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A Comparitive Study of CNC Milling Cutting Path Strategies

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Abstract:

This paper investigates the effect of cutter path used in the milling process on the produced surface roughness using two different tools. The cutting paths which are named as; one directional, zigzag , Morph, overlap spiral and spiral are considered as cutter path strategies. The cutter path strategies greatly influenc the surface finish of the work pieces. The objective of this study is to investigate the best cutting characteristics and effects of cutting path for aluminuim using end mill and ball mill tools. MASTER CAM software has been used in design and producing NC CODE. The results indicate that the raw tool path strategy and flat end mill tool gives minimum roughness value with (0.15µm), while the spiral tool path strategy and ball end mill tool gives minimum roughness value with (0.76µm).

Keywords: CAD/CAM Process, Milling Path Strategies, CNC Milling

1- Introduction

Milling is the name given to the machining process in which the removal of metal takes place due to the cutting action of the revolving cutter when the work is fed past it. Milling machine has acquired an indispensable position in all modern production workshops. Its specific significance lies in its capability to perform a large number of operations which no other single machine tool can perform [1,2]. There are many cutter tool paths strategies used in milling process which are very effective on the producing the surface finish of the work piece. The different cutter path strategies generate different surface finish on the work piece [3,4]. In any machining operations, the surface finish of the work piece is most desirable parameter. In milling process which is often encountered in die manufacture operations, the demand is to narrow the interval between the surface roughness values obtained at finish milling and the surface roughness values will be met by further finishing operations as far as possible [5]. The implementation and selection of cutting path strategies with appropriate cutting parameters have significant effect on surface roughness. Proper selection can lead to substantial savings in machining time, improvement of work piece surface quality and improvement in tool life, thereby leading to overall cost reduction and higher productivity [6,7].

2-Mastercam Software Simulation Technique

In this work, MasterCAM software is used to simulate the machining process of samples, and generate the required G-codes for the CNC milling machine. Different contouring toolpaths are available in this simulation tool as shown in figure (1) [8]. Throughout the adopted experiments, cutting parameters, sample geometry, first point and end point of tool movements are same for all cutting strategies.

2-1-Tool selection using MasterCAM:

Two kinds of milling tools have been used in the experiment adopted in this workr, first one is the ball end and the other is flat end. After the machining process is done with each tool, surface roughness is to be measured for every workpiece. The parameters of the tools used are shown in figure (2).

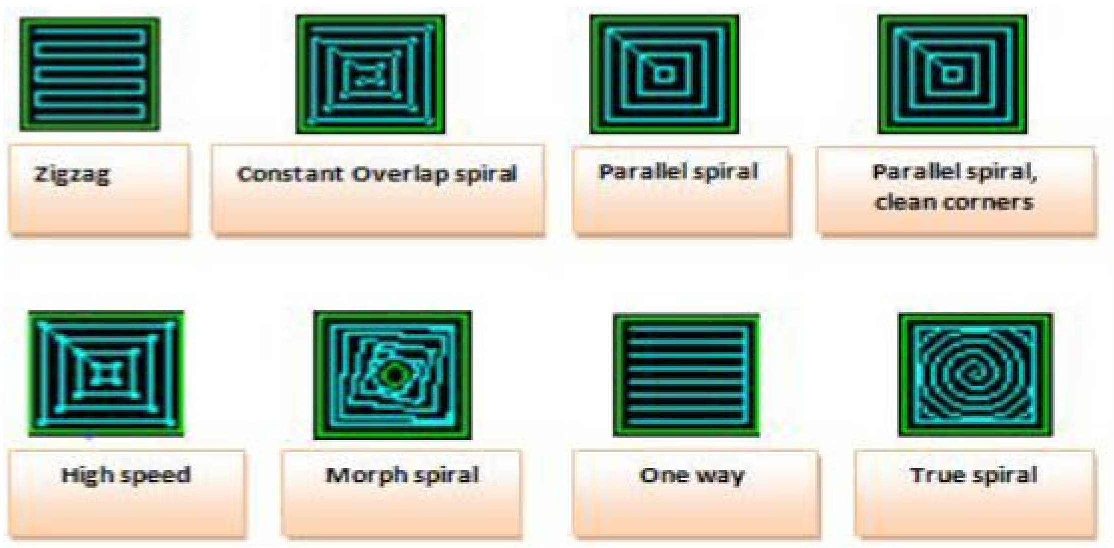


Figure (1) Various toolpaths available in MasterCAM software [8]

2-2-Materail selection in MasterCAM:

material definition by setting material type (aluminum – 6061) according to the software library of mastercam as shown in figure (3).

2-3-Selection of cutting parameters:

According to the mastercam software, machining parameters window gives spindle speed and feed rate with respect to work piece material, tool material and tool diameter.

2-4- Simulation of the selected Tool paths:

After setting the required machining parameters of the cutting process, it is required to choose the type of toolpath and then execute the simulation process as described in figure (4).

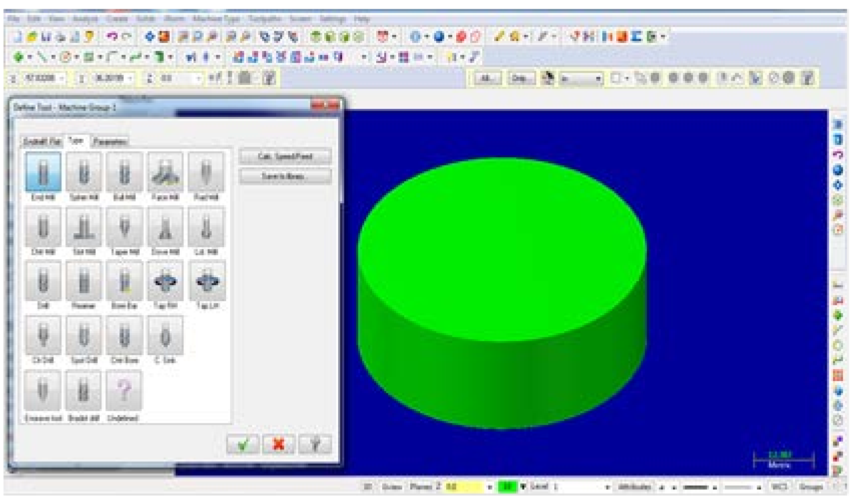
2-5- NC file generation using MasterCAM:

According to the simulation process, numerical control (NC) file is required to generate in G code form and saved for each type of toolpath, and then issued to the CNC milling machine as a *.txt file as shown in figure (5) which is explains a part of the generated G-code of oneway toolpath.

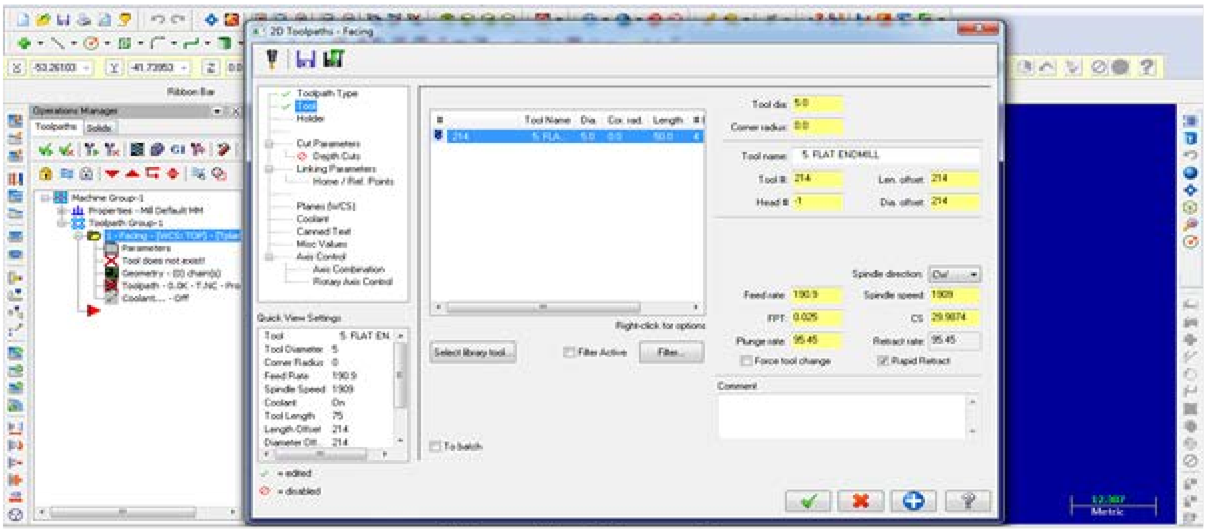
3-The Experimental Work

3-1-Tool used:

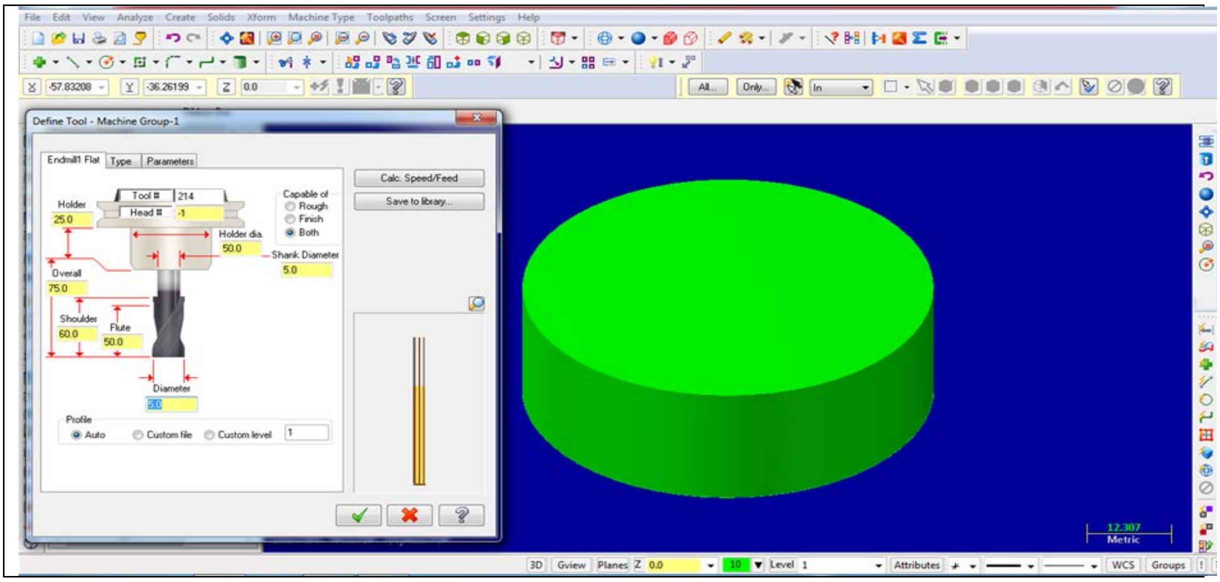
Both ball and flat end milling cutting tools, with 5mm tool radius, are used in the conducted experiments of this work, as shown in figure (6).



(a) MasterCAM window for selecting tool type



(b) Tool definition window



(c) Setting tool diensions

Figure 2: Tool setting windows in MasterCAM softwear.

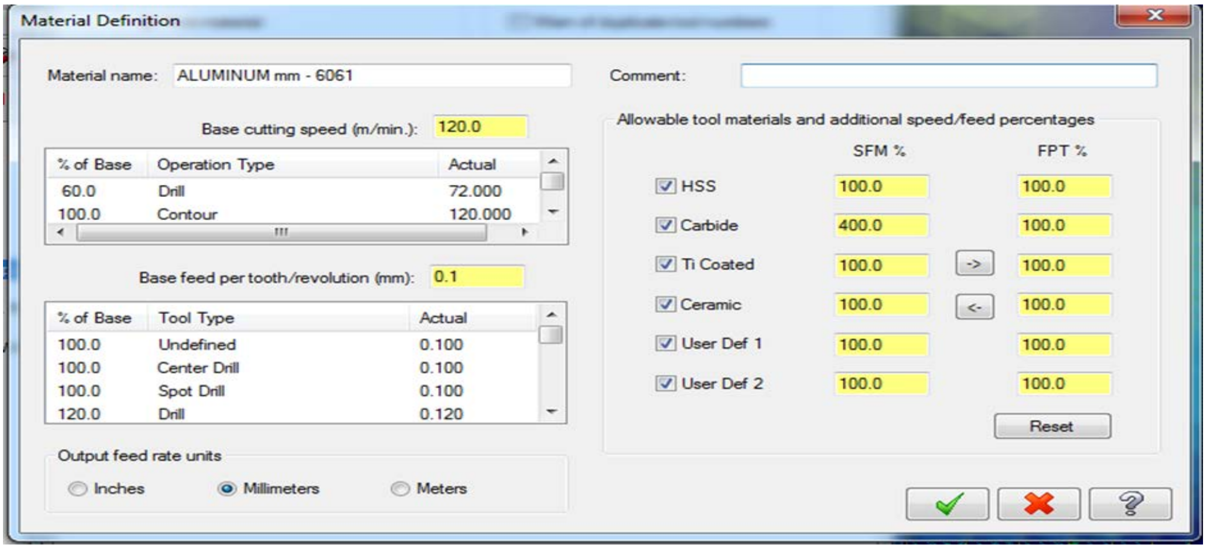


Figure 3: Material definition window in Mastercamsoftware

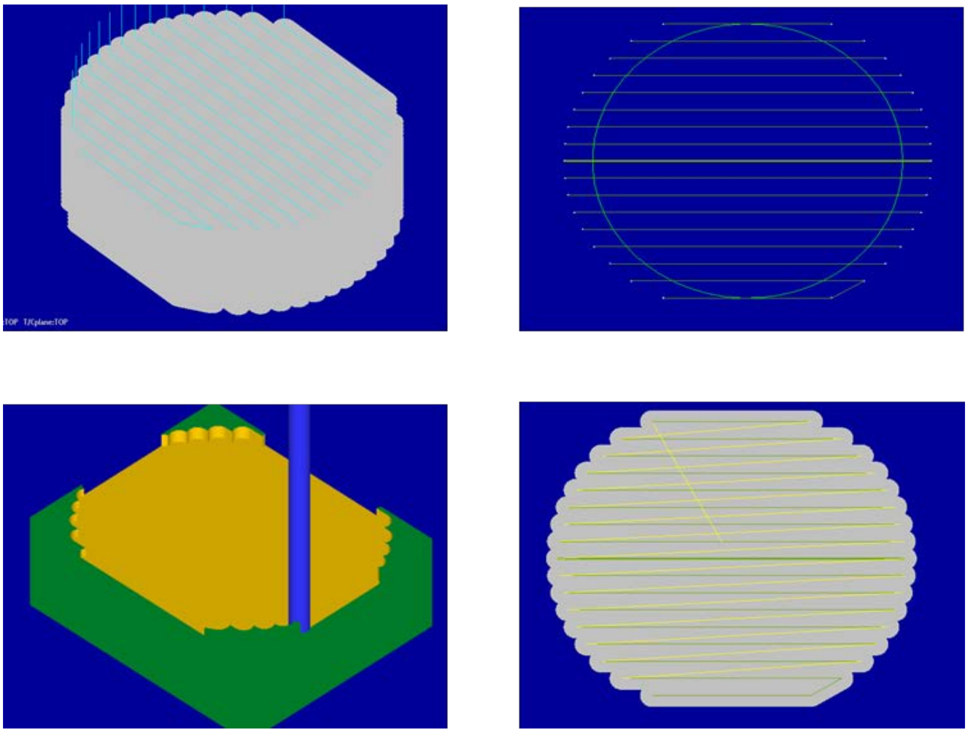


Figure 4: Simulation process in MasterCAM softwear

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N10 G21
N20 G0 G17 G40 G49 G80 G90
N30 T214 M6
N40 G0 G90 G54 X-16.252 Y29.998 A0. S2000 M3
N50 G43 H214 Z50.
N60 Z30.
N70 G1 Z19. F95.5
N80 X16.252 F190.9
N90 G0 Z44.
N100 X-22.501 Y26.248
N110 Z29.
N120 G1 Z19. F95.5
N130 X22.501 F190.9
N140 G0 Z44.
N150 X-26.642 Y22.499
N160 Z29.
N170 G1 Z19. F95.5
N180 X26.642 F190.9
N190 G0 Z44.
N200 X-29.657 Y18.749
N210 Z29.
N220 G1 Z19. F95.5
N230 X29.657 F190.9
N240 G0 Z44.
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Figure 5 : NC file generation for oneway toolpath type

Figure 6: The cutting tools used, (a) ball end cutting too (b) flat end cutting tool

3-2-Material used:

The material used in the experimental work is Aluminium (6061), the chemical composition for the specimens was tested in the Central Organization for Standardization and Quality Control/Baghdad, and listed in table (1). The workpieces are ten discs with 60mm diameter and 30mm length.

Table 1: Aluminium (6061) chemical composition

Metal Name	Weight (%)
Aluminum	95.15-98.56
Silicon	0.4-0.8
Iron	0.0-0.7
Copper	0.15-0.4
Manganese	0.8-1.2
Chromium	0.04-0.35
Zinc	0.0-0.25
Titanium	0.0-0.15
Other Metals	0.05-0.15

3-3- CNC Milling Machine:

The experimental work is done using C-TEK CNC milling machine, as shown in figure (7), which is available in the Workshop and Training Center in the University of Technology / Baghdad –Iraq , was used to manufacture the models adopted in this work. The machine specifications are listed in table (2).

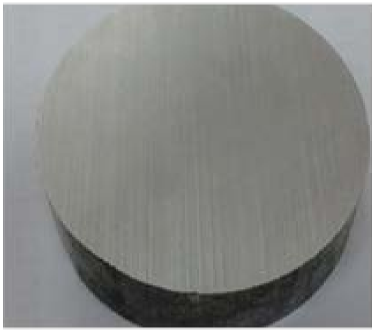
Figure 7: CNC C-TEK 3-axis milling machine

Table 2: Specification of CNC Milling Machine

Table surface dimension	305*1270 mm
T- Slot (W*N)	18/3T
Table load capacity	400kg
X travel	800 mm
Y travel	500 mm
Z travel	500 mm
Spindle center to column	530 mm
Spindle nose to table	620 mm
Taper of spindle nose	BT40 or CAT40
Spindle speed	6000 rpm
Rapid feed on X,Y&Z axis	10000mm/min

3-4- Machining of the specimens:

The samples were divided into two groups, each group consists of five samples with 50mm in diameter and 15mm in thickness. The milling cutting tool is replaced for each sample. The first group was machined using flat end mill cutting tool while the second group was machined useing ball end mill cutting tool. Both groups were machined using spindle speed equal to 2000rpm, while feed rate was equal to 200mm/min. Each machined sample is then tested for surface roughness and then compared the results between the two groups.The cutting toolpath used in these expierments are: zigzag ,raw ,spiral ,morph and constant overlap spiral, as shown in figures (8) and (9) respectively, with an overlap distance of 1mm between the cutting paths.

(a) Morph tool path (b)Zigzag tool path



(c) Constant overlap spiral (d) Spiral tool path (e) Raw tool path

Figure 8: Machined samples using flat end mill tool


(a) Morph tool path (b) Zigzag tool path



(c) Constant overlap spiral (d) Spiral tool path (e) Raw tool path

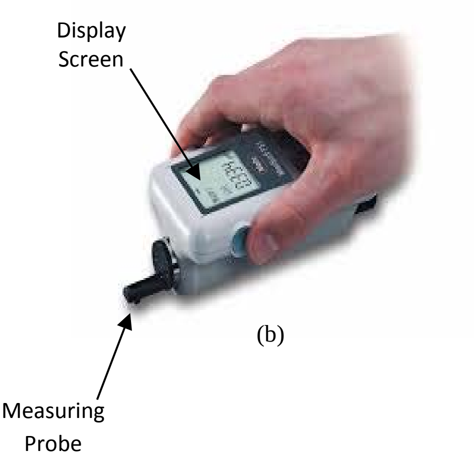
Figure 9: Machined samples using ball end mill tool

3-5- Roughness Measurment:

In this work, surface roughness (Ra) tester brand “Mar Surf PS1” USA made is used as shown in Figure (10) and specification as listed in table (3), the parameter automatic travel length (Ra) is chosen because it is simple and widely used as a parameter for the surface roughness indicator. The average roughness (R_a) has been tested for the machined samples to explain the effect of using different tool paths, different milling cutting tool geometry in surface roughness values.

A full experimental procedure is carried out for each machined sample, using 1.75mm instrument probe movement, holding the sample in an arrangement that permits to achieve five lines measurement, perpendicular to the direction of the tool movement. The average of these five measurements is recorded as the surface roughness of that sample

(a)



(b)

Figure (10) (a) Photograph of roughness measurement instrument (b) roughness measurement instrument in use.

Table 3: The specification of MarSurf PS1

Range:	Ra 0.03µm to 12.7µm
Probe	skidded probe 2µm
Travel length	1.75 mm, 5.6 mm, 17.5 mm and **automatic**

4- Results And Discussion

This research was carried out in order to find the best cutter geometry and cutting tool path strategy, which could have an effect on surface roughness. According to table (4), results show that the samples machined using ball mill tool increases the amount of surface roughness (Ra) or the surface quality is going to be worse rather than the samples machined using flat end mill tool. The reason of this matter is that increasing of tool contact area in flat end mill tool has a significant effect on improving samples surface roughness values rather than using ball mill tool. Table (4) shows the experimental results of the surface roughness values of the machined tool paths using flat end tool, there are five values for five paths and the highest value for zigzag path with (0.70 µm) while the lowest value for raw path with (0.15 µm), that mean the best surface roughness is raw path. The toolpath using ball end tool with the highest value of roughness is found in morph path with (3.21 µm) while lowest value is for spiral (0.76 µm). Thus the flat end tool gives better surface finish as compared with ball end tool as shown in figure (11).

Table 4: Surface roughness values

Name of path	**Roughness value (µm)**	
	End mill tool	**Ball mill tool**
Raw	0.15	1.74
constant overlap spiral	0.35	1.61
Morph	0.45	3.21
Spiral	0.65	0.76
Zigzag	0.70	1.14

5-Conclusion

The comparison between the machining results shows that the best tool path depends on the tool geometry and the cutting conditions. Among various cutting strategies available in MasterCAM, raw tool path is found to be more favourable than the other strategies for the obtained surface roughness values.

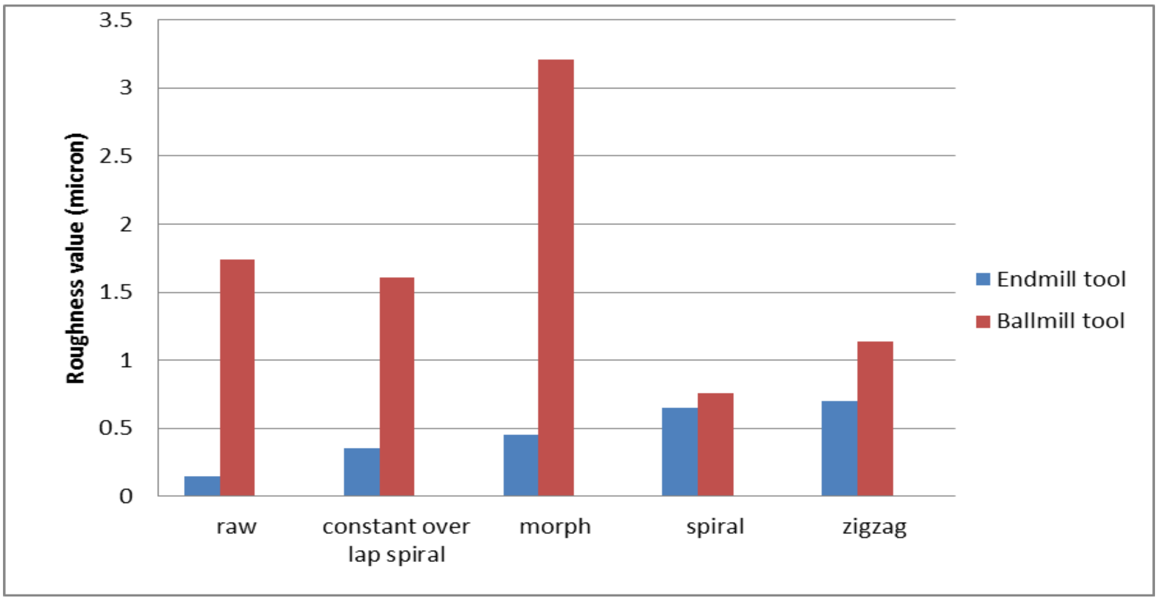


Figure 11: Surface roughness values of end mill and ball mill cutting tools.

6- References:

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دراسة مقارنة لستراتيجيات مسار القطع باستخدام مكائن التفريز المبرمجة

علي عبار خليف مجيد نعمت محمد حسن نعمه خنيفر

قسم هندسة الأنتاج والمعادن / الجامعة التكنولوجية

الخلاصة:

يتناول هذا البحث تأثير مسار عدة القطع بالتفريز على مقدار الخشونة السطحية الناتجة باستخدام عدتي قطع مختلفة. تم أعتماد مسارات القطع المعروفة بالأتجاهي، المتعرج، خلال عملية دوران العدة، والمسار الحلزوني للعدة. تعتبر هذه المسارات مؤثرة جدا على مقدار الخشونة السطحية للمشغولات الناتجة. ان اهمية البحث تتضمن الحصول على افضل خصائص لمسار القطع لعينات من الألمنيوم باستخدام عدد قطع بالتفريز ذات نهايات مستوية وكروية. تم في هذا البحث استخدام برنامج (MASTER CAM) لغرض النمذجة والحصول على الرموز التشغيلية الخاصة بمكائن القطع المبرمج. بينت النتائج بان المسار الخام الاتجاه المنتج بواسطة عدة تفريز ذات نهاية مستوية يعطي اقل قيم للخشونة السطحية (0.15µm)، بينما يوفر المسار الحلزوني المنتج باستخدام عدة ذات نهاية كروية اقل قيمة للخشونة السطحية (0.76µm).

الكلمات الدليلية: عمليات التصميم والتصنيع المعان بالحاسوب، مسارات القطع بالتفريز، التفريز بمكائن التحكم الرقمي.