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Modeling and Manufacturing of K1-Connector of Two Wheeler Silencer by Using CAD/CAM Tools

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ABSTRACT: *Today many industries use CNC machines for production of complicated parts, contouring operations etc. This paper represents the role of CAD/CAM tool for the manufacturing and modeling of K1-Connector which is part of two wheeler silencer comparative study has been carried out between the part code generated by CAM systems and one part program generated by manual part programming method. Considering various parameters like tool paths, cycle time, power consumption and productivity. the sample part is produced using the same machine tool, tooling and process parameters, and of productivity, cycle time and power consumed by the machine is measured by considering various tool paths like linear zig, zig-zag, zig with counter, step turning, and current tool path followed by operator (Manual Part Programming). The results shows that there is a considerable variation between cycle time, power consumption and production rate, between CAM tools and Manual Part Programming. In this project work after comparing the above tool path for part programming the zig-zag tool path generation strategy is suggested as it take minimum cycle time and power consumption to produce part and as well as increase in production rate of the machine.*

Keywords: *Tool path, linear Zig, Zig-Zag, Zig with counter, step turning, cycle time, power consumption.*

I. INTRODUCTION

Manufacturers of machined parts use Computer Aided Manufacturing (CAM) to increase their productivity; CAM systems help them to achieve high precision tolerance levels. CAM software developers and engineers use different strategies and methods to generate Computer Numerical Control (CNC) part programs. Unigraphics software through which one can draw and create the part module with different tool paths, visualize material removal, simulate the machine tool, and post process. In this paper, study has been carried out for the modeling of part, planning of tool path, generation of NC post processor and simulation to find cycle time, power consumption and effect on production rate of K1-connector. This project presents effect of various strategies of tool paths like zig-zag, linear zig, zig with counter these are generated by CAM software and current tool path followed by company, step turning (i.e. Manual Part Programming) for turning process of K1-connector in the graphical interface of CAD/CAM system. All simulations of cutting experiments show that the proposed clear-up tool path works well in the real cutting process and can improve the machining efficiency of the machining process. Industries cannot survive worldwide competition unless they introduce new products with better quality, at lower costs and with shorter lead-time. There is intense international competition and decreased availability of skilled labor. Based on the literature review it is evident that the factors that highly influence the process efficiency and output characteristics in a CNC machine tool are tool geometry, cutting velocity, feed rate, depth of cut and cutting environment, tool path.

Energy savings is increasingly recognized as one of the most important features in consumer products and industrial equipment. Electrical energy can be reduced simply by shutting down unnecessary devices during set-up and/or minimizing ideal times. The many goals focused in a manufacturing industry, energy consumption plays a vital role. The current work considers the most efficient tool path for production of K1-connector, which take minimum cycle time and power consumption also give maximum production rate.

K1-connector is used to connect silencer and engine exhaust, which is generally used in two wheeler bikes. Octane Engineers Pvt. Ltd. Pune is manufacturing K1-connector. They manufacture K1-Connector on 2 axis lathe machine (ACE Micromatics) 3-phase AC machine. “K” letter stands for connector and “1” number stands for it is first part, that is use to join engine exhaust to silencer.

Two CAM software produces different NC part programs, CAM software selection affects the cycle time to produce the part. Cycle time of a simple part could be reduced by using nested cycles and reducing the lines of the part program via the use of loops. This reduces the response time between the controller and the servomotors of the machine tool. Energy consumption could be caused by the higher number of lines of the part program generated by the commercial software .The energy consumption is influenced by the cutting tool, its number of flutes and the feed rate [1]. Energy based optimization of process parameters can be performed for roughing and finishing separately for a constant cutting speed, the total specific energy increases with decreasing feed. This indicates that more energy is required for machining a unit amount of material in the finishing process. The optimal cutting parameters for finishing turning operations for minimal energy consumption, by guaranteeing a specified surface roughness [2]. Different tool path strategies for milling a mold cavity during finishing operation. A mold cavity was manufactured and the results show that the tool path strategies have a great influence on the real milling time, surface roughness and hand finishing time and also show that the traditional roughness parameters were not adequate to measure the roughness in molding applications [3]. Selection of Appropriate cutting parameters that ensure less power consumption in high tare CNC machines. Using Taguchi's technique with cutting speed, feed rate and depth of cut as process parameters. Power consumed (energy), the output characteristic was measured [4]. From direct power measurement of the spindle and machine tool during endmilling tests, the impact of different machining parameters on peak power and energy consumption of the total machine tool and machine spindle for a 3-axis CNC milling machine was examined. Increasing spindle speeds (cutting speed), feedrates, and tooling immersions leads to an increase in MRR. This leads to an increase in peak power of both the spindle and the machine tool. Increased spindle speeds and feedrates increases MRR and can actually lead to overall energy consumption decrease [5]. Compared the power efficiency of various machining processes at different scales. Power efficiency is defined as the ratio of the process power to the total power consumption, and it was calculated using experimental results from conventional milling, micro-scale drilling, and brushing. The calculated power efficiency was compared for the processes reported, as well as with selected published data. Found that the power efficiency varied regardless of machining scales or specific energy consumed, and also vary widely in terms of the peripheral devices used [6].

II. METHODOLOGY

Based on the work in literature review which states that the workpiece orientation and the length of the NC code segments influence the reduction of machining time, the experiment reported in this paper uses three different options to generate NC part programs. Following main activities were carried out during this experiment. These are presented below.

2.1 Case study part modeling

A particular part was modeled for the experiment the part was modeled by using Unighraphics 9.0 and NC Program was generated on Unigraphics. Its general dimensions are 62 mm length, 43 mm in diameter. The case study part's geometry Fig. (i) required different machining operations: The purpose of using different operations was to compare diverse strategies when generating the NC part programs. The material selected for the part was shown in fig (i), and fig (ii), (iii), (iv), (v) shows the various toolpaths for the given object

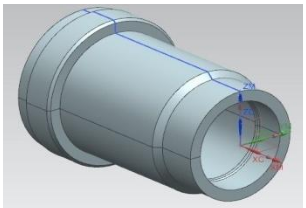

Fig (i)

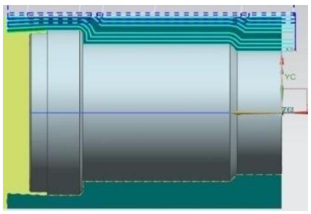

Fig (ii)

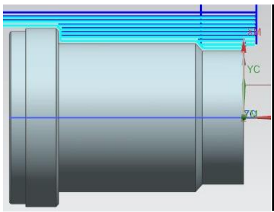

Fig (iii)

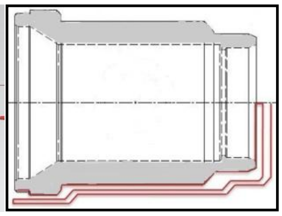

Fig. (iv)

Fig(i) shows the modeled object which is going to be studied, fig(ii) shows the Zig with counter toolpath, Fig (iii) shows the linear Zig toolpath, Fig (iv) shows the Zig-Zag toolpath, fig (v) Shows the Step turning Profile,

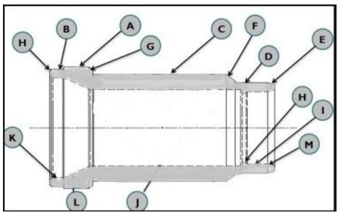

Fig (v)

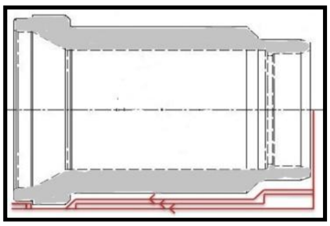

Fig (vi)

Fig (vi) shows the toolpath generated/followed by operator for production of object.

2.2 Machining process design

As mentioned before commercial software Unigraphics NX 9.0 was used to generate the NC code for the case study part. A third part program was generated by the authors directly on the controller of the machine tool used for this experiment. Table 1 presents the strategies and process parameters selected for the different tool paths required by the case study part. These parameters were used to generate all of the NC part programs. The Design of Experiments was carried according to full factorial design methods.

Characteristics	Parameter
Cutting Speed (m/min)	0.1
Feed Rate (mm/min)	0.6
Spindle speed (RPM)	1550
Depth of Cut (mm)	0.35 for rough cut
	0.25 for semi-finished cut
	0.15 for finished cut

Table 1. Machining parameters for cutting tool

2.3 Machine center and measurement equipment, circuit diagram

The experimental work was carried out at Octane Engg. Pvt. Ltd. Pune on Computerized Numerical Control (CNC) lathe machine shown in figure 1(a) and 1(b). Power consumption was measured by using two wattmeter method. Both calibrated wattmeter was used and their reading were added after multiplying suitable multiplying factor to get Power Consumption (PC) in watt, wattmeter arrangement shown in fig below fig (b) and fig(c) we set current at 10 amp and voltage at 600V the multiplying factor is 8, therefore multiply the wattmeter reading by multiplying factor we get power consumption in Watt. The cycle time can be measure with help of stopwatch.In this work alternate connection of wattmeter has been made with 3 phase for measurement of power consumption.

Fig (a)

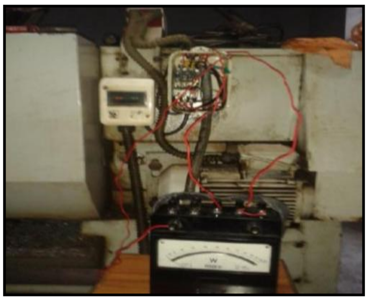

Fig (b)

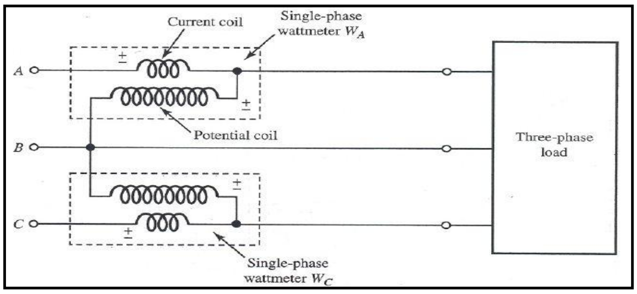

Fig (c)

2.4 Generation of the NC code

In order to increase productivity, it is necessary to consider the final surface quality of the desired part when designing the machining process. Productivity is associated to the use of the standard ISO 10303- AP238, which is related to the data communication between CAM systems and NC machining centers. As mentioned above, the experiment reported in this paper studies the code generated by Unigraphics NX 9.0 to manufacture the same part. The different machining strategies included in the CAM software were used, the tool supplier's process parameters were employed and tool trajectories were planned including the required air cut movements. This air cut movements were considered since they contribute to energy consumption of the machining process. the strategies to generate tool paths offered by the software were selected based on the least machining time criterion.

NC program of the part was written by the authors on the machine tool controller, Fig. (vi) as mentioned above. Each part trajectory was programmed using a drawing that includes all the distances, radii and intersection points required by the NC program. To generate a NC part program in the machine controller, the authors looked for the easiest way, as technicians normally do. Each part program was tested in the simulation software of the machine controller to verify their functionality and trajectories. This allowed the detection of possible program mistakes and if extra G codes had to be added in the part program.

III. EXPERIMENT READINGS

Four part samples were machined using similar process strategies and parameters. Samples were measured at the end of the experiment to verify that final dimensions matched the original design. The codes produced by the software tools and the code programmed by the authors were compared taking into account the differences between the cycle time, energy consumption corresponding machining processes. Surface finish and tool life were considered out of the scope of this investigation. The authors' approach studied only three output variables i.e. cycle time, energy consumption and productivity from the many comprehended in a machining process. Yet, authors believe that researching these three variables helped in achieving some important energy consumption conclusions. As mentioned above, for the various NC programs, the same type of cutting tool and machining parameters were used. The readings for the various toolpaths as given below.

Table 3: Cycle time, Power consumption for Zig-Zag toolpath

Sr. no.	Strategy	Operation	Machining time (T_M)	Power consumption (KW)		
				W_1 (Watt)	W_2 (Watt)	$W_t=(W_1+W_2)$ (KW)
1	Zig-Zag	Rough	56.55 sec	639.33	624.66	1.263
2		Semi-finished	21.24 sec	336	341.33	0.677
3		Finished	11.87 sec	220	229.34	0.449
		Total	1.48 min			2.389 KW

Table 4: Cycle time, Power consumption for linear Zig toolpath

Sr. no.	Strategy	Operation	Machining time (T_M)	Power consumption (KW)		
				W_1 (Watt)	W_2 (Watt)	$W_t=W_1+W_2$ (KW)
1	Linear Zig	Rough	60.89	738	738	1.476
2		Semi-finished	25.48	360	356	0.716
3		Finished	13.95	244	250	0.494
		Total	1.67 min			2.686 KW

Table 5: Cycle time, Power consumption for Zig with counter toolpath

Sr. no.	Strategy	Operation	Machining time (T_M)	Power consumption (KW)		
				W_1	W_2	$W_t=W_1+W_2$
1	Zig with counter	Rough	63.79 sec	746	748	1.494
2		Semi-finished	25.51 sec	356	360	0.716
3		Finished	12.96 sec	244	246	0.49
		Total	1.70 min			2.7 KW

Table 6: Cycle time, Power consumption for Manual programe

Sr. no.	Strategy	Operation	Machining time (T_M)	Power consumption (KW)		
				W_1 (Watt)	W_2 (Watt)	$W_t=W_1+W_2$
1	Manual	Rough	53.93	746	742	1.488
2		Semi-finished	27.41	326	328	0.654
3		Finished	14.675	210	200	0.41
		Total	1.60 min			2.552 KW

Table 7: Cycle time, Power consumption for Step turning toolpath

Sr. no.	**Profile**	**Machining time (T_M)**	**Power consumption (KW)**		
			W_1 (Watt)	**W_2 (Watt)**	**$W_t=W_1+W_2$ (KW)**
1	A	8.46	168	176	0.344
2	B	4.27	120	112	0.232
3	C	18.86	336	328	0.664
4	D	10.20	208	200	0.408
5	E	4.15	160	160	0.320
6	F	3.62	80	88	0.168
7	G	3.17	80	80	0.160
8	H	2.33	80	72	0.152
9	I	10.25	200	192	0.392
10	J	17.92	360	336	0.696
11	K	8.46	208	192	0.400
12	L	10.75	232	240	0.472
13	M	4.7	96	112	0.336
Total		1.78 min			4.744 KW

IV. RESULTS & DISCUSSION

Allowances: Machining time and power consumption required for each tool path is measured. To find standard time (Cycle time) add various allowances to the machining time, loading and unloading time. Here neglecting the line failure, delay time, probability of failure and down time.

Let, T_c is the cycle time; T_{load} is loading time (10 sec); T_{unload} is loading time (10 sec), T_M =Machining time;

Therefore; Cycle time (T_c) = T_M + Allowances + T_{load} + T_{unload}

Table 8: Allowances according to British standard

Sr. No.	Allowances	% of standard time
1	Personal Allowances	5 %
2	Fatigue Allowances	4 %
3	Contingency Allowance	5 %
4	Special Allowances	8 %
	Total Allowances	22 %

Table 8: Comparison between various toolpaths

Sr. No.	**Toolpath**	**Machining Time (min)**	**Cycle time (T_c)** = T_M + Allowances + T_{load} + T_{unload}	**Power consumption**
1	Zig-zag	1.48 min	2.13	2.389 KW
2	Linear Zig	1.67 min	2.37	2.686 KW
3	Zig with counter	1.70 min	2.42	2.7 KW
4	Manual programming	1.60 min	2.28	2.552 KW
5	Step turning	1.78 min	2.52	4.744 KW

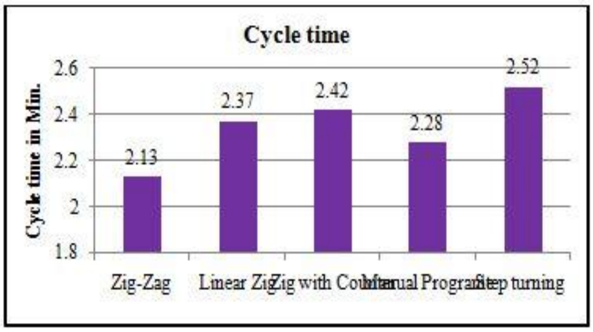

Fig (01) Comparison between various tool paths Vs cycle time

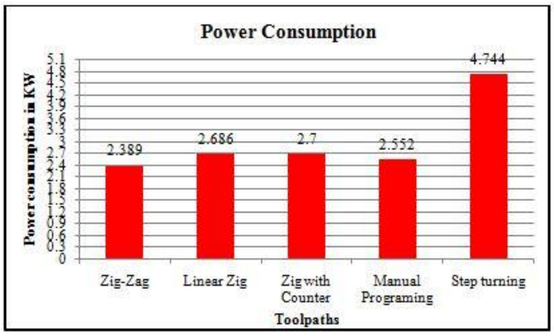

Fig (02) Comparison between various tool paths Vs Power Consumption

From the experimental data, both power consumption and cycle time required for each toolpath studied, which shows that, as cycle time increases power consumption increases as shown in fig.03. Table 3, 4, 5, 6, 7 shows the cycle times and the power consumption studied in this experiment. Generally, power is monitored and loading time is not taken into account but in this work, total machining time taken is monitored, hence energy is computed and is used for analysis and the results are discussed below.

Many of the codes of the part program produced with Unigraphics NX 9.0 were G1, so the generated trajectories are based on point coordinates. The energy consumption of the machining process and cycle time is presented in Table 5 and as shown in fig (03). The rows of the table present toolpath for geometry feature of the sample part. The total cycle time for the zig-zag toolpath program is 1.29 minutes, having an energy consumption of 2.389 kW. The total cycle time for the linear zig toolpath program is 1.40 minutes, having an energy consumption of 2.686 kW. The total cycle time for the zig with counter toolpath program is 1.42 minutes, having an energy consumption of 2.7 kW. Current toopath followed by the operator required 1.36 min cycle time for completion of single job and consume 2.552 kW power. The total cycle time for the step turning toolpath program is 1.50 minutes, having an energy consumption of 4.744 kW.

V. CONCLUSION

The aim of this paper is to realize practical examples of turning machining technology and programming of CNC machines with CAD/CAM tools. The manufacturing process is first designed and simulated using the CAM software i.e. Unigraphics. This work investigates the influences of the tool path strategy on the cycle time, power consumption and effect of these parameters on production rate for turning operation on K1-connector. The results demonstrate that by using zig-zag tool path (Computer Assists Part Programming), it can save cycle time upto 6.57 % and 6.39% of the power consumption. When compared with manual part programming which is currently followed by Octane Engineers Pvt. Ltd. zig-zag tool path reduce cycle time by 7.20 sec/job and power consumption by 170 Watts/job. The results also shows that by manual part programming current production rate is 210 jobs/shift for single machine, by using Zig-Zag tool path there is increase in production rate by 15 jobs/shift.

So, it is recommended that zig-zag tool path is preferable for manufacturing K1-connector. 1 unit of electrical energy saving is better than production of 1 unit of electrical energy.

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