Estimation of Tool Life by Industrial Method and Taylors Method Using Coated Carbide Insert in Turning of Work-Material Ss316L

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Abstract. In metal cutting process, selection of process parameters is important to enhance the machining performance and to improve the production rate. Tool life plays a vital role in deciding the overall productivity of manufacturing. In this paper, turning experiment is conducted to calculate the tool life of coated carbide insert in wet environment in a CNC lathe machine. The work material used was stainless steel SS316L. The tool life was calculated by industrial method that is by taking into account the number of jobs turned till it is declared fail, and then tool life is calculated by using theoretical method (Taylor’s tool life Equation). During the turning operation modes of tool failure were identified.

1. Introduction
Increasing demand for good quality smooth surface has led to optimize the machining processing. Over the past decades, researchers are trying to optimize the parameters affecting tool life such as feed, depth of cut, material hardness etc[1–4]. Tool life basically indicates the amount of time, tool point can perform a metal cutting process or the satisfactory performance given by a single point tool until it is considered failed. Study of different types of tool inserts and developing method for monitoring tool life is an important aspect in any machining industry which can save a lot of time thereby saving cost. Proper selection of tool material has a huge impact on the tool life. Manufacturing a new tool is costly and even time consuming. The existing tool is coated with materials like titanium or carbide in single layer or multilayered by CVD/PVD technologies depending upon the type of application. For Mass production industries multilayered coated carbide is economical and provides good surface finish [5]. During any metal cutting process tools are highly influenced by the amount of heat that gets generated due to chip removal at the face and the flank. Moreover because of thermal and mechanical stress, physical and even chemical changes take place in the tool, because of this the tool loses its cutting properties and can cause plastic deformation or even fracture. Now a days there is an increasing demand for stainless steel because of its properties of high strength, low thermal conductivity but has a problem of poor machinability [6].
2. Literature Reviews

Dubovská et al. (2016) [6] conducted an experimental study on turning of material DiN 1.4301 with coated carbide insert to find out the influence of cutting speed on tool life and showed that tool life reduces with higher cutting speed. Tyagarajan [5] used EN hardened steel as work material and multilayered AL-Ti-N coated carbide insert as cutting tool in a dry cutting environment and concluded that tool life increases due to coating. Senthil Kumar et al. (2006) [7] performed an investigation using martensitic steel with alumina based ceramic tool and showed that tool life is affected by flank wear at lower speed and crater and notch wear at high speed.

Ghubade et al. (2015) [8] demonstrated an experiment on EN27 steel with coated and uncoated carbide insert and found that coated carbide insert has more tool life than uncoated carbide insert. Baviskar et al. [9] performed an experiment on AISI 4340 using tool insert of tungsten carbide material and another tool coated by AL2O3 and proved that Tool life significantly increases by using coated tools. Rao et al. (2014) [10] showed that tool life decreases with increase in cutting force, MRR and cutting speed by performing an experiment on aluminum work material by using a single point tungsten carbide.

Qehaja & Kyçyku, (2017) [11] focused on experiment using hardened 42CrMo4 steel to find out the cutting parameters that influence the tool life. Observational details say that tool life decreases with increasing speed, depth cut, material hardness and feed rate. Bh et al. [12] discussed the most common causes of failure of tools. Kumbhar & Waghmare, n.d. [13] reported that feed is the most important factor that affects tool life by performing an experiment using hardened EN31 alloy steel using PVD multilayer carbide insert for the estimation of tool life. Wongpanya et al. 2013 [14] successfully conducted an experiment to increase the tool life by coating the end mill cutter with ALcrTisiN film.

Krogstrup et al., 2013 [15] experimented using duplex stainless steel using TNMG inserts and reported that longer tool life was obtained at low range of feed value. Work reported in Calaph et al. (2020) [16] describes turning of AISI 416 steel using one tool of plasma enhanced CVD and another tool of PVD nanocoated tools. Wear rate of Plasma enhanced CVD tool was low as compared to PVD nanocoated tools, hence Plasma enhanced CVD tools gave more tool life. A study was performed on AISI 304 steel using coated carbide insert to find out the relation between tool life and cutting speed. Results show that as cutting speed increases tool life decreases [17].

3. Experimental Work

In this study we have calculated the tool life of a coated carbide insert by using industrial method, which is by counting the number of job the tool can machine until tool it is declared fail and finding out time in minutes to machine these jobs. Secondly we calculate tool life by using Taylor’s tool life equation. Types of tool wear that take place during the machining of jobs are identified.

3.1. Work Material and Tool used.

Different types of cutting tool are available for rough, semi finish and finish turning on CNC machine. Figure1 (a) shows coated carbide insert of Grade TNMG-160404MS is used for the turning operation.
This type of tool is mostly used for mass production due to its capacity of high speed cutting, good crack resistance and reduction in cutting time due to effective chip control.

Figure 1. (a) Coated carbide Insert; (b) Raw Material-SS316L

Figure 1(b) represents Stainless steel SS316L is used as the work material. This steel has particle size of about 150µm has fatigue strength of 65-72Mpa and tensile strength of about 300MPa[18]. CNC machine used for turning operation is SUPER JOBBER-1428 manufactured by ACE designers limited with Fanuc Oi-Mate –TD controller is shown in Figure 2

Figure 2. Super Jobber CNC

3.1.1 Industrial method

Industrial method for calculating the tool life is to calculate the number of jobs the tool can machine before it is declared failed. We are performing rough turning operation of material SS316L. Time for roughing one job is 27 seconds. Figure 3 shows work material after roughing cycle. During the rough turning operation the following parameters were kept constant

1. Vc=120 rev/min
2. RPM= 2000
Figure 3. Output of Rough turning

Table 1 shows the number days and the number of jobs machined before the tool was declared failed.

| No. of days | No. of Job done before tool failure |
|-------------|------------------------------------|
| Day 1       | 80                                 |
| Day 2       | 70                                 |
| Day 3       | 75                                 |
| Day 4       | 77                                 |
| Day 5       | 75                                 |
| Day 6       | 79                                 |
| Day 7       | 80                                 |
| Day 8       | 83                                 |
| Day 9       | 92                                 |
| Day 10      | 89                                 |
| Day 11      | 73                                 |
| Day 12      | 76                                 |

Average tool life = \( \frac{80+70+75+77+79+80+83+92+89+73+76}{12} \) = 79 Jobs

For roughing, one Job it takes 27 seconds.
Therefore, for roughing 79 jobs, it takes 2133 seconds.
That is 2133/60 = 35.55 minutes.

3.1.2 Theoretical method

Theoretical method of calculating the tool life is by using Taylors tool life equation

\[ VT^a = C \] \[ 120 \times T^{0.4} = 500 \]

\[ T = 35 \text{ minutes.} \]
3.1.3 Tool wear
Figure shows the tool wear that took place during the rough turning operation
1) Flank Wear: Flat surface perpendicular to rake face is called the flank. Flank wear is shown Figure 4 by the blurred mark on the surface. Energy required to remove the material increases due to flank wear.

![Flank wear](image)

Figure 4. Flank wear

2) Brittle Wear: Brittle wear occurs when the tool is not able to support the cutting force over tool chip interface. This results in removal of small part of tool. Tool is not able to perform cutting operation after this type of failure. Refer Figure 5

![Brittle wear](image)

Figure 5. Brittle wear

4. Results
The Table 2 shows the results were obtained by turning SS316L using coated carbide insert.

| Method Used          | Tool life in Minutes |
|----------------------|----------------------|
| Industrial Method    | 35.55                |
| Theoretical Method   | 35                   |

2. Two type of tool failure modes were observed during the turning operation,
   1. Flank wear
   2. Brittle Wear
5. Conclusion
There are many methods for estimation of tool life used by different industries. Experimental results indicate that both industrial method and theoretical methods can be used successfully for evaluation of tool life. Industrial method for evaluation of tool is based on counting the number of jobs a tool can machine until tool is declared failed and is purely based on the expertise of the operator, moreover it takes many days to evaluate the tool life by this method. Theoretical methods which is based on Taylors tool life equation has more scientific approach in calculating the tool life as it used the number of input such as machining constant(C), function of tool workpiece interface (n) etc. Theoretical method can be successfully implemented for measuring the tool life in machining industries saving, operator time, rework cost, machining cost etc. Flank wear and brittle wear were found to be the most common cause of tool failure.

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