AN EXPERIMENTAL ANALYSIS OF SURFACE GENERATION IN MICRO FACE MILLING

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Abstract

*These days, miniaturization is raising its importance in terms of increasing the need for micro-components for more and more industrial applications. Therefore micro-**machining** processes are in full expansion. One of them is micro-milling, whose applications are varied in terms of performance of the machinable materials. Principles of metal cutting enable to explain formation of surface after machining. Plain surface generation mechanism in face milling is studied in this paper and the model developed to predict the surface roughness value for intermediate cutting parameters. Also the intensity of the cutting parameter having influence on roughness value has been investigated.*

Index Terms*— ANOVA, chip load, Micro machining, Micro milling, Regression, surface roughness, Taguchi, etc..*

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1. INTRODUCTION

Micro machining or miniature machining refers to the machining of very small parts. The most common applications of micro machining are for the medical and electronics industries. Parts that are produced by micro machining are typically so small that they must be inspected using a microscope. Micro machining is typically performed by machine shops that specialized in the machining of miniature parts to precise tolerances. Micromachining techniques have their roots in 1960s when the need for miniaturized electronic components was sensed. [1]

The principles of micro machining are similar to those of conventional cutting operations but with scaling down the tools and parameters. 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, that has been addressed in numerous publication on the effect of round edges and minimum chip thickness. Although based on the same principle as macro-milling, the phenomena of micro-cutting involved in micro-milling are not a simple scaling of macro-cutting. A significant difference between these two cutting processes is the chip formation involving the so-called ‘minimum chip thickness’ phenomenon. [2]

In metal cutting operations it is well known that, energy needed to remove a unit material volume (specific energy) depends on the chip thickness. With a smaller chip thickness the specific energy expenditure increases at a potential law due to an increased ratio of micro-plowing on chip formation. At the same time, the sum of the friction and plastic deformation energy fractions can exceed the pure cutting energy fraction when very small chip thickness values are applied.[3]

2. LITERATURE REVIEW:

To the conventional mechanical machined products, their dimensions are in the millimeter order, and their surface roughness is in the micrometer order according to the requirement. This surface quality could be satisfied to its usages. To these micro products, their shapes are very delicate, which belong to the precision manufacturing fields. However, compared with their small size in micrometer order, their surface quality, which are always in sub-micrometer order, are not very satisfied. This phenomenon is caused by many factors, such as processing parameters, machine tool and materials [4].

M. Takacs found that the harder the material the better the surface quality and the lifetime of the tool is better, if the material is more ductile. [5] Lucca experimentally determined that the shearing process could not account for all of the observed energy when machining OFHC copper at small values of depth of cut. They showed that the ploughing and elastic recovery of the work-piece along the flank face of the tool play a significant role when machining with chip thickness values approaching the edge radii of the cutting inserts. They noticed that the specific cutting energy required to machine at very low chip thickness values could not be explained by the energy required for shearing and for overcoming friction on the rake face of the tool [6].

An experimental study was carried out to prove the existence of the minimum chip thickness in micro milling. The chip volumes were then estimated using the trapezoidal numerical integration formula and compared with the nominal chip volume for different feed rates. It was found that for very small feed rates, the measured chip volume is much larger than the nominal chip volume, indicating that a chip is not formed with each pass of the cutting tooth [7]. C Natrajan 36 specimens which are made up of the brass C26000 material have been machined and the surface recognition model had been developed through Artificial Neural Networks technique. He found that feed rate had been found to be the most influencing parameter followed by spindle speed and depth of cut, as the spindle speed increases for lower feed rates the surface roughness decreases. For the higher feed rates the surface roughness changes considerably [8].

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 ETP copper was studied.

3. EXPERIMENTAL PROCEDURE:

The goal of experimental work was to investigate the effect of chip load on surface roughness value and to establish a correlation between cutting parameters and roughness value.

The work material was ETP copper of a block with dimensions 145mm (length) x 57 mm (width) x 22 mm (height) The material is having 99.96% Cu without the presence of Ti, Pb and Zn

The face milling is carried on The Makino Japan make Makino V33, 3 axis milling center having Maximum spindle speed of 20000 rpm and feed 20000 mm/min., the machine tool has a 15KW motor. The cutting tool used was solid carbide End mill of zero radius, 6mm diameter four flutes CVD coated 30o helix and 12o rake angle, made by Hanita Cutting Tools Israle with 1 micron run out.

The experiments were conducted with constant feed and the three levels of both the cutting speed and the depth of cut as shown in table 1.

Level	Cutting Speed (rpm)	Depth of cut (μ)
1	10000	1
2	14000	2
3	18000	3

Table-1: Assignment of the levels to the factor

This process parameter at three levels led to a total of 9 test using L9 orthogonal array. One test was performed for each combination resulting in a total 9 tests, which allows analysis of the variance of the results. Also a random order was determined for running the tests.

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 generated by experiment is shown in table 2.

Sr. No.	Depth of cut (μ)	Cutting Speed m/min	Chip Load (μ)	Roughness (Measured in μ)	Roughness (Calculated in μ)
1	1	3.15	1.04	1.26	1.28
2	1	4.4	0.93	1.35	1.34
3	1	5.66	0.87	1.36	1.38
4	2	3.15	0.93	1.77	1.75
5	2	4.4	0.87	1.8	1.8
6	2	5.66	1.04	1.79	1.78
7	3	3.15	0.87	2.2	2.21
8	3	4.4	1.04	2.18	2.19
9	3	5.66	0.93	2.24	2.25

Table-2: Experimental result for Ra (with chip load)

4. REGRESSION EQUATION:

The relationship between the factors and the performance measures were modeled by using multiple linear regressions. The regression equations obtained were as follows:

$$Ra = 1.05 + 0.442\ d + 0.0212\ Vc - 0.272\ ft$$

Where

Ra= Surface Roughness,

d= Depth of Cut,

Vc= Cutting Velocity and

ft= Chip Load

Coefficient of determination =R2=99.8

This equation gives the expected value of surface roughness for any combination of the factor levels given that the levels are within the range.

5. VALIDATION OF MODEL

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.

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

This implies the alternative hypothesis

$H0 : \beta1 \neq 0$ or

$\beta2 \neq 0$ or

$\beta3 \neq 0$

Total sum of square (SST) = 1.1798

Error sum of square (SSE) = 0.0018

Group sum of square (SSR) = 1.1780

Coefficient of determination = R2 = 0.9985

F ratio =F = 4426.3

6. DATA ANALYSIS:

The plan of the experiment was developed for assessing the influence of the cutting speed (vc), chip load (ft) and depth of cut (d) on the surface roughness (Ra). Table 3 illustrates the experimental results for Ra. The experimental results were analyzed by Taguchi method using MiniTAB, which is used for identifying the factors significantly affecting the performance measures.

Level	d	vc	ft
1	-2.428	-4.605	-4.875
2	-5.041	-4.827	-4.857
3	-6.874	-4.911	-4.611
Delta	4.446	0.306	0.264
Rank	1	2	3

Table-3: Response Table for Signal to Noise Ratios

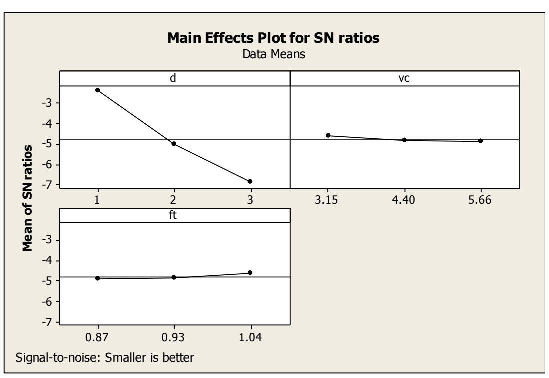

Fig-1: Signal to Noise ratio plot

7. RESULT AND DISCUSSION:

For ETP copper standard error of the estimate is 0.019 i.e 1.9% and coefficient of determination i.e. R2 = 0.9985. 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.

8. CONCLUSION:

The empirical model generated which includes the effect of chip load, cutting speed and depth of cut and predicts the surface roughness values. The measured values of surface roughness were found to be in most reasonable agreement to the predicted ones.

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. The graph of the S/N ratio indicates that in face milling of ETP copper the surface roughness value increases with increase in depth of cut. Also it was evident that the cutting speed and chip load is having marginal effect on roughness value as a response.

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