Effect of Chip Load on Surface Finish In High Speed Micro Milling.

Vivek B. Pansare, Sunil B. Sharma

Abstract: *In a modern manufacturing of sophisticated parts with3D sculptured surfaces such as dies and moulds bull nose face milling is one of the most widely used machining process. Due to the rapid growth, competitiveness and high accuracy miniaturized components are increasingly in demands for various industries viz. aerospace, electronics and automotive etc. In this paper the study presents the result of test done with high speed face milling machine tool. Experiments wear performed to investigate the influence of chip load (feed per tooth) on surface roughness along with cutting parameters such as cutting speed and depth of cut for HcHcr steel as work material. To predict the value of surface finish, empirical equation is developed using linear regression analysis. This equation is validated by equivalence variance test i.e. F- test.*

Keywords: *Chip load, micro milling, F-test, high speed machining.*

Introduction:

These days, miniaturization is rising in importance, increasing the need for micro-components for more and more industrial fields. Therefore micro-machining processes are in full expansion. One of them is micro-milling, whose applications are varied in terms of machinable materials (metallic alloys, composites, polymers and ceramics) and areas (micro-injection moulds, watch components, optical devices, components for the aerospace, biomedical and electronic industries).

The principles of micro machining are similar to those of conventional cutting operations. The surface of the work piece is mechanically removed using micro tools. Unlike conventional macro machining processes, micro machining displays different characteristics due to its significant size reduction. Most chip formation investigation are derived from macro-ultra-precision diamond and hardened steel cutting operations, with numerous publication on the effect of round edges and minimum chip thickness.

Micro-milling is a micro-manufacturing techno-logy by removal of material making it possible to produce parts and features ranging from several mm to several µm. It requires a miniature tool (called a micro mill) with a diameter between 100 µm and 500 µm, which is often in tungsten carbide in order to allow ferrous material machining. Micro-milling seems to be the most flexible and the fastest way to produce complex tri dimensional micro-forms including sharp edges with a good surface finish[1].

Minimum chip thickness in micromilling the depth of cut and the feed are very small, of the same order of magnitude as the tool edge radius. Below a certain value, called "minimum chip thickness", no chips formed. The concept of minimum chip thickness is that the depth of cut or feed per tooth must be over a certain critical chip thickness before a chip will form. Its value is often between 5 % and 38 % of the tool edge radius. [2].

The minimum chip thickness phenomenon leads to a rising of slipping forces and ploughing of the machined surface, contributing to the increase of cutting forces, burr formation and surface roughness. In order to correctly choose the cutting condition, it is therefore crucial to estimate its value. The strong dependency of the minimum chip thickness to the machined material and the tool geometry complicates this evaluation. [2,3]

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Literature Review

Vogler[4] made the first attempt to explicitly apply the minimum chip thickness concept in modeling the surface generation of the micro end milling. Vogler [4,5]also found that the surface generation process for multiphase ductile iron is affected by the micro burr formation occurring at the phase boundaries. The micro burr formation is attributed to the interrupted chip formation process as the cutting edge moves from one phase to another. Xinyu Liu [6] develops the surface generation models for the sidewall and floor surfaces consist of deterministic and stochastic models. In the sidewall surface generation model includes the effect of the process kinematics, dynamics, and tool edge serration and process faults. This model predicts the increased surface roughness generated from ploughing due to the significant tool edge radius effect. In the floor surface generation model considers the effects of the minimum chip thickness, the elastic recovery and transverse vibrations. This model is developed to generate 3d surface topography and surface roughness variation over the entire floor surface.

Ikawa[7] discussed the significance of minimum chip thickness of a cut under perfect performance of the metal

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cutting system. The minimum chip thickness was found to be more strongly affected by the sharpness of the cutting edge than by the tool – work interaction.

In microscale machining the relationship of the cut geometry to the work piece micro structure is also markedly different from micro scale machining. In microscale machining, where chip load may range from sub micron to a few micron and the depth of cut may be in the range of a few micron to perhaps 100 micometer[8].

Experiment Procedure and data collection:

Details of the machine tools, materials and tests, surface roughness measurement, model development and F test are explained as follows.

Machine Tool:

Makino Japan make Makino V33, 3 axis milling center was used for the experiment. Maximum spindle speed of 20000 rpm and feed 20000 mm/min., the machine tool has a 15KW motor.

Work material:

The work piece material High Carbon High Chromium (HcHcr) steel Cutting experiments were carried out in a block with dimensions 145mm (length) x 57 mm (width) x 22 mm (height) The chemical composition is given in table 1 .

Table 1: Material Composition for HcHcr steel.

Alloy	**C**	**Si**	**Mn**	**P**	**S**	**Cr**	**Mo**	**V**	**W**
HCHCR 58 HRC	1.46%	0.65%	0.3%	0.021%	0.015%	12.80%	0.91%	0.81%	0.50%

Cutting Tool:

The cutting tool used for experimentation was Solid Carbide Bull Nose D12R2 (PVD Coated 300 Helix, four Flute).

Design of Experiment:

For the experimentation three levels of depth of cut and cutting speed are chosen and feed is kept constant (600 mm/ min)through out the experiment. The experiment was conducted by considering L9 orthogonal array of Taguchi design. Chip load value was observed with the help of facility available with milling centre and was recorded when the tool first time interact (contact) with material for cutting.

Homell Tester made in Germany was used for surface roughness measurement in experimental work at NABL certified Dimensional Metrology Lab of IGTR. Three small regions on the machined surface were determined for measurement. The measurements in these regions were conducted and the average value of these measurements was recorded as the Ra value. The data collected by experiment is shown in table2.

Table 2. Surface Roughness and chip load.

Sr. No.	Depth of cut (µ)	Cutting Speed m/min	Chip Load (µ)	Roughness (Measured in µ)	Roughness (Calculated in µ)
1	1	8.8	0.81	0.32	0.32314
2	1	10.06	0.8	0.35	0.339858
3	1	11.31	0.79	0.36	0.356483
4	2	8.8	0.8	0.27	0.27144
5	2	10.06	0.79	0.28	0.288158
6	2	11.31	0.81	0.28	0.289783
7	3	8.8	0.79	0.22	0.21974
8	3	10.06	0.81	0.23	0.221458
9	3	11.31	0.8	0.24	0.238083

Empirical Equation

To determine the value of surface roughness for intermediate parameter of speed and feed an empirical equation was developed using the linear regression using MINIAB

Ra = 0.703 - 0.0567 d + 0.00930 vc - 0.500 ft

Where Ra= Surface Roughness, d= Depth of Cut, Vc= Cutting Velocity and ft= Chip Load

Coefficient of determination =**R^2 = 98.2 %**

Validation of Equation.

When we want to test the equality of variances of two normal populations, we make use of F-Test based on F distribution. F-Test is used in context of analysis of variance (ANOVA) for judging the significance of more than two sample means at one and the same time. It is also used for judging the significance of multiple correlation coefficients. Test statistic, F, is calculated and compare with its probable value for accepting or rejecting the null hypothesis.

H0 : $\beta1= \beta2 = \beta3 =0$

Note that this implies the alternative hypothesis

H0 : $\beta1 \neq 0$ or

$\beta2 \neq 0$ or

$\beta3 \neq 0$

Total sum of square (SST) = 0.0206

Error sum of square (SSE) = 0.00036574

Group sum of square (SSR) = 0.0202

Coefficient of determination = R2 = 0.9822

F ratio =F = 368.82

Analysis of Data:

To determine the most influencing factor which has effect on surface roughness, the collected data is analyzed by using Taguchi design analysis available in MINITAB.

The signal to noise ratio for surface roughness is shown in table3.

Table3. Response Table for Signal to Noise Ratios

Level	d	vc	ft
1	9.297	11.474	11.027
2	11.162	10.980	10.962
3	12.771	10.776	11.240
Delta	3.474	0.698	0.277
Rank	1	2	3

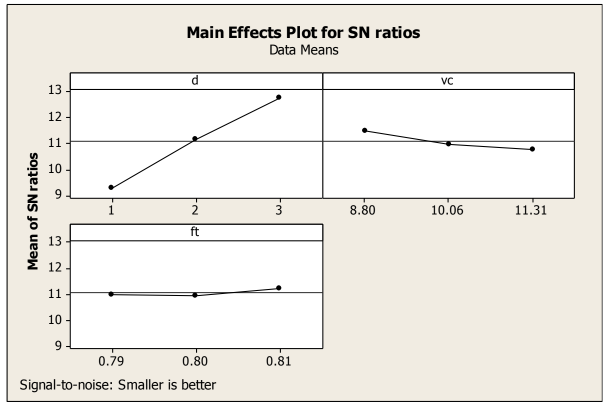

Fig.1: Signal to Noise ratio plot

Result and discussion:

For HcHcr steel standard error of the estimate is 0.01 i.e 1% and coefficient of determination i.e. R2 = 0.9822. This shows that the regression model as a whole is suitable estimating model which has less standard error of the estimate.

At 5 % level of significance the critical value for F distribution is 3.34 as calculated value for the same is much greater than critical F value so that the regression as a whole is significant.

In Taguchi analysis the major delta values for depth of cut, cutting speed and chip load as represented in Table 3 clearly indicate the relative influences in terms of the rank.

Conclusion:

Set of experiment design to begin the characterization of surface quality for the micro face milling process. Micro face milling have been performed, the effect of chip load, cutting speed and depth of cut on surface roughness of HcHcr steel was studied.

The empirical model generated, which includes the effect of chip load, cutting speed and depth of cut and predicts the surface roughness values. The deviation between predicted and measured surface roughness value was with in an error band of ±5%.

According to the rank of the parameter in Taguchi analysis, the depth of cut has most influence on surface roughness value where as chip load is less influencing factor.

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