Performance evaluation of Titanium nitride coated tool in turning of mild steel

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Abstract. The growth in demand for bio-gradable materials is opened as a venue for using vegetable oils, coconut oils etc., as alternate to the conventional coolants for machining operations. At present in manufacturing industries the demand for surface quality is increasing rapidly along with dimensional accuracy and geometric tolerances. The present study is influence of cutting parameters on the surface roughness during the turning of mild steel with TiN coated carbide tool using groundnut oil and soluble oil as coolants. The results showed vegetable gave closer surface finish compares with soluble oil. Cutting parameters has been optimized with Taguchi technique. In this paper, the main objective is to optimize the cutting parameters and reduce surface roughness analogous to increase the tool life by apply the coating on the carbide inserts. The cost of the coating is more, but economically efficient than changing the tools frequently. The plots were generated and analysed to find the relationship between them which are confirmed by performing a comparison study between the predicted results and theoretical results.

1. Introduction

The usage of coated tools in the present days are getting importance in the industries than the uncoated tools because it reduces the friction between tool and chip. Also, it can be operated at lower temperatures with ease [1]. The surface properties of the substrate are altered by the coatings, such as adhesion, wettability, corrosion resistance and wear resistance [2,3]. In addition to above the coatings are used in semiconductor device make up to add a new property such as a magnetic response or electrical conductivity of the product [4]. The coating is to be applied at inhibited thickness on the product to achieve this simple brush for painting a wall, to some very expensive machinery to add coatings [5]. Some of the industrial coating processes entail the application of a thin film of functional material to a substrate, such as paper, fabric, foil and layer [6-9]. The high rectical contact tips used to braze or welding to the tool for holding firmly [10-17]. The conventional arc welding processes were not suitable due to the thin contact tip of hard metal and it can easily melts. Due to these reasons, advanced welding techniques like friction welding and laser beam welding processes can be preferred [18-23]. The main objective of all the industries through these machining processes were to reduce the manufacturing cost, increase the quality of the product and productivity. In that the major care to be taken on the tool. The tool life and its properties decides the quality, productivity and cost The cutting fluids are important as it acts as a coolant which reduces the heat generation through the tool life increases effects the other factors like productivity, quality. It should be non-toxic, non-harmful, should not release hazardous gases, available for lower cost [24-29]. The present study was focused on influence on the surface roughness during the turning operation of mild steel by varying the cutting parameters with TiN coated carbide tool by using groundnut oil as coolants. Design of experiments techniques used to optimize the cutting parameters like spindle speed, feed and depth of cut to increase the tool life and its influence on surface roughness by applying the coating on the tool holder and carbide inserts.
2. Experimental Procedure

In this work the performance of TiN coated tool with groundnut oil as cutting fluid was taken at different cutting speeds and depth of cut by keeping the feed rate constant. Mild steel rod of diameter 25 mm was selected as work material. The substance composition of the base metal is shown in Table 1.

Table 1: Chemical composition of base material

| Mild steel | Mn  | C   | Si  | Cu | S  | P  | Fe   |
|------------|-----|-----|-----|----|----|----|------|
| Wt.%       | 1.03| 0.28| 0.275| 0.2| 0.05| 0.04| balance |

A long mild steel rod of length about 1m is taken and is cut into 2 equal parts of length 500 mm by using power hack saw. Total 4 rods of length 500 mm are taken and each rod is made into 4 partitions for each operation. The divided piece of mild steel was held in lathe machine and facing operation was performed to have smooth face. The faced work piece is turned in lathe machine and approximately 1mm thickness is reduced. The main purpose of turning operation is to make the outer surface of work piece smooth so that the operation would be smooth. Pure ground nut oil was used as cutting fluid for the study. After extensive preliminary study on all the parameters, the parameters considered for turning operation by keeping feed rate as constant by varying the speed and depth of cut. The cutting parameters for turning operation were listed in Table 2.

The laboratory used lathe machine used to reduce the diameter of a part to a desired dimension. First, clamp the 25 mm diameter work piece securely in a lathe 3-jaw chuck and tighten down the jaws until they just start to grip the work piece. Rotate the work piece to ensure that it is seated evenly and to dislodge any chips or grit on the surface that might keep it from seating evenly. Tighten the chuck using each of the three chuck key positions to ensure a tight and even grip. The flow rate measurement has been taken from the time taken to fill the beaker by using stop watch. Surface Roughness is measured by using electronic instrument Talysurf. The cutting forces along the axis were calculated by using lathe tool dynamometer which was connected to a software dynamo. Titanium nitride cutting tool and insert are shown in Fig. 1.

Table 2: Cutting parameters selected for turning operation

| Spindle speed (rpm) | Depth of cut (mm) | Feed (mm) |
|---------------------|-------------------|-----------|
| 710                 | 0.5               | 0.16      |
| 1120                | 1                 | 0.16      |
| 1800                | 1.5               | 0.16      |

Figure 1 Titanium Nitride coated tool insert.
3. Results and Discussions

The evaluations of Titanium Nitride (TiN) coated cutting tool with respect to cutting forces and surface roughness measurements were determined and obtained results from ground nut oil.

Cutting forces measurement: The turning operation is carried out for TiN coated cutting tool using groundnut oil as cutting fluid with respect to cutting forces at various machining conditions. As we discussed in the beginning the experimentation aims at coated tool chosen Titanium Nitride (TiN) as coating to cutting tool. The results are shown in Table 3. Also, it was represented in graphical form in Fig. 2. The TiN is an extremely hard and tough material which is used as coating on various components to increase surface properties. The measurement of the forces are shown in the below Fig. 2.

![Fig. 2 Cutting forces measurement by using dynamometer.](image)

The results shows that at minimum speed i.e., 710 RPM the increase in depth of cuts i.e., 0.5mm/rev, 1mm/rev and 1.5mm/rev increases the cutting forces that are developed when the cutting tool is brought near rotating work piece. Similarly when the speed increases i.e., 1120 RPM & 1800 RPM and the turning operation is carried at the same depth of cut that we have discussed earlier the cutting forces tend to decrease. If we compare the cutting force values at same depth of cut i.e., 0.5mm/rev at different cutting speeds, the cutting forces values decreased from 51 N/mm² to 46 N/mm². Similarly if we observe the values at 1.5mm/rev depth of cut there was a decrease in the cutting forces from 85 N/mm² to 58 N/mm². It shows that the increase in depth of cut at constant speed will results in increasing cutting forces and increase in cutting speed will result decreasing cutting forces. The results obtained in turning operation with ground nut oil were showing reduction in the cutting forces are shown in Fig. 3. Table.3 cutting forces values for TiN coated tool with ground nut oil.
Fig. 3. The graph shows the relationship between cutting forces and speed

Table 3 cutting forces values for TiN coated tool with ground nut oil

| S. No | Feed (mm/rev) | Spindle Speed (RPM) | Depth of cut (mm) | Cutting forces (N/mm²) |
|-------|---------------|---------------------|------------------|------------------------|
| 1     | 0.16          | 710                 | 0.5              | 51                     |
| 2     | 0.16          | 710                 | 1                | 67                     |
| 3     | 0.16          | 710                 | 1.5              | 85                     |
| 4     | 0.16          | 1120                | 0.5              | 48                     |
| 5     | 0.16          | 1120                | 1                | 62                     |
| 6     | 0.16          | 1120                | 1.5              | 74                     |
| 7     | 0.16          | 1800                | 0.5              | 46                     |
| 8     | 0.16          | 1800                | 1                | 53                     |
| 9     | 0.16          | 1800                | 1.5              | 58                     |
Fig. 4 Surface roughness measurement by using Talysurf.

**Surface roughness measurement**: The turning operation is carried out for TiN coated cutting tool using groundnut oil as cutting fluid with respect to surface roughness at various machining conditions. The obtained values are graphically represented in Fig. 4. The surface roughness measurement results were shown in Table 3.

The results showed that at minimum speed i.e., 710 RPM the increase in depth of cut i.e., 0.5mm/rev, 1mm/rev and 1.5mm/rev increases the surface roughness values. Similarly when the speed increases i.e., 1120 RPM & 1800 RPM and the turning operation is carried at the same depth of cut that as discussed earlier the surface roughness value tend to decrease. Comparing the surface roughness values at same depth of cut i.e., 0.5mm/rev at different cutting speeds, the roughness value decreased from 5.79 Ra to 4.39 Ra. Similarly, the measurements at 1.5mm/rev depth of cut, initially roughness is high, but increase speed there is much decrease in the roughness from 7.21 Ra to 6.02 Ra. This shows that the increase in depth of cut at constant speed will results in increasing the roughness at the same
time increase in cutting speed will result decreasing in roughness. From the above results, it is clear that as the speed increases the surface roughness value decreases which indicates the smooth finish of the component. The TiN coated cutting tool for groundnut oil with respect to surface roughness shows that the roughness was reduced for TiN coated tool. The graph is drawn (see Fig. 5) to represent the trend with respect to surface roughness for TiN coated cutting tool with groundnut oil with respect to Table 4 results.

4. Conclusions
This experimental investigation was performed on Titanium Nitride coated tool in turning of Mild steel under wet conditions. On the basis of various experiments and study of the results, the following conclusions have been drawn.
1. The cutting forces are enhanced with the increase in depth of cut and decreases with the speed similarly surface roughness increased with increase in depth of cut and decrease with the speed.
2. In this work the Depth of cut was found to be the most influential parameter to enhance the cutting forces followed by the feed.
3. Other observations, the groundnut oil increases the tool life, surface finish and dimensional accuracy of the base metal. The cutting fluid offer higher cutting speeds, feed rates and depths of cut so that material removal rate has to be increased.
4. TiN coated inserts gave better performance followed by uncoated with fluid as compared to uncoated carbide insert.
5. Lower cutting forces have been observed in case of TiN coated followed by uncoated with fluid as compared to uncoated tool.

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Table 4: Surface roughness measurement for TiN coated tool with groundnut oil

| S. No | Feed (mm/rev) | Spindle Speed (RPM) | Depth of cut (mm) | Surface roughness (Ra) |
|-------|---------------|---------------------|------------------|-----------------------|
| 1     | 0.16          | 710                 | 0.5              | 5.79                  |
| 2     | 0.16          | 710                 | 1                | 6.43                  |
| 3     | 0.16          | 1120                | 1.5              | 7.21                  |
| 4     | 0.16          | 1120                | 0.5              | 5.42                  |
| 5     | 0.16          | 1120                | 1                | 6.04                  |
| 6     | 0.16          | 1120                | 1.5              | 6.72                  |
| 7     | 0.16          | 1800                | 0.5              | 4.39                  |
| 8     | 0.16          | 1800                | 1                | 5.61                  |
| 9     | 0.16          | 1800                | 1.5              | 6.02                  |
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