IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 04, Issue 11 (November. 2014), ||V2|| PP 01-06

Effect of CNC Cutting Parameters on Dimensional Accuracy of circular pockets using CMM

Omar Monir Koura* & Salah H. R. Ali**
*Mechanical Dept., Faculty of Engineering, Modern University for Technology & Information, Egypt,
**Engineering and Surface Metrology Dept., National Institute for Standards (NIS), Giza 12211-136, Egypt

Abstract: - Several factors affect the accuracy and quality of manufactured parts when machined using circular pocket cycles on CNC machining centers. Such accuracy depends to a great extent on work-piece material, the cutting conditions; namely spindle speed, feed rate, depth of cut and the structure of the fixed cycle. This accuracy plays an important role on the required tolerance and fit of manufactured parts to be assembled. The present paper studies the influence of those parameters on the accuracy and quality of milled pocket diameter with its roundness. Several specimens made of aluminum, copper and steel were pocket milled on a CNC using different cutting conditions. Coordinate Measuring Machine (CMM) was used to assess the errors in diameter and roundness measurements of machined parts. In despite of scientific advances in machining technology, however there are still clear deviations in the measurement results according to choice of the cutting condition, especially when change the type of work-piece material. Moreover, expanded uncertainty in measurement has been estimated using most effective experimental parameters and statistical analysis.

Keywords: ***-*** *CNC-CMM, cutting conditions, CNC circular pocket cycles.*

I. INTRODUCTION

CNC CAD/CAM programming software provides machinists with solutions to cutting their materials faster. One of the most used types of cutting operations is the Pocket Milling. This is due to the great need in the machining of mechanical parts, dies, and moulds. The style of pocket milling tool-path determines how long it will take to machine a part as well as its finished quality. This style includes traditional lace or zig-zag, concentric or offset In/Out and high speed cutting paths. A survey paper [1] shows the relationships between the shape, cutter, machine tool, and cutting conditions in the process of optimizing the cost and lead time of pocket milling. Geometric aspects of pocket extraction and tool path generation with optimization of cutting conditions are reviewed and discussed.

A Sΰtcΰ and U. Karagὂz [2] studied the effect of machining parameters which are related to the surface roughness of the pocket milled MDF routed by a CNC machine. The effects of the spindle speed, feed rate, step-over and depth of cut were investigated on the surface roughness of the MDF panels. Surface parameters used to evaluate surface quality in this study were roughness average (Ra), mean peak-to-valley height (Rz) and Root-mean-square (Rq). The results demonstrated that the surface roughness decreases with increasing spindle speed and increases with increasing step-over, feed rate and depth of cut.

Law K.M.Y and Geddam A. [3] studied the effect of cutting force on the accuracy of pocket milling. They stated that cutting forces causes deflection to the end mill cutter which results in cutter deflection. They concluded that controlling the radial width during corner cutting reduces the cutting forces. Hence reduces the deflection and better cutting quality is achieved.

Same authors [4] presented a computerized methodology for calculating the voluminous deflection and path determination program for end milling of pockets to compensate the error due to cutter deflection.

B.K. Hinds and T.S. Ong [5] studied the effect of several cutting parameters to predict the forces while end milling of circular pockets and, hence to meet the geometrical tolerances required by the machined part.

M. N. Islam, N. H. Rafi, and P. Charoon [6] studied the effects of the cutting conditions (cutting speed and feed rate) and cutting configurations (tool material, diameter, and geometry) on the accuracy of drilled holes. The objective of this project is to explore this possibility in detail. This paper presents experimental and analytical results of an investigation into the dimensional accuracy and surface finish of drilled holes using three different canned cycles with different styles. Measurement were taken on CMM with eight points were probed to determine the diameter in the horizontal plane. Circularity was, also, checked. Results demonstrated that there are noticeable effects as the cutting condition changes particularly when the canned style varied.

Mohammed T. Hayajneh, Montasser S. Tahat, Joachim Bluhm [7] performed experiments on end mill operations and studied the effects of spindle speed, cutting feed rate and depth of cut on the surface roughness. They built a multiple regression model representing such effects.

In the present paper, the effect of cutting conditions on the accuracy of pocket diameter and roundness will be, further, investigated for three different materials; namely Aluminum (AL), brass (Cu) and steel (St)

II. EXPERIMENTAL SETUP

The experimental proceeding undergoes three stages. The 1st stage is to prepare and run tests for 10 samples of each of Aluminum (AL), brass (Cu) and steel (St), at different cutting conditions using circular canned cycle. The 2nd stage is to determine the suitable measuring strategy for the CMM machine after verifying the accuracy of measurement. The 3rd stage is the measurement of five repeated tests for each material at defined environmental conditions on the high precision CMM machine

2.1. Circular canned cycle

A bench type CNC milling machine was used to perform the experiments fitted with 8-mm four-flutes high-speed steel cutter. The canned cycle used is of a concentric canned style. The tool started at the center of the pocket and pecks out by an increment of 1.5 mm.

2.2. CMM verification and measurement strategy

The mean average values of measured parameters, diameters and roundness form have been measured off-line by CMM machine. The accuracy of measurement depends up on the cutting parameters. The environmental contentions were:
Temperature: 20 ±1 ^{o}C
Relative Humidity: 50 ±5 %
Master probe, R= 4.001 mm
Reference Sphere Serial No.: 2916, R=14.9942 mm, S=0.0001, Tilt= 135^{o} (Rotate= 225^{o})
The measurement Strategy of CMM:
File name: D and G St; D and G Cu; D and G AL
Measuring Force: 100 mN
Used Long probe Serial No.: 600342-8020-000, 3*33.5 (D=3 mm*L=33.5 mm), R= 1.4994 mm, S= 0.0001 mm
Machine traveling speed = 20 mm/s
Probe scanning speed= 12 mm/s
Fitting method is LSQ technique for all measurements
No. of scanning points for diameter and roundness measurements =29 points, steep with= 2, Angle rotation range = 365^{o}
No. of scanning points for straightness measurement =32 points, steep with= 3

The maximum permissible values of error of the used CNC-CMM machine can be judged using the following equations:

$$MPE_E = \pm [0.9\ \mu m + (L/350)]\ \mu m \quad (1)$$

$$MPE_P = \pm 1.00\ \mu m \quad (2)$$

$$MPE_{Tij} = \pm 1.90\ \mu m \quad (3)$$

where MPE_E is the maximum permissible equipment error where L is the measured length in mm, MPE_P is the maximum permissible probing error, and MPE_{Tij} is the maximum permissible tangential scanning probing error.

III. EXPERIMENTAL PROCEDURE

10 specimens of each of Aluminum (AL), brass (Cu) and steel (St) were machined. The cutting conditions used are given in table 1.

Table 1: cutting conditions

Test	Material	Speed (rpm)	Depth (mm)	Feed rate (mm/min)
1	Aluminum (Al)	300	0.1	400
2		500	0.1	400
3		800	0.1	400
4		1500	0.1	400
5		500	0.2	400
6		500	0.25	400
7		500	0.3	400
8		500	0.1	800
9		500	0.1	1200
10		500	0.1	1600

11	Brass (Cu)	300	0.1	400
12		500	0.1	400
13		800	0.1	400
14		1500	0.1	400
15		500	0.2	400
16		500	0.25	400
17		500	0.3	400
18		500	0.1	800
19		500	0.1	1200
20		500	0.1	1600
21	Steel (St)	300	0.1	400
22		500	0.1	400
23		800	0.1	400
24		1500	0.1	400
25		500	0.2	400
26		500	0.25	400
27		500	0.3	400
28		500	0.1	800
29		500	0.1	1200
30		500	0.1	1600

Fig.1.ilustrates the typical result of circular pockets diameter and roundness for AL work-pieces at 300 rpm and 493 rpm cutting speeds using CMM. Fig.2.ilustrates the typical result of circular pockets diameter and roundness for AL work-pieces at 800 rpm and 1500 rpm cutting speeds using CMM.

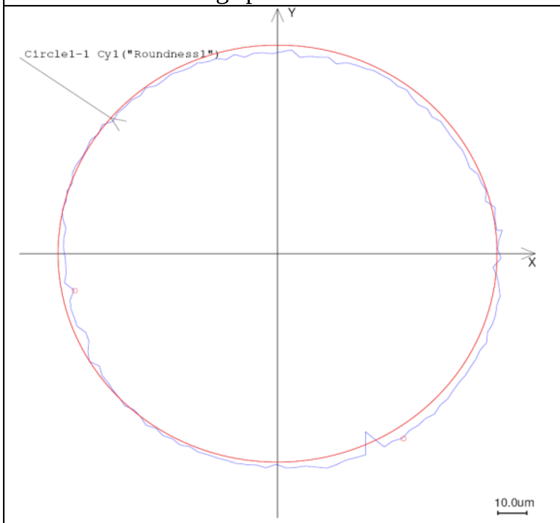
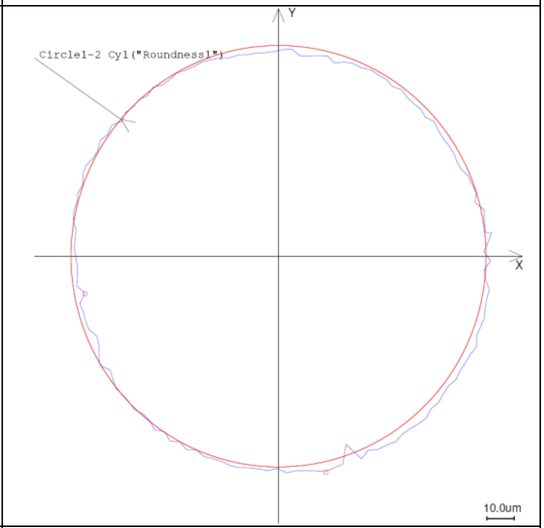
Sample-1-1	Sample-2-1
Drilling speed= 300 RPM	493 RPM
	
D_m(mm)= 20.6753	20.8858
RON (mm)= 0.2979	0.3661

Fig.1: Form measurement for two AL samples with speeds 300 & 493 rpm

Sample-3-1	Sample-4-1
800 RPM	1500 RPM

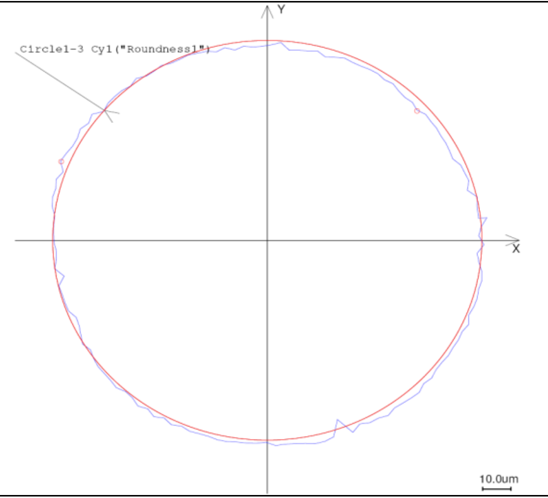
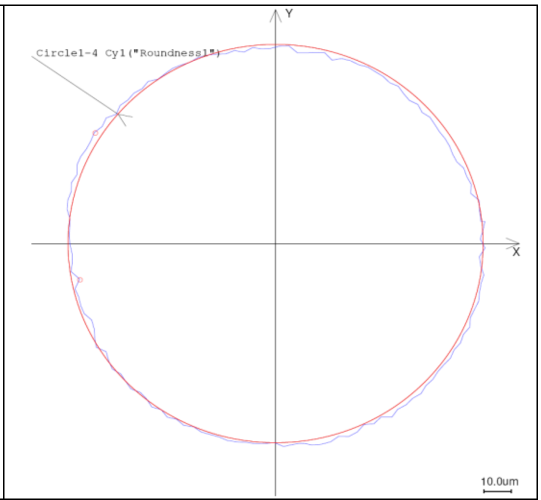
	
20.8945	20.9747
0.3310	0.3468

Fig.2: Form measurement for two AL samples with speeds 800 & 1500 rpm

IV. UNCERTAINTY IN MEASUREMENTS

The statistical and experimental analyses of uncertainty *(types A & B)* in measurements for the diameter and roundness of the circular pocket cycles for specimens are evaluated using GUM [8-9]. Table 2 gives the estimated values of the expanded uncertainties of the proposed accurate method. The estimated values of expanded uncertainty (U_{exp}) of measured 30 work piece using CMM is 2.4 µm. Where the standardized variable that called coverage factor equal to 2 according to the value of probability or confidence level which equal 95% [10-11].

Table 2: The budget of uncertainty estimation of error deviation in measurement

Sources of uncertainty	Standard uncertainty	Assumed Distribution	Combined uncertainty
Repeatability	0.053	Normal	**0.053**
Resolution	0.100	Rectangular, 2√3	**0.029**
Temperature	0.050	Normal	**0.050**
MPE	0.9+ (L/350)	Normal, based on k=3	**0.300**
MPE_P	0.500	Rectangular	**0.290**
Combined Standards Uncertainty, u_c= ±1.202 µm			
Expanded Uncertainty U_{exp}= ±2.4 µm			

V. RESULTS AND DISCUSSION

The effect of the cutting conditions on the diameter and roundness are shown in Fig 3. The diameter was programmed to be 21 mm as set in the part program. Increasing the spindle speed over 800 rpm improves both the pocket dimensional accuracy and the pocket roundness of the part as the speed below may have caused built up edge and as the speed increases greater deflection to the end mill causes greater error in both the diameter size and the pocket roundness. Again higher speed may cause greater inertia as the end mill continuously change angle to maintain circular path interpolation. In general, it is clear that deviation on diameter and roundness results when changing the cutting speeds (fig 4a & 4b) with the worth results around 500 rpm. Increasing the feed rate, particularly, when cutting Al or Cu (fig 4c & 4d) causes greater errors. So it is recommended that feed rate should always be reduced when machining pocket. Increasing the depth of cut improves the pocket accuracy (fig 4f & 4e).

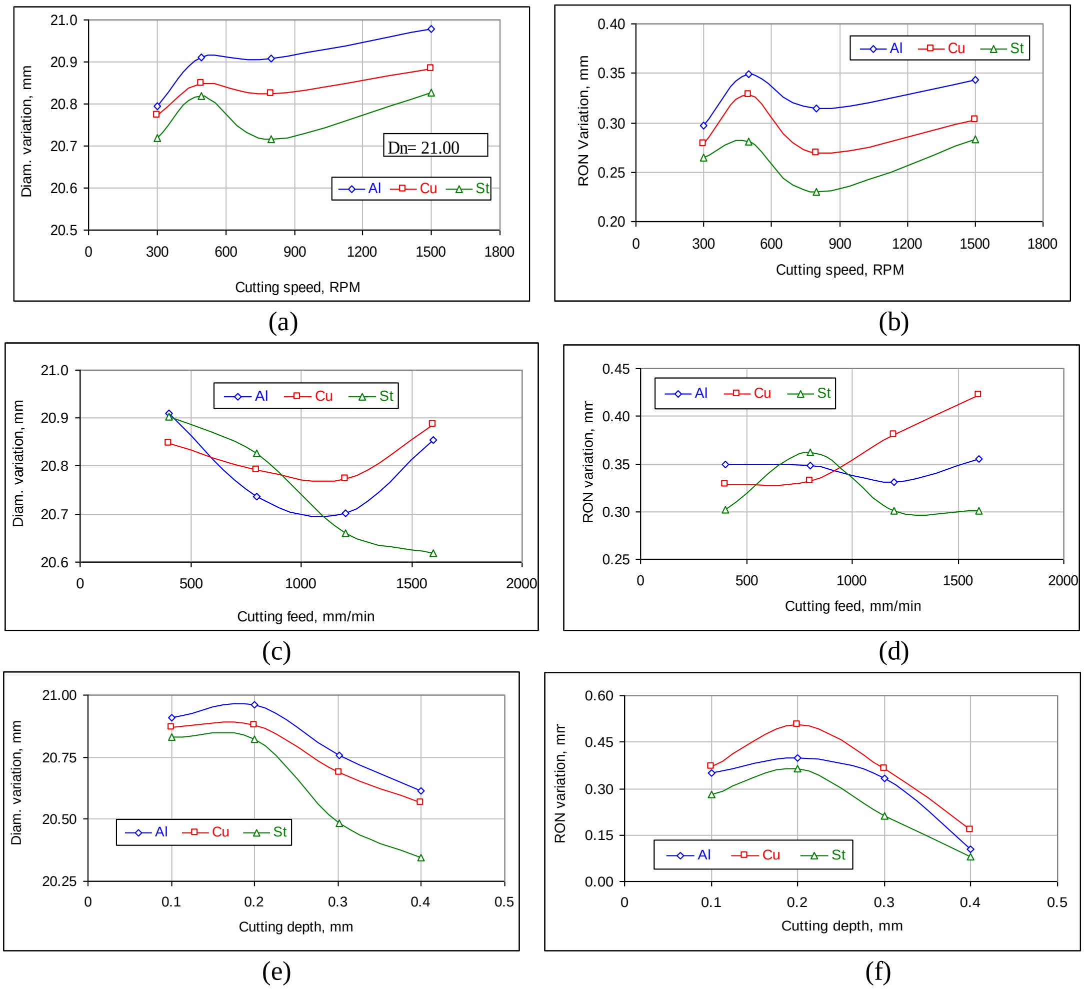


Fig .3: Effect of the cutting condition on the diameter & roundness accuracy

Again, increasing the feed rate appears to increase the overshoot of the cutter as it decelerates while it moves from interpolated point to the next around the circular path. Increasing the depth of cut till 5% of the cutter diameter improves the accuracy of the pocket.

VI. CONCLUSIONS

The accuracy of pocket mill is affected by the choice of the cutting condition. Cutting speed is better to be limited to 800 rpm, feed rate should be kept minimum and increasing the depth of cut to 5% of the cutter diameter improved the accuracy pocket diameter and pocket roundness. The highest value of estimated results of expanded uncertainty using CMM is 2.4 µm. The standardized variable that called coverage factor equal to 2 according to the value of probability or confidence level which equal 95% gives suitable estimation. Higher error of both diameter and roundness measurement was obtained when machining Aluminum.

REFERENCES

[1] Sotiris L. Omirou and Andreas C. Nearchou, An Epitrochoidal Pocket -A New Vanned Cycle for CNC Milling Machines, Robotics and Computer - Integrated Manufacturing, Vol. 25/1, pp. 73-80, February 2009.

[2] Abdullah Sütcü and Ümmü Karagöz, Effect of Machining Parameters on Surface Quality after face Machining MDF, Wood Research, Vol.57, NO.2, 2012, pp. 231-240.

[3] Kris M.Y. Law and A. Geddam, Prediction of Contour Accuracy in the End Milling of Pockets, Journal of Material Processing Technology, Vol.113, 2001, pp. 399 – 405.

[4] Kris M.Y. Law and A. Geddam, Error Compensation in the End Milling of Pockets: A Methodology, Journal of Material Processing Technology, 139, 2003, pp. 21–27.

[5] B.K. Hinds and T.S.Ong, End Milling of Circular Pockets to Meet Geometric Tolerances, Journal of Material Processing Technology, Vol.152, 2004, pp. 339 – 345.

[6] M. N. Islam, N. H. Rafi and P. Charoon, An Investigation into Effect of Canned Cycles on Drilled Hole Quality, Proceedings of the World Congress on Engineering 2009 (WCE 2009), July 1- 3, 2009, London, U.K.

[7] Mohammed T. Hayajneh, Montasser S. Tahat and Joachim Bluhm, A Study of the Effects of Machining Parameters on the Surface Roughness in the End-Milling Process, Jordan Journal of Mechanical and Industrial Engineering, Vol.1, No.1, Sep. 2007, pp.1 – 5.

[8] BIPM, Evaluation of Measurement Data - Guide to the Expression of Uncertainty in Measurement (GUM), 2008.

[9] Birch, K., Measurement Good Practice No. 36 – Estimating Uncertainties in Testing, British Measurement and Testing Association, 2003.

[10] Salah H. R. Ali, Performance Investigation of CMM Measurement Quality using Flick Standard, Journal of Quality and Reliability Engineering, Vol. 2014, Article ID 960649, pp.1-11, July 2014.

[11] Salah H. R. Ali and Jariya Buajarern, New Measurement Method and Uncertainty Estimation for Plate Dimensions and Surface Quality, Advances in Materials Science and Engineering, Vol. 2013, Article ID 918380, PP.1-13.