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Optimization of Machining Parameters for Face Milling Operation using ANOVA

G. Tamil Kumaran, R. John Stephen
(Mechanical Engineering, Apollo Priyadharshanam Institute of Technology, Anna University, India)

ABSTRACT : *To remain successful in today's competitive market, the manufacturers should rely on their Engineers and production professionals for quick and effective manufacturing setup and also to achieve Quality products. The machining process on a CNC Milling is programmed by speed, feed rate, and cutting depth, which are frequently determined based on the job shop experiences However, the machine performance and the product characteristics are not guaranteed to be acceptable. Therefore, the optimum Face Milling conditions have to be accomplished. This will increase the setup time and decrease the productivity. It will be interesting to machine EN19/EN31 steel with PVD and CVD coated tools on FANUC series Vertical CNC Milling for these types of experiments. At the end of this experiment, the effective of machining parameters for good surface finish are determined.*

Keywords - *Computer Numerical Control, Optimization, Physical, Chemical Vapor Deposition inserted tool, Analysis of Variance*

I. INTRODUCTION

The manufacturing industry is constantly striving to decrease its machining cost and increase the quality of the machined parts as the demand for high tolerance of manufactured goods is rapidly increasing. The requirement to boost productivity, to machine more difficult materials and to improve quality in quantity by the manufacturing industry has been the driving force behind the Optimization of machining parameters.

First introduced (around 1926) cemented carbides are the most popular and most commonly high production tool materials available today. One important aspect that is being vigorously researched and developed is the hard coating for cutting tools to achieve superior tribological attainment. These hard coatings are thin films that range from one layer to hundreds of layers and have thickness that range from few nanometers to few millimeters. This increase in tool life allows less frequent tool changes, therefore increasing the batch sizes that could be manufactured and in turn, not only reducing manufacturing cost, but also reducing the setup time as well as the setup cost. In addition to increasing the tool life, hard coating deposited on cutting tools allows consistent surface finish of the machined area. The cutting tools need to be capable to meet the growing demands for higher productivity and economy as well as to machine the exotic materials which are coming up with the rapid progress in science and technology.

1. Tool

CVD coatings are used in many manufacturing applications as a wear-resistant coating: carbide milling and turning inserts, wear components, some plastic processing tools, etc. However, the most common application for CVD Coating is for metal–forming tools. In high stress metal-forming applications, where the tool's tolerances and substrate permit, high temperature CVD coating processes will perform better than "cold" processes like PVD, thin-dense chrome (TDC), nitriding, etc. The chemical/metallurgical bonding that results from the CVD coating process creates adhesion characteristics that simply cannot be duplicated by a "cold" process.

PVD (TiN, TiCN, etc) tool has very strong bond between the coating and the tooling substrate and tailored physical, structural and tribolgical properties of the film PVD , CVD coating compositions have shown the benefit of:

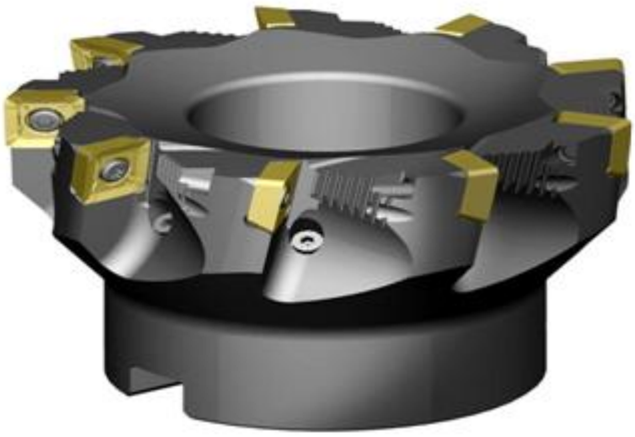

Fig. 1. Face Milling Cutter with Inserted Tool

1. Reduced down-time towards tool changing
2. Increased production rate
3. Improved finished surface quality

2. Work Material

EN31 is a high carbon alloy steel which achieves a high degree of hardness with compressive strength and abrasion resistance.

C.	Mn.	Cr.	Si.
1.00%	0.50%	1.40%	0.20%

EN19 is a high quality, high tensile alloy steel usually supplied readily in machined 'T' condition, giving good ductility and shock resisting properties combined with resistance to wear. The composition of EN19 die steel is listed below:

C.	Si.	Mn.	Cr.	Mo.
0.40%	0.25%	0.70%	1.20%	0.30%

3. Milling Operation

Milling is the process of removing metal by feeding the work past a rotating multipoint cutter. In milling operation the rate of metal removal is rapid as the cutter rotates at a high speed and has many cutting edges. Thus the jobs are machined at a faster rate than with single point tools and the surface finish is also better due to multipoint cutting edges. Milling operation may be considered as the combination of peripheral and face milling operations. The cutter has teeth both on the end face and on the periphery. The cutting characteristics may be of peripheral or face milling type according to the particular cutter surface used.

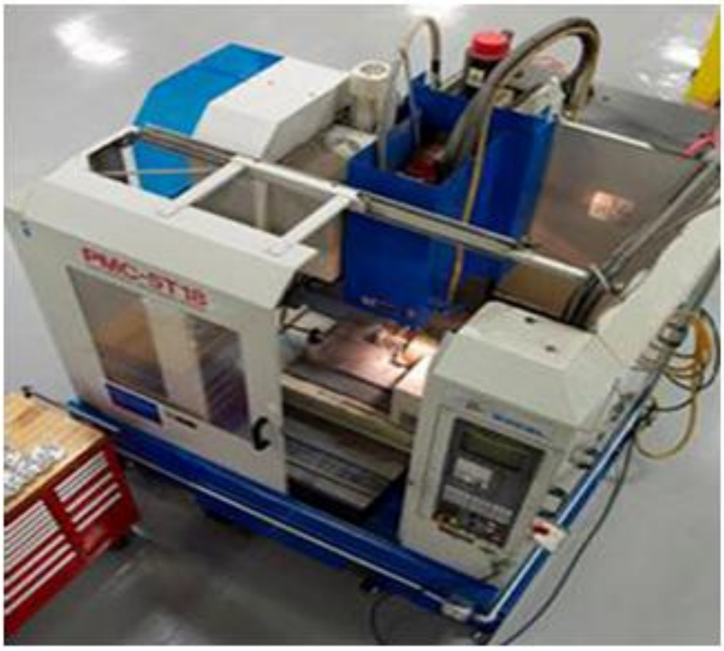

Fig. 2. CNC- Vertical Milling Machine

II. OBJECTIVE

The main objective of this project is to examine proper or optimum machining parameters values for doing specific face milling operation on FANUC series VMC. This experiment is tested with EN19 die steel (high tensile alloy steel) and tool chosen are PVD and CVD coated inserted tool. It is expected that this condition is best suited for obtaining the optimal machining parameters (spindle speed, feed and depth of cut) to achieve good quality surface finish.

III. LITRATURE SURVEY

In earlier case, Julie Z.Zhang et al. (2006) determined optimum cutting parameters for face milling through the Taguchi parameter design method. The experiment results showed that the effects of spindle speed and feed rate on surface roughness were larger than depth of cut for milling operations. In addition, one of the noise factors, tool wear was found to be statistically significant.

1. Study the change of surface finish throughout the tool life of each cutting tool.
2. Asses and analyze the results obtained for each tool, and evaluate their performance based on the effects of the coating material used.
3. To achieve the project objectives, multiple regression analysis is used for statistical method and ANOVA method.

Shau et. al. has reported the work on end milling of 3% Co and 12% Cr heat resistance stainless steel. They have found that small rake angles give longer tool life and large rake gives steady machined surface integrity. Coating over the tool effectively decreases the formation of adhesive layer on tool and no BUE observed on inserts.

About-El-Hussein et al. has done the experiments using AISI304 stainless steel. They had observed that increase in cutting speed caused a dramatic reduction in tool life and feed variation at high cutting speeds had small effect on tool life.

After all the discussion done by various researchers it was found that no one has handled SS above 150 m/min, using end milling cutter. Also there is no sufficient data available about the effect of feed, as well as surface finish of the machined surface.

In this work, we have investigated the effect of speed and feed on the tool life of coated carbide inserts, while machining EN19/EN31 steel.

IV. MACHINING PARAMETERS

1. Cutting speed

The relative motion of the work piece past the cutting edge is cutting speed which is calculated from the following relation.

Cutting Speed (v) = $\pi DN/60$ m/min

Where D-Diameter of the cutter

N-Rpm of the cutter

2. Feed

The feed in a milling machine is defined as the rate with which the work piece advances under the cutter. The feed per minute is defined by the distance the work advances in one minute . It is expressed in mm/min.

3. Depth of Cut

The depth of cut in milling is the thickness of the material removed in one pass of the work under cutter. It is the perpendicular distance measured between the original and final surface of the work piece and is expressed in mm.

DOC = (d1-d2) / 2

d1 = diameter of the work surface before machining

d2 = diameter of the work surface after machining

4. Material Removal Rate

Material removal rate is the volume of the material removed per minute . It is expressed in mm3/min which is calculated by using the formula given below

MRR=B*t*T

Where B - width of the cut in mm

T - Table Travel in mm/min

t - depth of cut or thick of cut

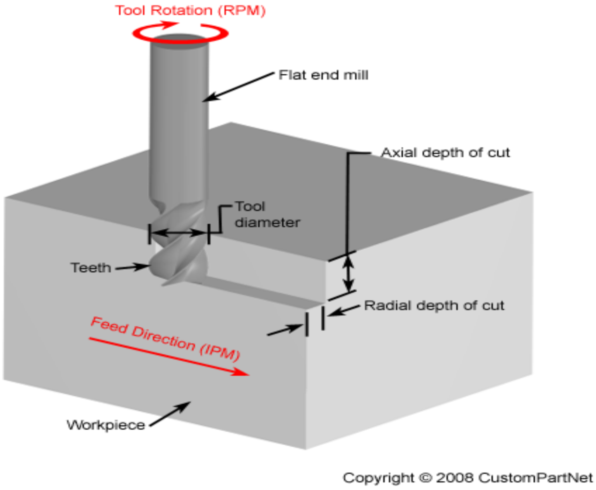

Fig. 3. Different Machining Parameters

5. Surface Roughness

Whatever may be the manufacturing process, an absolutely smooth and flat surface cannot be obtained. The machine elements or parts retain the surface irregularities left after manufacturing The surface of a part is exterior or boundary and the surface irregularities consists of numerous small wedges and valleys that deviate from a hypothetical nominal surface. These irregularities are responsible to a greater extent for the appearance of a surface and its suitability.

Surface roughness value is measured by roughness tester and is denoted as *Ra.*

Fig. 4. Surfest SJ-210 Portable Surface Roughness Tester

IV. METHODOLOGY

Surface finish is one of the most important quality characteristics in manufacturing industries which influences the performance of mechanical parts as well as production cost. In actual practice, there are many factors which affect surface roughness, e.g., cutting conditions, tool variables and work piece variables. Cutting conditions include speed, feed and depth of cut where as tool variables include tool material, nose radius, rake angle, cutting edge geometry, tool vibration, tool overhang, tool point angle etc. and work piece variable include material hardness and other mechanical properties. However, it is very difficult to control all the parameters at a time that affect the surface roughness for a particular manufacturing process. In a turning operation, it is a vital task to select the cutting parameters properly to achieve the high quality performance.

A. Methodology involved

- Identification of Problem
- Selection of Machine work piece and tool
- Choosing of machining parameters
- Conduct the experiments
- Check the Roughness value
- Model the process
- Optimization of process parameter
- Repeat the experiment for another set of values
- Valediction of result

4. ANOVA PROCEDURE

Analysis of variance is powerful statistic and core technique for testing causality in nonlinear models. ANOVA used to test the process variables for significant effect on objective function of the desired model. According to ANOVA if the Probability "P-value >F" less than 0.05 than said to be the model terms are significant.

The design of experimentation has a significant role on the number of experiments needed. Therefore cutting experiments have to be designed. In this study a 3 level full factorial were performed to obtain the surface roughness values. A total of 27 experiments can be conducted at 3 levels for the three input variables speed, feed, and depth of cut.

Table. 1 shows the minimum, maximum and average values of the machining parameters

Sl. No	Cutting Speed (m/min)	Feed Rate (mm/rev)	Depth of Cut (mm)
1	100	0.2	0.2
2	150	0.25	0.3
3	200	0.3	0.4

Following steps are involved in ANOVA procedure

a. Calculate the Square for the X value

b. Sum the X and X^2 Value

c. Compute the Sum of Squares Value by using the Formulae given below

d. sum of squares within

1. $SS = \sum X^2 - \frac{(\sum X)^2}{n}$ → sum of squares within

2. $$SS_{total} = \sum X^2 - \frac{G^2}{N}$$

3. $SS_{betw} = [\sum \frac{T^2}{n}] - \frac{G^2}{N}$ → sum of squares between

e. Calculate the degrees of freedom

1. Total= N-1 where N means the total number of samples

2. Within= N-K where k means number of treatment

3. Between=K-1

f. Calculate the mean square value for between and within values

$$MS_{between} \frac{SS_{between}}{df_{between}}$$

$$MS_{within} \frac{SS_{within}}{df_{within}}$$

g. Calculate the F Value

Finally the optimum values are determined with 5% significant level

V. CONCLUSION

From the Literature reviewed, most of the researchers were interested in optimizing the parameters for CNC Turning operation using coated and or uncoated tools. None of them have involved in using PVD, CVD coated tool for Optimizing the machining parameters while face milling Operation with the help of ANOVA technique. For a high depth of cut, the material removal rate increases with increase in cutting speed. Better surface finish is produced by machining PVD inserts.

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