 | 235.45 | 6.98 | 0.75 | -40.72 | -47.44 | -47.44 |
| 4 | 70 | 0.25 | 0.03 | 62.9 | 163.28 | 5.38 | 1.65 | -35.97 | -44.26 | -44.26 |
| 5 | 70 | 0.3 | 0.045 | 77.8 | 198.77 | 5.96 | 1.89 | -37.82 | -45.97 | -45.97 |
| 6 | 70 | 0.35 | 0.015 | 103.5 | 276.77 | 6.66 | 1.98 | -40.30 | -48.84 | -48.84 |
| 7 | 80 | 0.25 | 0.045 | 62.8 | 175.45 | 7.76 | 2.27 | -35.96 | -44.88 | -44.88 |
| 8 | 80 | 0.3 | 0.015 | 80.6 | 288.98 | 7.81 | 2.68 | -38.13 | -49.22 | -49.22 |
| 9 | 80 | 0.35 | 0.03 | 116.5 | 376.65 | 8.66 | 2.98 | -41.33 | -51.52 | -51.52 |

Analyses of Variance (ANOVA) for coated tool insert machining with titanium grade-5

TABLE 7 Analysis of Temperature (T)

| Source | DF | SS | MS | F | P | % |
|---|---|---|---|---|---|---|
| Vc | 2 | 44.563 | 16.325 | 6.458 | 0.56 | 52.87 |
| Ap | 2 | 24.231 | 1.889 | 1.326 | 0.88 | 28.75 |
| f | 2 | 12.85 | 0.1485 | 1.632 | 0.85 | 15.25 |
| Error | 2 | 2.638 | 0.995 | | | 3.13 |
| Total | 8 | 84.282 | | | | 100 |

TABLE 8 Analysis of Cutting Force (Fz)

| Source | DF | SS | MS | F | P | % |
|---|---|---|---|---|---|---|
| Vc | 2 | 18.23 | 9.630 | 6.652 | 0.118 | 23.59 |
| Ap | 2 | 21.637 | 11.576 | 7.632 | 0.133 | 28.00 |
| f | 2 | 33.56 | 16.489 | 16.78 | 0.078 | 43.42 |
| Error | 2 | 3.856 | 1.987 | | | 4.99 |
| Total | 8 | 77.283 | | | | 100 |

TABLE 9 Analysis of Surface Roughness ($R_a$)

| Source | DF | Adj SS | Adj MS | F-Value | P-Value | % Cont |
|---|---|---|---|---|---|---|
| Vc | 2 | 9.568 | 4.568 | 8.36 | 0.012 | 17.51 |
| Ap | 2 | 15.487 | 7.412 | 11.36 | 0.019 | 28.35 |
| f | 2 | 28.369 | 15.697 | 14.59 | 0.043 | 51.93 |
| Error | 2 | 1.2068 | 563 | | | 2.21 |
| Total | 8 | 54.6308 | | | | 100 |

From the ANOVA table, from the table no 5 the speed which contribute the 88.92% which is the most significant cutting parameters which influence on the surface roughness and followed by the depth of cut at 5.7%. However, the feed rate at least efficacy of 0.72% which controlling the surface roughness of the materials and it is also not statistically significant to influence. From the ANOVA table no 6 shows that the P-value of feed rate is 0.062 which are very less than the 0.1. It shows that depth of cut which influence significantly on the cutting force on tool. The depth of cut and cutting speed which has been contribute more on the tool are 26.47% and 22.25% but the biggest contribution came from the feed rate is about 48.1 % which is not significant. The contribution of error is 4.67% and 3.18% for surface roughness and cutting force respectively.

### 4.3 Mean Effect Plots

For the analysis the data to study the amount of cutting parameters and the main effect plots on the surface roughness were analyzed. With the help of Minitab soft wear shows the variation of individual response with three machining parameters separately. In the plots X-axis indicates the values of cutting machining parameters and Y-axis denotes the response value. The plots are used to find the design condition for surface roughness.

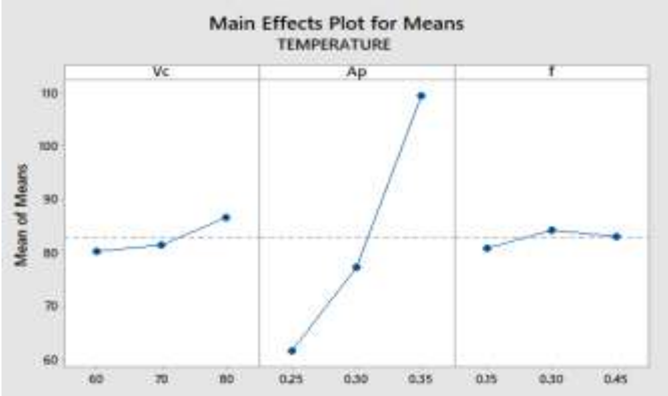


FIGURE 4 Main effect plots for Temperature (T) for CVD coated Ceramic Insert

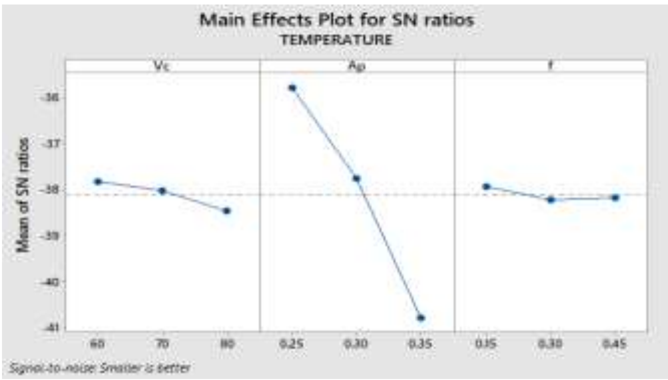


FIGURE 5 Main effect plots for S/N ratio Temperature (T) for CVD coated Ceramic Insert

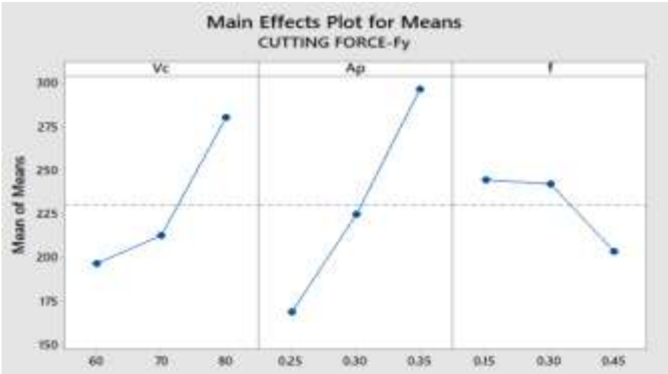


FIGURE 6 Main effect plots for Cutting Force (Fz) for CVD coated Ceramic Insert

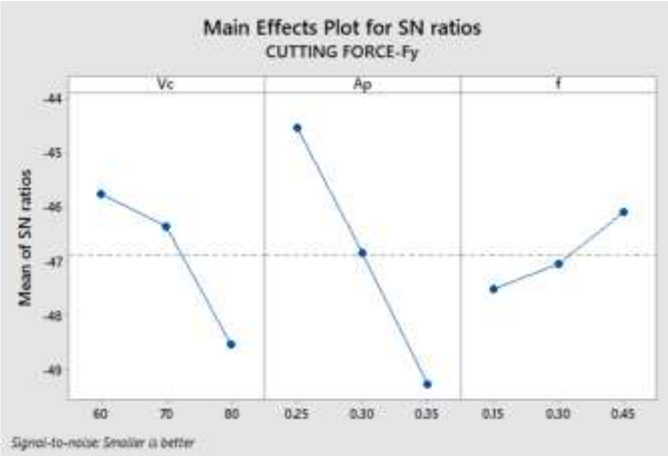


FIGURE 7 Main effect plots for Cutting Force (Fz) for CVD coated Ceramic Insert

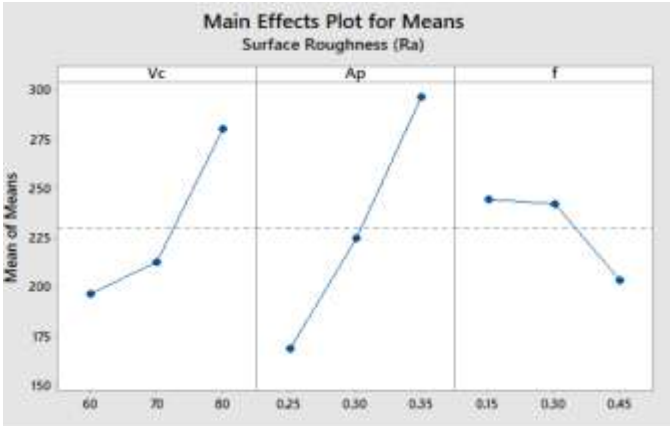


FIGURE 8 Main effect plots for surface roughness for CVD coated carbide Insert

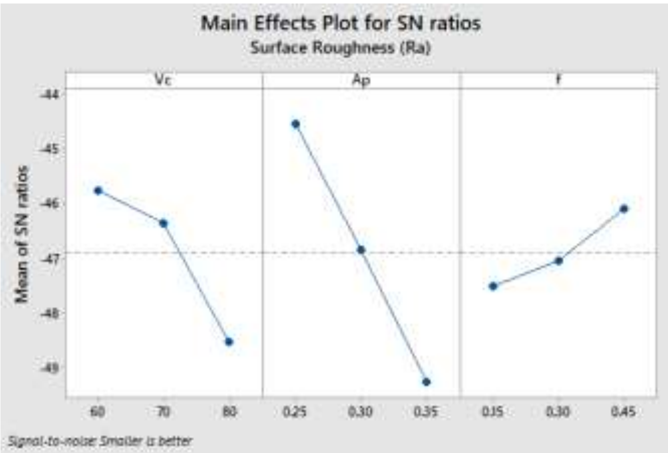


FIGURE 9 Main effect plots for surface roughness for CVD coated carbide Insert

Figure 7 &8 shows that the MEP for surface roughness, the graph shows that increase the depth of cut significantly roughness also increases in smaller rate, but when the speed increases there will be continuous increases in surface roughness. A feed rate increases there is decrease the surface roughness. Figure shows that the S/N Ration for surface roughness, the graph shows that increase the depth of cut significantly roughness also decreases, but when the speed increases there will be continuous fall down in surface roughness. A feed rate increases there is increases the surface roughness. shows that the MEP for cutting force, the graph shows that increase the depth of cut significantly cutting force also decreases, but when the speed increases there will be continuous decreases in cutting force. A feed rate increases there are increases the cutting force. Figure 6 shows that the S/N Ration for cutting force, the graph shows that increase the depth of cut significantly force also increases, when the speed increases there will be continuous increases in force. A feed rate an increase there is decreases the surface roughness.

TABLE 7 Optimal Conditions

| Optimal parameters for uncoated inserts | | | |
|---|---|---|---|
| | $V_c$ | Ap | Fy |
| T | 0.15 | 30 | 0.046 |
| $F_z$ | 0.1 | 50 | 0.046 |
| $R_a$ | 0.15 | 30 | 0.046 |

TABLE 8 Response table for S/N ratio for Temperature Smaller the best

| **Level** | **Vc(speed)** | **ap(depth of cut** | **f(feed rate)** |
|---|---|---|---|
| **1** | -37.82 | -35.77 | -37.94 |
| **2** | -38.03 | -37.76 | -38.21 |
| **3** | -38.47 | -40.78 | -38.17 |
| **Delta** | 0.65 | 5.01 | 0.27 |
| **Rank** | 2 | 1 | 3 |

TABLE 9 Response table for S/N ratio for cutting force Smaller the best

| **Level** | Vc(speed) | ap(depth of cut | f(feed rate) |
|---|---|---|---|
| **1** | -45.77 | -44.54 | -47.51 |
| **2** | -46.36 | -46.86 | -47.06 |
| **3** | -48.54 | -49.27 | -46.1 |
| **Delta** | 2.77 | 4.73 | 1.42 |
| **Rank** | 2 | 1 | 3 |

TABLE 8 Response table for S/N ratio for Surface roughness Smaller the best

| **Level** | **Vc(speed)** | **ap(depth of cut** | **f(feed rate)** |
|---|---|---|---|
| **1** | -40.64 | -41.72 | -42.8 |
| **2** | -42.06 | -42.94 | -42.83 |
| **3** | -45.6 | -43.65 | -42.67 |
| **Delta** | 4.96 | 1.93 | 0.16 |
| **Rank** | 1 | 2 | 3 |

The table no 8 and 9 shows the response for the signal to noise ration of different cutting condition for smaller is better. The response table no 8 shows that the speed rate is significantly dominate the machining performance whereas compare to given different higher values. The table no 9 S/N ratio indicates that feed rate is significantly contributing more of the machining performance in the cutting fore condition and followed by the Depth of cut and speed.

## 5.Confirmation Test

After the experinmental test Applying the Taguchis method with ANOVA successfully It is found that the optimime condition from the taguchis L9 array obtained the values, based the optimum values the conforimation test was conducted and to validate the results in table 10.The predicated experinmental values are gives less error and it found to be good.

TABLE 10 Confirmation Test

| | Input | | | output | | S/N Ratios | |
|---|---|---|---|---|---|---|---|
| Sl No | ap | Vc | f | Ra | Fz | Ra | Fz |
| 1 | 0.15 | 30 | 0.046 | 2.56 | 186.45 | -08.26 | -48.17 |

## CONCLUSIONS

In this experinmental study the taguchis array method is used to determine the optimal cutting parameters in the turning of Titanium grade-5 with PVD coated carbide inserts. With the help of ANOVA the experinmenatal test results are evulated.

- Accoring to experinmental results the taguchi technique determines the optimum machining cutting condition achives the low surface roughness and low cutting speed.
- According to the test the percentage contribution of speed (88.92%) , depth of cut (5.7%) which the larger value affect the surface rouhness of materials and the feed rate is 0.72% is smaller value.
- In the cutting force the significant parameters of work piece were feed rate which contributes 48.1 %, depth of cut 26.47% and speed 22.25% respectively. These parameters influence the cutting force.
- According to the confirmation experinmental test results, the measured values are shows the minimum values of the surface roughness and cutting speed.

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