Optimization of surface roughness of Titanium Gr-9Alloy Turning using Taguchi method

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Abstract: - In this work, the performance of chemical vapors deposition coated carbide insert has been described by Taguchi’s manner, a whirling of Titanium(gr–9) alloy, for investigation consider a machine hurtful parameters like machining Feed-rate, Depth of cut and Cutting speed by the help of input evaluation of investigation of surface irregularity and cutting tangential force. The experimental test was carried. Based on the optimization techniques like Taguchi’s of an orthogonal array system. The optimization of the output response by the analysis of variants (ANOVA) to estimate the nominal surface roughness and maximum tool life. The test result shows that increases in feed-rate and cutting speed correspondingly, the surface irregularity is higher, varies in cutting tangential forces increases cutting speed force also increased, decrease with feed-rate and speed correspondingly and significantly decrease cutting tangential forces.

Keywords: Titanium, Taguchi optimization technique; Turning; Cutting force; Surface roughness;

1. Introduction
Titanium is one of the best super alloys. Which is highly applicable in aerospace and medical field? Due to its chemical position and mechanical behavior. titanium super alloy is a hard material. Which rust-free alloys because it is not chemical reaction with air and water. the iron percentage in the chemical composition is very less. When aluminum and vanadium is added in the alloys some of the mechanical properties may varies. Titanium alloys is having different types of grades system due to its chemical composition and different application. the titanium is very hard materials but the machining will be done with help of coated carbide inserts like PVD A&CVD. While making the components with the help of of titanium alloys for machining the cutting speed should be high from 50m/min to 300m/min and able to achieve an actual good surface quality when the feed is less than the 0.1mm/rev. the cutting force which acts on the tools and also tool wear is very less when matching action is taken place in above condition. exactly concerning multiple efforts and productivities with non-linear relative’s midst themselves, are found extremely effective cheers to the progressive procedures and multiplication science. Hence, optimization of high-speed machining replies of Ti–3Al–2.5V has been scrutinized within this training employing a Taguchi’s Method is used.

2. Experimental procedure
The below figure illustrates that experimental setup of research work. Titanium grade 9 alloy as a wok specimen of diameter 50 mm and 160 mm length specimen are used in research work for machine-ability testing. The cutting inserts are CVD coated carbide inserts about 80-degree diamond shape and 0.8 mm nose radius having the geometry minus chip breaker. The pullouts are fasenated into the tool holder of right hand of ISO designation PCLNR 2525-M12. the chemical vapour deposition coated carbide inserts having multi-layer of coating materials Al2o3 and TiN having thickness about 8-16 micro meter thickness layer on inserts. The CNMG 120408 CVD inserts which purely made for machining like hard metals, super alloys like Ti and Ni based alloys The titanium grade 9 alloy is a wide variety of application in sports equipment, dental applications, surgical applications, aerospace
and aircraft solicitations due to its high forte and high current resistance power the titanium alloys find application in this area.

Work piece material consist of 3% Al, 0.2% Fe, 0.15% O, 0.035% N, 3% V and 92.75% Ti, 0.015% H and 0.86% others. The input parameters are cutting speed, feed rate and depth of cut or selected every level of machining design pf experimentations are implemented on full factorial method of orthogonal array L9 of taguchi’s technique. The experimental trial runs or carried out on machining of Ti grade 9 with CVD inserts. With the help of taguchi’s L9 the output response of results is optimized by taguchi’s technique, the interference of results is drawn from the ANOVA table with the help of Minitab software, the graphical representation of each trial run are validate by analysis of SN ratio. The effect of each machining process parameters at different levels are analysed by SN ratio. To validate the output response was carried out by SN ratio considering smaller the better criteria each factor of response as shown in delta statistics and the rank table. The experimental trial runs are carried out on machining of Ti grade-9 with coated CVD inserts. With the help of taguchi’s L9 the output response of results is optimized by taguchi’s technique, the interference of results is drawn from the ANOVA table with the help of Minitab software, the graphical representation of each trial run are validate by analysis of SN ratio. The effect of each machining process parameters at different levels are analysed by SN ratio. To validate the output response was carried out by SN ratio considering smaller the better criteria each factor of response as shown in delta statistics and the rank table. The SN ratio indicates that when increasing cutting speed and feed rate the surface roughness on material also increases when decreases feed rate and cutting speed the surface roughness also reduces. The trial runs are passed on the conventional engine lathe under dry environment machining condition. The lathe runs between 30 rpm to 1250 rpm, the specimen of trial runs between two centres, the centre which consist of three jaw chuck and dead centre. The main key factor for these trial runs was to evaluate the machining factors which special effects on tool wear, surface roughness and tip temperature on machining of Ti-Gr-9 compound.

![](image)

**Figure 1.** Experimental setup

### 3. RESULT AND DISCUSSION

The justification of trial outcomes was accompanied on using the inspiration of taguchi’s L9 technique with support of Minitab. The illustration of the table explains the restrictions on Titanium grade 9 alloys through coated CVD inserts. The formulated S/N ratio ideals are assimilated machining process of titanium grade-9 with productivity comeback.

#### 3.1 Analysis of Signal to noise ratio

Signal to noise relation is to quantity castoff in a production structure. That associates flat of the favorite signal to the noise ratio. The Taguchi's system of orthogonal array practices is used to quantity the input ideals for the peak explanations and signal to noise ratio is to be grander values. Their determination be three appearances like i) lesser the better, ii) superior the better and iii) minimal are recovering. In this experimentations, force of cutting, finish of surface is recorded by means of quality appearances like smaller the healthier. Where y is the restrained value and n is the amount investigational trial manner in which contribution constraints consuming tall gesture to noise ratio which gives the smallest adjustment and superiority of organization.
Table 1. CVD coated Cutting insert variables in machining

| Sl No | ap  | Vc  | f   | Fz  | Ra  | Fz  | Ra  |
|-------|-----|-----|-----|-----|-----|-----|-----|
| 1     | 60  | 0.25| 0.015| 167.45 | 6.03 | -44.48 | -44.48 |
| 2     | 60  | 0.3 | 0.03 | 186.18 | 6.78 | -45.40 | -45.40 |
| 3     | 60  | 0.35| 0.045| 235.45 | 6.98 | -47.44 | -47.44 |
| 4     | 70  | 0.25| 0.03 | 163.28 | 5.38 | -44.26 | -44.26 |
| 5     | 70  | 0.3 | 0.045| 198.77 | 5.96 | -45.97 | -45.97 |
| 6     | 70  | 0.35| 0.015| 276.77 | 6.66 | -48.84 | -48.84 |
| 7     | 80  | 0.25| 0.045| 175.45 | 7.76 | -49.22 | -49.22 |
| 8     | 80  | 0.3 | 0.015| 288.98 | 7.81 | -51.52 | -51.52 |
| 9     | 80  | 0.35| 0.03 | 376.65 | 8.66 | -51.52 | -51.52 |

3.2 Analysis of variance (ANOVA)

The discrete process limitations will be strong-minded by using ANOVA Minitab soft wear. ANOVA is practices which inspect the consequence of machining progression constraints and taguchi’s system cannot belief for define the consequence of specific method restrictions will be in calculation involvement and roughly of the features impact the proposal classical.

CVD Coated Insert ANOVA Table

Table 2 Represents investigation of Surface Roughness (Rₐ)

| Source | DoF | Sum S | Mean S | Value-F | Value-P | % |
|--------|-----|-------|--------|---------|---------|---|
| ap     | 2   | 9.568 | 4.568  | 8.36    | 0.012   | 17.51 |
| Vc     | 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    | 6.67    | 0.018   | 2.21 |
| Total  | 8   | 54.6308|       |         |         | 100 |

Table 3 Represents investigation of cutting force (Fz)

| Source | DoF | Sum S | Mean S | Value-F | Value-P | % |
|--------|-----|-------|--------|---------|---------|---|
| ap     | 2   | 18.23 | 9.630  | 6.652   | 0.118   | 23.59 |
| Vc     | 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  | 1.987   | 0.018   | 4.99 |
| Total  | 8   | 77.283|       |         |         | 100 |

From the analysis of the ANOVA table no3 which gives the overall information reading the output response of the machining parameters on the titanium grade-9 alloys. Considering the input variable in the dry machining all the input variables have the 2 degree of freedom each, ANOVA table represents the overall values of the output response. the sum of square values is 9.568 by the depth of cut, 15.487 are the cutting speed and 28.369 from the feed rate, by conserving significantly the feed rate is more concentrated on the surface roughness on the titanium grade-9 alloys, correspond lying the cutting speed and depth of cut are 15.48 and 9.568 respectively. As per the standard if the probability values which are laws less than the 1, when the p-values is less than or equal to one, whatever the model we
selected for machining is good for machining parameters. In the similar way the percentage contribution feed rate is directly influences on the surface roughness on the titanium grade-9 alloys, the cutting speed is indirectly contributed the surface roughness have the % about 28.35. From the table no 4 give the brief representation on the cutting force on the alloys titanium grade-9, where the percentage contribution on the cutting force 43.42% which is directly influence by the fee rate on the cutting force on the titanium alloys. Whereas other two parameters like depth of cut and cutting speed are sucesely contributed 23.59 and 28.00 respectively, which means the other two parameters are indirectly contributed on the cutting force.in this model the p-values are less the 1

3.3 Mean effect plots
Aimed at the investigation the statistics to review number of critical limitations and thus the most outcome plots on the surface coarseness stayed evaluated. Through an assistance of soft wear like Minitab expressions, the distinction of disconnected rejoinder per three machining bounds individually. indoors the designs Axis of X signposts the ethics of cutting restrictions and Y-axis represents comeback charge. The intrigues are rummage-sale to treasure the plan complaint for surface roughness. Figure 4 shows that the MEP for surface roughness, the diagram displays that intensification the depth of cut pointedly coarseness also upsurges in smaller rate, but once the speed growths their motivation be unremitting growths in surface roughness. Some feed rate intensifications there's decline surface roughness.

Figure 2 CVD coated carbide insert on surface roughness
Figure 3 expressions that signal to noise Ration on surface roughness diagram confirmations an upsurge the depth of cut suggestively surface irregularity similarly declines, then after nearby willpower be higher speed roughly unceasing dewdrop downhearted in surface roughness. A feed rate rises around is growths a surface roughness. From Figs. 3 and 4 it's pure that diverse depths of cut require unalike speed, feed and spindle speed in command to get a noble exterior roughness.
The optimal principles of cutting speed (60 m/min) besides shaft rapidity (1200 rpm) are repeatedly endangered to high hurry machining thru moral accuracy, lessening in burr formation, stoppage of manufactured up edges and immaterial surface roughness devoid of hurt to insert or specimen.

The table no 4 expressions the answer for signal to noise ratio to dissimilar cutting situation for slighter is better. The reaction table no 4 indications a speed rate is suggestively dictatenmachining concert while associate to agreed dissimilar difficult standards.

**Table 4** optimal conditions

| Optimal cutting parameters for uncoated inserts |  |
|----------------|----------------|
| a<sub>p</sub> | V<sub>c</sub> | F  |
| R<sub>a</sub>     | 0.25 | 60  | 0.15 |
| F<sub>s</sub>     | 0.30 | 80  | 0.15 |

**Table 5** Surface roughness response table of Smaller the best

| Level | a<sub>b</sub>(depth of cut) | V<sub>c</sub>(speed) | f(feed rate) |
|-------|-----------------|-----------------|-------------|
| 1     | -08.326         | -7.205          | -11.561     |
| 2     | -11.662         | -11.858         | -09.65      |
| 3     | -13.455         | -12.562         | -12.356     |
| Delta | 2.786           | 1.45            | 1.42        |
| Rank  | 3               | 1               | 2           |

The table top no 5 S/N ratio shows that feed rate is expressively underwriting supplementary of turning presentation in the cutting fore disorder and monitored by the Depth of cut and Cutting speed.
Table 6 Response table for S/N ratio for cutting force Smaller the best

| Level's | \( a_p \) (Depth of cut) | \( V_c \) (speed) | \( F \) (feed rate) |
|---------|--------------------------|-------------------|---------------------|
| 1       | -34.86                   | -36.25            | -52.66              |
| 2       | -38.16                   | -35.99            | -37.65              |
| 3       | -36.49                   | -35.68            | -3756               |
| Delta   | 3.68                     | 3.01              | 4.54                |
| Rank    | 2                        | 3                 | 1                   |

The table no 6 demonstrates the reaction of the S/N ratio of various machining complaint for lesser are best. retort table no 7 displays that cutting speed is expressively govern the machining presentation however associate to given unlike complex ethics. The counter no 6 S/N fraction signposts that feed rate is expressively subsidizing supplementary of the machining presentation within the fore of cutting complaint tailed by the Depth of cut and Cutting speed.

3.4 Approval Test

It is initiate that the optimime illness from the taguchis array L9 gained the principles, constructed the optimal values of conforimation trials and it is accompanied and find that optimum parameters .

Table 7 Trial of Conformation Test

| Sl No | \( a_p \) | \( V_c \) | \( f \) | \( Ra \) | \( F_z \) | Signal to noise Ratios |
|-------|----------|----------|------|-------|-------|----------------------|
| 1     | 0.25     | 60       | 0.15 | 1.45  | 166.45 | -07.56               |
|       |          |          |      |       |       | -56.17               |

4. CONCLUSIONS

In the experimentataal work, the trail runs are carreied out with FFD of Level-9 orthogonal taguchi’s skills was engaged to finding out optimal solution for creadte problem under the machining run at various speed , feed and depth of cut. By using the ANOVA table, feed rade are more influence on the cutting forece on the alloys, where as the cutting speed and depth of cut are influence comparatively less on cuttin ng force.

Oberves that when the cutting speed increases cutting force alos increases, while surface roughness, increasing the feed rate and cutting speed the surface roughness also increases correspondingly. While decreses the feed rate and cutting force surface roughness also decreses. While in machining increases the depth of cut , the cutting tool tip temperature also increases which results in consumption of energy is more on the system, while the tool tip temperature increases the plastic deformation of the alloys which grows the superiority of the surface .

Obesrved the when the cutting force intensifications with feed rate the deline in surfaced roughness and cutting force , which results need to be remove the materials consuming more energy on the system.

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