Experimental Investigation on Minimizing Cycle Time and Cost of Radial Drill Head Feed Box Housing in Vertical Machining Centre (VMC) using Optimized Canned Cycles

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***Abstract*—Computer Numerical Control (CNC) machines are the devices used predominantly in manufacturing a value added good compared to non-conventional machining. These machines are capital intensive. However, their maximum utilization is due to their economic viability in terms of reduced machining time, lower work in process inventory & increased production rates. In today's manufacturing market, the demand of a product depends on quality with precise machining time and shortest possible delivery time. In order to reduce the machining time, knowledge base expertisation on preparation of optimized part program, choosing appropriate cutting tool, optimized cutting parameters and minimization of tool path is needed. Nevertheless, an optimization of part program is still necessary to reduce the tool path.**

In this context, the optimization of CNC part program, reduction of cycle time and machining cost is possible with improved programming techniques using Canned cycles including R-parameters and subroutines. A Vertical Machining Centre (VMC 400M) is selected to machine Radial Drill Head Feed Box Housing includes processing operations such as face interpolation, milling, drilling and boring. The modified CNC part program with R parameters and subroutines decreases the length of part program which in turn decreases the movements of the cutting tool over work part in each cycle. From the experimental investigation, it is observed that cycle time, machining cost are reduced using canned cycles compared to XYZ parametric program. The Breakdown time per month is compared before and after implementation of R-parameters and subroutines.

Keywords*— *Vertical Milling Machine; Reduction of machining cost and Cycle time; Radial Drill Head Feed Box Housing; Canned cycles; R-parameters; CNC Part programming

I. INTRODUCTION

The main focus of manufacturing industries is to produce extreme quality and higher productivity of the product. In order to increase productivity of the product computer numerical control machine tools play major role during the past decades. However, there are many parameters [1] need to be considered while machining such as feed [2]–[4], tool geometry and cutting speed [2], [5]–[7], machining time [8]–[10], lead time [10], surface quality [3], [11], surface roughness [12], depth of cut [6], [13] , spindle speed [4] and diameter of tool plunger rate[4], part program execution speed and efficiency[10]. Moreover, the optimization of these parameters depends on automation of machining centre and accuracy of part program. Different algorithms are used for optimizing different process parameters in various machines. In the past Balic et al [14] discussed about artificial intelligence technique which is a computational method employed with autonomous mechanisms of Genetic Algorithms for optimizing complicated relations in job shop scheduling and CNC machine tools program. Further, Gjelaj et al [7] discussed about optimization of the tool selection based on Genetic Algorithm. Furthermore, implementation of CNC part program using group technology is studied by Manocher et al [15] for minimizing machine operations to reduce cost. The intelligent control CNC machines based on Fuzzy logic controller is studied for better and accurate transient response, manipulation of variables in speed relation during breakdown conditions. Ahmet Murat PINAR et al [2] developed an algorithm for minimizing the time in VMC by using time calculator and CNC editor. In the past Islam et al [16] discussed about introduction of different canned cycles in determining cutting speed, feed rate, dimensional accuracy and surface finish of drilled holes.

However, many analyses is carried deeply in order to increase manufacturing capabilities, minimizing of machining cost, machining time and quality of end product. These analyses are yet to adopt in real manufacturing practice. In reality, PLC part programs are

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used for short time demands with scan cycles. Further nonlinear algorithms are used for monitoring drill bolt holes in real time analysis. The implementation of canned cycles involved with R-parameters and subroutines for machining Radial Drill Head Feed Box Housing are not yet investigated. Motivated by this work, investigation is carried on optimizing the CNC part program using canned cycles for minimizing cycle time and cost with different operations such as face interpolation, milling, drilling & boring.

II. PROBLEM DESCRIPTION

In any manufacturing sector, the demand of the product depends on the level of automation used in producing part geometry, finished product delivery within due date, excellent quality and customer satisfaction. During production of complex part geometry using XYZ parametric program the size of part program is vast. Furthermore, the tool movement over the work part increases the machining cost and cycle time drastically. A real time Radial Drill Head Feed Box Housing was machined in VMC 400M using various operations such as interpolation, milling, drilling & boring. No variations in drilling and boring are considered because of less complications are included with part geometry. A critical comparison of operations Vs machining cost and operations Vs machining time has been investigated using XYZ part program and R- parametric part program with subroutines. Fig. 1shows Radial Drill Head Feed Box Housing modelled in the AutoCAD.

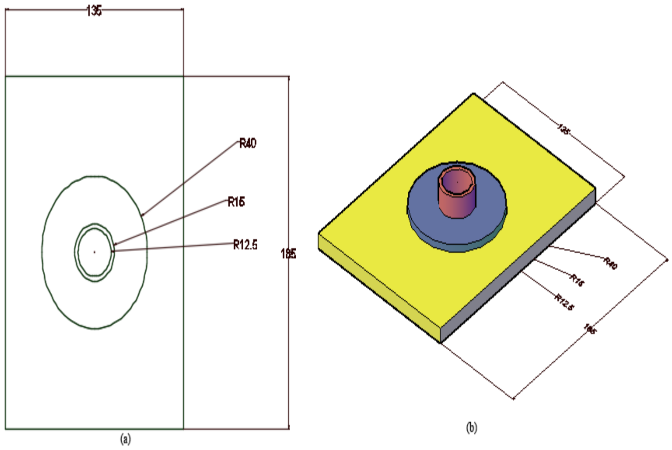

Fig. 1. Radial Drill Head Feed Box Housing modelled in AutoCAD

III. EXPERIMENTAL SETUP

CNC Machining Center is a machine tool capable of multiple machining operations on a work part in one setup under NC program control. There are Vertical, Horizontal and Universal types. Advantages of machine centre compared to conventional machines are fewer setups, reduced part handling, increased accuracy and repeatability, faster delivery of part in small lot sizes. Idea behind development of VMC is to reduce non productive time and provides the features such as Automatic tool change, Automatic work part positioner and Automatic path changer. A Vertical Machining Center (VMC 400M) shown in Fig. 2 is considered for analyzing the cycle time and cost used for processing a radial drill head feed box housing. The specifications of the VMC 400M, speed and feed rate is shown in Table I. The modified CNC part program using canned cycles with set of instructions is shown in Fig. 3. The setup and machining of radial drill head feed box housing using XYZ parameters and R-parameters with subroutines is shown in Fig. 4.

Fig. 2. Vertical Machining Center (VMC 400)

Fig. 3. Program of Instructions

Table I Specifications of VMC 400M

VMC	400
CNC system	Siemens
Axis movement	3
Tool post carrying capacity	12
X-axis	1200 mm
Y-axis	600 mm
Z-axis	600 mm
Guide ways	t-slot bed
Speed maximum	600 rpm
Speed minimum	50 rpm
Feed rate	10 to 250 mm/min

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Fig. 4. Setup and machining of Radial Drill Head Feed Box Housing

IV. Solution Methodology

The main objective of this work is to investigate machining time and machining cost of Radial Drill Head Feed Box Housing by optimizing the CNC part program in VMC 400M. The optimization includes implementation of R-parameters and subroutines. Machining cost and time are analyzed using XYZ parameters and Canned cycles for different operations specified earlier. The results are evaluated after machining the Radial Drill Head Feed Box Housing in VMC 400M and machining time is calculated. The flow chart for evaluation of Machine Cost and Time is shown in Fig. 5. The machining cost using XYZ parameters and R-parameters with subroutines is calculated as follows.

$$Cost\ of\ machining\ a\ component = Total\ Operating\ Cost * MHR \quad (1)$$

$$Total\ Cost = \frac{Operating\ Cost}{60} \quad (2)$$

$$Total\ Cost\ with\ XYZ\ parameters = total\ XYZ\ parametric\ time * MHR \quad (3)$$

$$Total\ Cost\ with\ R-parameters = total\ R-parametric\ time * MHR \quad (4)$$

$$Total\ savings = Total\ Cost\ with\ XYZ\ parameters - Total\ Cost\ with\ R-parameters \quad (5)$$

where,
MHR = Machine Hour Rate
MHR is taken as 800 per hour

The programs with R-parameters and subroutines for interpolation and milling is specified in the Table II.

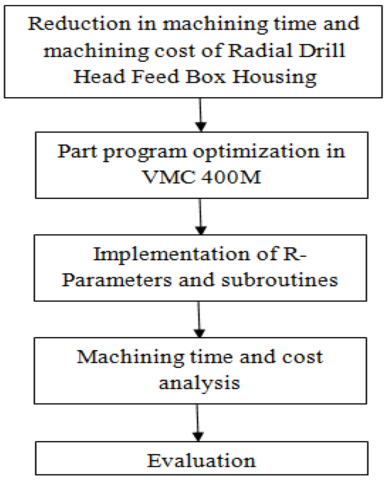

Fig. 5. Flow chart for evaluation of Machining Cost and Time

Table II Programs with R-parameters for Interpolation and Milling

Face Interpolation	Outer Dia 55 Interpolation	Outer Dia157 Interpolation	Milling
N10 G15 S300 M3 F 150 D1	N130 G0 X0 Y-165	N240 G0 X0 Y-185	N400 T2 END MILL
N20 G0 X-100 Y0	N140 R05=1 R06=2	N250 R05=12 R0=2	N410 G0 G54 S800 M3 F150 D1
N30 R05 = 14 R06 =2	R07=9;.........R05=1	R07=14;........R05=12	N420 G0 X0 Y-145
R07= 0; …….. R05 = 14	N150 AA3: Z=-R05	N260 AA5;Z=-R05	N430 AA7: Z=-R05
N40 AA1: Z = R05	N160 G01 X0 Y-69.5	N270 G01 X0 Y-121	N440 R05=24 R06=3
N50 G01 X-20 Y0	N170 G02 X0 Y-69.5 I0	N280 G02 X0 Y-121 I0 J121	R07=27:....R05=24
N60 G02 X-20 Y0 120 J0	J69.5	N290 G01 Y-185	N450 G01 Y-124
N70 G01 X -100	N180 G01 Y-165	N230 G0 X135	N460 X161
N80 IF R05 = R07	N190 IF R05= =R07 GO TO	N310 G01 Y185	N470 Y128
GOTOF AAZ	F AA4	N320 G0 X-135	N480 X-169
N90 R05 = R05 – R06	N200 R05=R05+R06	N330 G01 Y-185	N490 Y-124
N100 GOTO B AA1	N210 GO TO B AA3	N340 G0 X0	N500 X0
N110 AAZ : GO Z100	N220 AA4: G0 Z100	N350 IF R05==R07 GO TO F AA6	N510 Y-145
N120 M0	N230 M0	N360 R05=R05+R06	N520 IF R05==R07 GO TO F AA8
		N370 GO TO B AA5	N530 R05=R05+R06
		N380 AA6:G0 Z100	N540 GO TO B AA7
		N390 M0	N550 AA8: G0 Z50
			N560 M0

V. RESULTS AND DISCUSSIONS

The motive of using canned cycles including with R-parameters and subroutines is to increase the productivity by minimizing cycle time and cost with reduction in tool path movements over the work part. The machining of the Radial Drill Head Feed box Housing includes with various operations such as interpolation (facing, circular), milling, drilling and boring. By using the XYZ parametric part program in the VMC 400M the tool path movements are enormously high.

Hence the utilization of canned cycles are better for optimizing part program. The machined work part (Radial Drill Head Feed Box Housing) in VMC 400M is shown in Fig. 6 and the different views are shown in

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Fig. 6. Complete geometry of Radial Drill Head Feed Box Housing

Fig. 7. (a) Front View (b) Top View (c) Back View (d) Side View of Radial Drill Head Feed Box Housing

A. *Machining Time Analysis*

In order to increase the productivity machining time is one of the important parameter need to be considered. A critical comparison is made between operations and their machining times by using XYZ parameters and R-parameters including with subroutines. The total cycle time using XYZ parametric part program is 4.8 hours and total cycle time using R-parametric part program and subroutines is 3.26 hours. The reduction in the total cycle time is 1.5 hours. Fig. 8 shows the comparison between Operations and Machining time with XYZ and R-parametric cycles. From the figure, it is observed that face interpolation having 53 minutes of variation in cycle time and 36.3 minutes of variation in cycle time for Milling using R-parametric part program compared with XYZ part program. Hence, from the investigation, it is concluded that the machining time has been reduced drastically by using the optimized canned cycles compared to the XYZ parametric part program cycles.

Table III shows the comparison between Operations versus Machining time.

Table III Operation Vs Machining time

S.NO	Operation	Machining Time	
		Xyz-Parameter Cycle Time (min)	R-Parameters Cycle Time (min)
1	Facing Interpolation (Facing)	52.26	27.7
2	Outer diameter 55 interpolation (OD 55)	32.6	16.25
3	Outer diameter 157 interpolation(OD 157)	33.6	21.6
4	Milling	72.2	35.9
5	drilling	28.42	28.42
6	Boring	32.3	32.3
7	Semi-finish bore (SF bore)	34.6	34.6

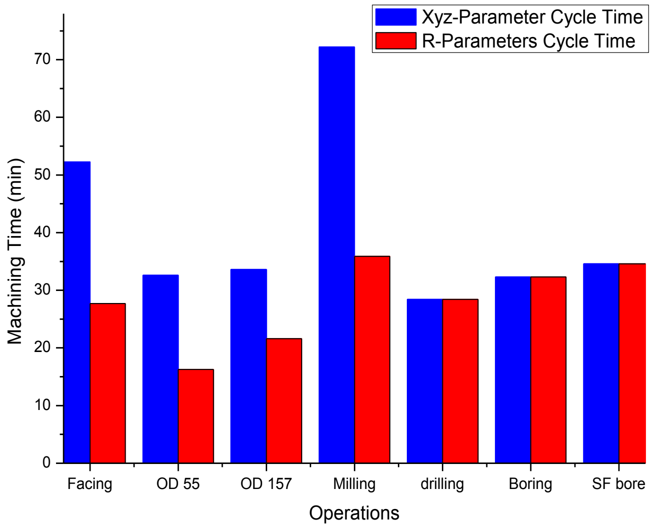

Fig. 8. Comparison between Operations Vs Machining Time with XYZ and R-parametric cycle time

B. *Machining Cost Analysis*

The demand of the product depends on better quality at low cost. If the machining cost is high, the total cost of the product also increases. So, we need to concentrate on the machining cost of the product. A critical comparison is made between operations and their machining cost by using XYZ parameters and R-parameters including with subroutines. The total machining cost using XYZ parametric part program is 3813.06 INR and the total machining cost using the R-parametric part program is 2613.33 INR. The total reduction in the machining cost is 1199.73 INR.

Fig. 9 shows the comparison between Operations versus Machining cost with XYZ and R-parametric cycle costs. From the figure, it is observed that face interpolation having 705.79 INR of variation in machining cost and 483.34 INR of variation in machining cost for Milling using R-parametric part program compared with XYZ part program. Hence, from the investigation, it is concluded that the machining cost has been reduced drastically by using the optimized canned cycles compared to the XYZ parametric part program cycles. Table IV shows the comparison between Operations versus Machining cost.

Table IV Operation Vs Machining Cost

S.NO	Operation	Machining Cost	
		Xyz- Parameter Cycle Cost (INR)	*R-Parameters Cycle Cost (INR)*
1	Facing Interpolation (Facing)	698.8	369.33
2	Outer diameter 55 interpolation (OD 55)	434.66	216.66
3	Outer diameter 157 interpolation(OD 157)	448	288
4	Milling	962	478.66
5	drilling	378.93	378.93
6	Boring	430.66	430.66
7	Semi-finish bore (SF bore)	461	461

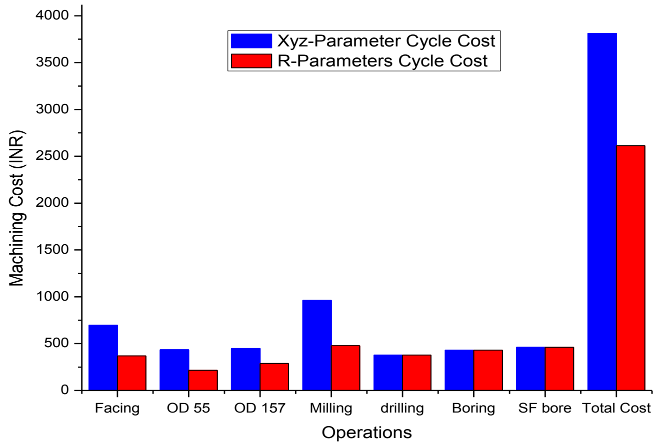

Fig. 9. Comparison between Operations Vs Machining Cost with XYZ and R-Parametric cycles

Fig. 10 shows the comparison between machining cost and time with R-parameters and XYZ parameters. From the figure it is evident that implementation of R-parametric part program will minimize the cycle time and cost compared with XYZ parametric part program. The cost saving percentage by using canned cycles is 68.54% and time saving percentage is 68.48%.

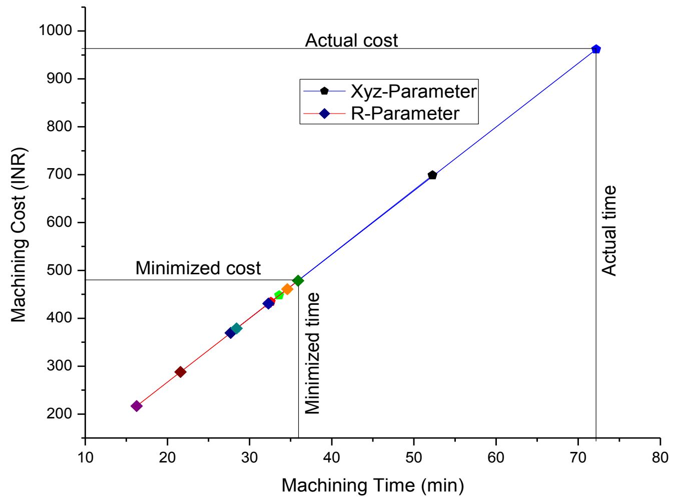

Fig. 10. Comparison between Machining time and Machining cost

VI. CONCLUSION

CNC machines provide faster through-put even for complex geometries with reduced machining time using a deterministic machining solution for precise execution speed of program parameters. The objective is to gain knowledge and to make the parameters of the program operator friendly and reducing the cycle time in order to increase productivity. The optimization of CNC part program, reduction of cycle time and machining cost is possible with improved programming techniques using R-parameters and subroutines. From the experimental investigation, it is observed that by using canned cycles machine cycle time, machining cost is reduced to 90 minutes and 1199.73 INR respectively compared to XYZ parametric program. Moreover, the machining cost and time are same for drilling, boring and surface finish bore with and without canned cycles because of any multiple movements of the cutting tool over work part in each cycle. The Breakdown time per month before implementation of R-parameters and subroutines is7440 minutes, after implementation of R-parameters and subroutines is 6060 minutes and 29% of time was optimized in availability of the machine.

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