Experimental Analysis on Tool Life during CNC by Determining Optimum Process Parameters

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***Abstract*—** In any CNC operation the features of tools, input work materials, machine parameter settings will influence the process efficiency and output quality characteristics. For ensuring a lower cost of manufacturing tool signature, tool and work piece plays a major role and so the cutting conditions i.e. Speed, Feed and Depth of cut plays an important role in the efficient use of a machine tool. In order to determine the optimum cutting conditions, one has to estimate the tool life and cutting forces with a reasonable degree of accuracy since many of the constraints those are applying on a process are influenced by these parameters. By using Tool is Tungsten Carbide Insert and Work piece is Mild Steel to obtain an effective and efficient outcome. Hence this Paper proposes an alternative approach to determine the optimal process parameters used to predict cutting forces, tool life and surface finish.

Keywords— CNC machining, Tool Signature, Surface Finishing, Tungsten Carbide Insert and Mild Steel.

I. INTRODUCTION

Metal cutting is one of the important and widely used manufacturing processes in engineering industries. The study of metal cutting focuses on the features of tools, input work materials, machine parameters and output quality characteristics. A significant improvement in process efficiency may be obtained by process parameter optimization that identifies and determines the regions of critical process control factors leading to desired outputs or responses with acceptable variations ensuring a lower cost of manufacturing. For a machining process such as turning, the cutting conditions like cutting speed, feed, depth of cut and cutting fluids plays an important role in the efficient use of a machine tool. For a practical machining situation, since no adequate machining theory is available to predict the tool life and cutting forces, one is compelled to rely on empirical equations to predict these parameters. However, these empirical equations involve a number of constants which are not readily available.

Hence this paper proposes an alternative approach to predict cutting forces, tool life etc.

II. EXPERIMENTAL PROCEDURE

Machining test was performed on a CNC machine. Cutting operation performed under various cutting condition like cutting speed, feed rate, depth of cut. In this experiment turning operation performed on mild steel and single point cutting tool with Carbide insert used as a cutting tool for experimentation. The dimension of the work piece samples are 90 mm length and 32 mm diameter. Work piece have been machined under different cutting speed, feed rate and depth of cut. The CNC machine with a spindle speed range 3500 RPM was used in machining. For experimentation Mild steel bar clamped in the CNC machine. CNC machine was driven by 0.18kw electric motor. The experiment was done under dry machining operation. In this investigation Tool life is determined by Taylor's equation and surface roughness determined by surface roughness tester.

III. PROPOSED WORK

A. Input Parameters

1) Speed

Speed always refers to the spindle and the work piece. When it is stated in revolutions per minute (rpm) it tells their rotating speed. But the important feature for a particular turning operation is the surface speed, or the speed at which the work piece material is moving past the cutting tool. It is simply the product of the rotating speed times the circumference of the work piece before the cut is started. It is expressed in meter per minute (m/min), and it refers only to the work piece. Every different diameter on a work piece will have a different cutting speed, even though the rotating speed remains the same.

$$V = \pi * D * N / 1000 \text{ m/min}$$

Here, v is the cutting speed in turning, D is the initial diameter of the work piece in mm, and N is the spindle speed in RPM.

2) Feed

Feed always refers to the cutting tool, and it is the rate at which the tool advances along its cutting path. On most power-fed lathes, the feed rate is directly related to the spindle speed and is expressed in mm (of tool advance) per revolution (of the spindle), or mm/rev.

$$F = f * N \text{ mm/min}$$

Here, F is the feed in mm per minute, f is the feed in mm/rev and N is the spindle speed in RPM.

3) Depth of Cut

Depth of cut is practically self explanatory. It is the thickness of the layer being removed (in a single pass) from the work piece or the distance from the uncut surface of the work to the cut surface, expressed in mm. It is important to note, though, that the diameter of the work piece is reduced by two times the depth of cut because this layer is being removed from both sides of the work.

$$d = (D - d)/2 \text{ mm}$$

Here, D and d represent initial and final diameter (in mm) of the job respectively.

B. Output Parameters

1) Tool Life: Tool life generally indicates the amount of satisfactory performance or service rendered by a fresh tool or a cutting point till it is declared failed. Tool life is the time period between two consecutive resharpening, with which the tool cuts the material effectively. Tool life is important factor in production work since considerable time is most whenever a tool is resharpened and reset on the machine.

Taylor tool life Equation

$$VT^n = C$$

V = cutting speed, m/min
T = Tool life, min
n = Tool life index,
C = Machining index.

2) Surface Roughness: Surface roughness is the measure of the finely spaced micro irregularities on the surface texture, which is composed of three components, namely roughness, waviness, and form. In this experiment surface roughness measured in micron (μm) and roughness measured in Ra value.

Cutting Tool and work material used:

Work material:

EN19-Mild Steel

En19 steel is a high quality engineering medium carbon alloy steel containing chromium (1.5%), manganese (0.60%), carbon (0.36%) and silicon (0.15) and majorly iron (96%). It has high fatigue strength, impact resistance, toughness, and torsional strength.

Tool material:

- A tungsten carbide insert tool is a cutting tool used in machining operations ,particularly in metal working processes for turning. Tungsten carbide inserts are made from a combination of **tungsten carbide powder and a binder metal**, typically **cobalt**. This composite material offers exceptional **hardness, wear resistance, and heat resistance**, making it ideal for cutting applications.
- It has **6 cutting** edges.

IV LITERATURE SURVEY

Literature on machining is huge and considerable amount of work has been done on analysis of tool life during machining. Most of the existing research focuses on influence of different parameters on tool life. Some literature related to the proposed works is given below.

Axinte et al. [1] in turning process, they proposed a methodology of evaluating those uncertainty components of a single cutting force measurement that are related to the contributions of the dynamometer calibration and the cutting process itself. On the basis of empirical model including errors from both the sources, the uncertainty for a single measurement of cutting force, and expressions for the uncertainty vs. cutting parameters are presented. For defined range of cutting parameters approach gives the possibility of evaluating cutting force uncertainty components, on the basis of few experiments.

Dahlman et al. [2] have conducted the study on the influence of rake angle, cutting speed and cutting depth on residual stresses in hard turning the results of their work shown that a greater negative rake angle gives higher compressive stresses and the compressive stresses increase with the increased feed rate.

Zhou et al.[3] have investigated the effect of chamfer angle on the wear of PCBN cutting tool. They concluded that the chamfer angle has a great influence on the cutting force and tool life and all the three force components increase with an increase of the chamfer angle. The optimized chamfer angle, for the maximum tool life as suggested by their study, is 15°.

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Chou and Song[4] have investigated the effects of tool nose radius on finish hard turning with ceramic tools. In their study, surface finish, tool wear, cutting forces, and, particularly, white layers were evaluated at different machining conditions. Their results shown that large tool nose radii not only give finer surface finish, but also considerable tool wear compared to small nose radius tools. Specific cutting energy also increases slightly with tool nose radius. They also have shown that large nose radius tools generate shallower white layers when cutting by worn tools. For new tools, small nose radius results in larger uncut chip thickness, and thus, induces deeper white layers.

Endres and Kountanya [5] have reported the effects of comer radius and edge radius on tool flank wear. The results of their work shown the interaction of corner radius and edge radius and their effects on process performance, measured in terms of tool flank wear and forces. Finally they concluded that there is an advantage exists in using a larger corner radius when using a larger edge radius.

Huang and Liang [7] focused on the finish turning in which the applied feed rate and depth of cut are usually very small. They initially predicted the chip formation forces by transforming the 3-D cutting geometry into an equivalent 2-D cutting geometry and after that calculated the total 2-D cutting forces by ploughing effect mechanistic model and finally then 3-D cutting forces are estimated by a geometric transformation.

Dahlman et al. [8] showed that rake inclination had the strongest influence on the residual stresses in turning. The residual stresses were measured by using the X-ray diffraction method in both speed and feed direction and concluded that greater negative rake angle gives higher compressive stresses and cutting depth does not affect residual stresses. Further it has been shown that compressive stresses become greater with increased feed rate.

V RESULT AND ANALYSIS

Evaluation of the parameters during turning operation:

The Expanded Taylor's tool life equation used in evaluating the parameters i.e. $\mathbf{VT^nF^aD^b=C}$. The exponents a and b are to be determined experimentally for each combination of cutting conditions. In practice typical values for carbide tools and mild steel as work piece are n=0.33, a=0.6, b=0.15 and c=80.

$$VT^{0.33}\,F^{0.6}\,D^{0.15}=80$$

The mathematical formulas used in calculating different parameters are as follows

(i) Power Required: P= (K x D x V x F)/ (60*1000)

(ii) *Cutting Force*: F = (KxDxF)

(iii)*Metal removal Rate (MRR)*: The MRR is Volume removed in machining Process per Machining Time. Where Volume removed is = (Initial weight of work piece - Final weight of work piece) /density of work piece.

We have taken mild steel as work piece material and carbide insert as tool material. Cutting speed, feed and depth of cut are taken as input parameters. Tool life and surface roughness are taken as output parameters. The relation between input and output parameters are shown in below table. The results are also shown in the table.

Sr No.	Spindle Speed (RPM)	Cutting Speed (m/min)	Feed rate (mm/rev)	D.O.C (mm)	Tool Life (min)	Surface Roughness (µm)
1	600	75	0.1	0.5	74	0.50
2	600	75	0.15	1.0	28.87	1.26
3	600	75	0.2	1.5	15.78	1.63
4	800	100	0.1	0.5	23.42	0.83
5	800	100	0.15	1.0	11.75	1.47
6	800	100	0.2	1.5	7.02	1.93
7	1000	125	0.1	0.5	9.59	1.12
8	1000	125	0.15	1.0	5.85	1.72
9	1000	125	0.2	1.5	4.26	1.33

VI CONCLUSION

The above work is experimentally investigated on the CNC machine. In this work mild steel taken as a work material and carbide insert used as tool material. By varying the different parameters like cutting speed, feed rate and depth of cut at different condition the tool life and surface roughness are calculated. The results showed that the tool life is decreasing as the speed, feed and depth of cut increasing. The all parameters are inverse relation with tool life. A lot of work has been done in finding out optimum values of cutting parameters which provide best surface finish. The optimal combination of low feed rate and low depth of cut is beneficial for good surface finish.

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