Study of Power, Torque and Cost Calculation Logic for Cycle Time Reduction in CAPSmill

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Abstract- *CNC machining is a process used in the manufacturing sector that involves the use of computers to control machine tools. Tools that can be controlled in this manner include lathes, mills grinding etc.CAPSturn and CAPSmill are the industrial products of CADEM.'Study of Power, Torque and Cost calculation logic for cycle time reduction in CAPSmill'involves the cost calculation of industrial products for different shapes and sizes (profiles) in CAPSmill. Power calculation and cycle time reduction are carried out for all types of machining operations. These cost calculation logic are automatically applied in money maker. Money maker involves machining parameters like feed, speed, depth of cut etc. The money maker can automatically calculate cost and power for various operations performed in CAPSmill software. The operations performed in CAPSmill are drilling, boring, reaming, face milling, side milling, pocket milling, chamfer milling, slot milling, side slot milling, T-slot milling, spot facing, thread milling, cylindrical interpolation, engraving etc.The money maker helps in cycle time reduction at shop floor.*

Keywords- Milling operations, Optimization, Cutting parameters, Cycle time reduction

I. INTRODUCTION

Milling is a cutting process that uses a multipoint cutter to remove material from the surface of a work piece. The milling cutter is a rotary cutting tool, often with multiple cutting points [1]. As opposed to drilling, where the tool is advanced along its rotation axis, the cutter in milling is usually moved perpendicular to its axis so that cutting occurs on the circumference of the cutter. As the milling cutter enters the work piece, the cutting edges (flutes or teeth) of the tool repeatedly cut into and exit from the material, shaving off chips from the work piece with each pass. The cutting action is shear deformation; material is pushed off the work piece in tiny clumps that hang together to a greater or lesser extent (depending on the material) to form chips. This makes metal cutting somewhat different from slicing softer materials with a blade.

The milling process removes material by performing many separate, small cuts. This is accomplished by using a cutter with many teeth, spinning the cutter at high speed or advancing the material through the cutter slowly most often it is some combination of these three approaches. The speeds and feeds used are varied to suit a combination of variables. The speed at which the piece advances through the cutter is called feed rate, or just feed; it is most often measured in length of material per full revolution of the cutter [1].

Milling is the cutting operation that removes metal by feeding the work against a rotating, cutter having single or multiple cutting edges. Flat or curved surfaces of many shapes can be machined by milling with good finish and accuracy. A milling machine may also be used for drilling, slotting, making a circular profile and gear cutting by having suitable attachments.

CNC machining is a process used in the manufacturing sector that involves the use of computers to control machine too1s. Too1s that can be controlled in this manner include lathes, mills etc.

Mil1ingis the machining process of using rotary cutter to remove material from a work piece by advancing in a direction at an angle with the axis of the tool. It covers a wide variety of different operations and machines, on sca1es from small individual parts to large. It is one of the most commonly used process in industry and machine shops today for machining parts to precise sizes and shapes.

Many different types of cutting too1s are used in the milling process. Mil1ing cutters such as end mil1s may have cutting surfaces across their entire end surface, so that they can be drilled into the work piece[1]. Mil1ing cutters may also have extended cutting surfaces on their sides to allow for peripheral mil1ing. Tools optimized for face mil1ing tend to have only small cutters at their end corners.

II. LITERATURE SURVEY

From the works of Othmani et al. [3], it's observed that, the method to calculate cutting time for complex geometry of contouring using linear or circular interpolation. The calculation method of cutting time is based on the ratio of the machined volume by the removed material rate during the contouring operation. This approach has been validated only for linear or circular interpolation.

From the works of V. S. Thangarasu [4], it's observed that, the relationship with the basic parameters to responses namely Surface roughness (Ra) and Material Removal Rate (MRR). The method is used to develop prediction formulas is used for High speed CNC milling process optimization. With higher Spindle speed, Feed rate and Depth of cut for better surface finish and material removal rate. The Ra and MRR is resultant of various controllable process parameters are Spindle speed,

Feed rate and Depth of Cut, Hardness of the material, wet or dry machining, type of insert, and Dynamic forces on the job, tool wear rate with Cutter geometry. The experiments and analysis of the experimental data in connection with multi RSM optimization of high speed CNC end milling operation has been found useful to get optimum parameter setting..

From the works of Dotcheva et al. [5],it's observed that, the optimization mechanism controls dimensional tolerance through knowledge of cutting forces and the associated cutting tool deflections. The developed model of the end milling process describes the main parameters. The parameters are chip thickness, engagement angles, cutting force, cutting tool deviation, and simulates the relationship between them during the cutting operation.. The experimental results validated the theatrically developed optimization strategy. With the new optimized feed rates an enhancement in productivity is achieved.

From the work of Viktor P. Astakhov[6], Its observed that, the "Effects of the cutting feed, depth of cut, cutting speed and work piece metal cutting as having the greatest influence on tool wear and tool life. This is because of the existence of a number of contradicting results on the influence of the cutting feed, depth of cut, and work piece (bore) diameter.. The obtained results reveal the true influence of the cutting feed, diameter of the work piece, and diameter of the hole being bored on the tool wear rate. It also found that the depth of cut does not have a significant influence on the tool wear rate. The obtained results provide methodological help in the experimental assessment and proper reporting of the tool wear rates under different cutting conditions.

III. IMPORTANCE OF CAPSmill [2]

CAPSmill is a CNC programing software. CAPSmill reduces cycle times and programming time. It enables to take on complex jobs confidently and first time right programs and accurate cycle time calculations are guaranteed.

Reduces machining cycle time: Reduce manufacturing lead times and production cycle times by reducing waiting times between processing stages, as well as process preparation times and product conversion times.

Reduce programming time: Automatic raw material up dation, tool selection guidance and conversational screens reduce programming time dramatically

Reduce part rejection: Automatic tool gouge prevention ensures that a tool does not gouge into the part even if its geometry does not allow it to enter a particular contour.

Reduce dependence on skilled CNC programmers: No CNC programming knowledge needed. Machine operator can do the programming.

Reduce machine downtime: Automatic safe tool path and gouge prevention eliminate the need for single-block check and dry run at the machine.

Eliminate accidents and rejections: Manual errors caused by misunderstanding programs is eliminated, and hence the resultant accidents and rejections.

Efficient programs, interchangeable between machines: Compact programs with canned cycles and subprograms output for repetitive operations. Support for all popular CNC controls Fanuc, Sinumerik, Haas, Fagor, etc.

IV MILLING OPERATION USED IN THE PROJECT

Face milling: The face milling operation generates a flat surfaces and mill a full surface, from edge to edge, or mill till a square shoulder.

Pocket milling: Pocket milling has been regarded as one of the most widely used operations in machining. It is extensively used in aerospace and shipyard industries. In pocket milling the material inside an arbitrarily closed boundary on a flat surface of a work piece is removed to a fixed depth. Generally flat bottom end mills are used for pocket milling. Firstly roughing operation is done to remove the bulk of material and then the pocket is finished by a finish end mill.

Side milling: This operation mills a wall along a contour. Rough milling is done at multiple widths and multiple depths, while finishing milling is done at a single depth.

Slot milling : Slot milling has been regarded as one of the most widely used operations in machining. It is extensively used in machine tables and shipyard industries. In slot milling the material inside an arbitrarily closed boundary on a flat surface of a work piece is removed to a fixed depth.

Drilling: Drilling is a cutting process that uses a drill bit to cut or enlarge a hole of circular cross-section in solid materials[1]. The drill bit is a rotary cutting tool, often multi point. The bit is pressed against the work piece and rotated at rates from hundreds to thousands of revolutions per minute.

Primary data used for the project.

Table I. Primary data used for the project.

Name of the operation	Number of trails	Depth of cut (mm)	Work piece material	Tool used	Tool material
Face milling	Trail 1	2	Mild Steels, high carbon low alloy,	Face milling cutter -80 mm Diameter	Carbide
	Trail 2	1.5			
	Trail 3	1			
	Trail 4	0.5			
Pocket milling	Trail 1	2	Mild Steels, high carbon low alloy,	End mill cutter-10 mm diameter	Carbide
	Trail 2	1.5			
	Trail 3	1			
	Trail 4	0.5			
Side milling	Trail 1	2	Mild Steels, high carbon low alloy,	End mill cutter-10 mm diameter	Carbide
	Trail 2	1.5			
	Trail 3	1			
	Trail 4	0.5			
Slot milling	Trail 1	2	Mild Steels, high carbon low alloy,	End mill cutter-10 mm diameter	Carbide
	Trail 2	1.5			
	Trail 3	1			
	Trail 4	0.5			
Drilling	Trail 1	10	Mild Steels, high carbon low alloy,	Twist drill-6.8 mm diameter	High speed steel
	Trail 2	15			
	Trail 3	20			

Operations performed on Vertical Machining Center (VMC)

The Figure 1 shows finishing part produced in Vertical Machining Center The finished part shows five operations such as face milling, slot milling, side milling, pocket milling, and drilling. For each operations the parameters like feed, speed and depth of cut varies and also diameter of cutter, number of teeth and depth of hole also different.

The CAPSmill software having a several number of work piece material like cast iron, aluminum, miles steel, stainless steel, iron based super alloys and nickel based super alloys and also several number of different types of cutting tools like side slotting, face milling, reaming, internal threading, boring, pocketing tool etc.

Cycle time data sheet:

Figure 1 Finishing part produced on VMC

The Figure 2show the cycle time sheet in a CAPSmill software. This cycle time sheet contain the machining parameters like cutting sopped, spindle speed, Feed rate and other parameters like cut length, cutting time rapid time, tool change time, miscellaneous time and the cycle time. Using this parameters from the software the power, torque, cost calculations has done.

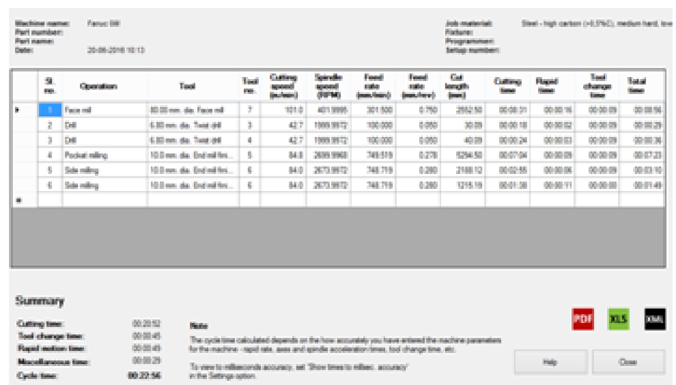

Figure 2.cycle time sheet

V RESULTS AND DISCUSSIONS

Face milling

Table II. Calculated values of Power, Torque, Cost and Cycle time for Face milling

Name of the Operations	Feed rate, mm/tooth (fz)		No. of teeth on cutter (N)	Diameter of cutter, mm (D)	Speed (RPM)	Cutting speed, m/min (V)	Feed rate mm/min (Vf)		Specific cutting force N/mm2 (Kc)	Power ,KW (P)	Torque , N-mm (T)	Cost, Rs.	Cycle time, sec (t)
Face milling													
	XY	Z					XY	Z					
Test 1	0.15	0.105	5	80	402	101	300	253	1211.9	0.975	23.17	22.36	322
Test2	0.15	0.105	5	80	402	101	300	253	1211.9	0.73	17.34	29.6	426
Test 3	0.15	0.105	5	80	402	101	300	253	1211.9	0.487	11.57	36.52	529
Test 4	0.15	0.105	5	80	402	101	300	253	1211.9	0.244	5.8	73	1048

Machine efficiency %	Actual power P_a KW	Material Thickness mm	Depth of cut (a_e) mm	Width of cut (a_e) mm	Machine hour rate, Rs.
80	0.78	5	2	80	250
80	0.59	5	1.5	80	250
80	0.39	5	1	80	250
80	0.12	5	0.5	80	250

Table III. Observed values of Power, Torque, Cost and Cycle time for Face milling

Name of the Operations	Feed rate, mm/tooth (fz)		No. of teeth on cutter (N)	Diameter of cutter mm (D)	Speed (RPM)	Cutting speed m/min (V)	Feed rate mm/min (Vf)		Specific cutting force N/mm2 (Kc)	Power , KW (P)	Torque N-mm (T)	Cost Rs.	Cycle time sec (t)
Face milling													
	XY	Z					XY	Z					
Test 1	0.15	0.105	5	80	402	101	300	253	1211.9	1.008	16.8	24.23	349
Test2	0.15	0.105	5	80	402	101	300	253	1211.9	0.768	12.8	31.25	450
Test 3	0.15	0.105	5	80	402	101	300	253	1211.9	0.504	8.4	38.12	549
Test 4	0.15	0.105	5	80	402	101	300	253	1211.9	0.28	4.66	75	1080

Machine efficiency %	Actual power P_a KW	Material Thickness mm	Depth of cut (a_e) mm	Width of cut (a_e) mm	Machine hour rate, Rs. mm
80	0.81	5	2	80	250
80	0.62	5	1.5	80	250
80	0.4	5	1	80	250
80	0.23	5	0.5	80	250

The Table I shows the calculated values of power, torque, cost and the cycle time for face milling. The feed rate along the XY axis and the machining parameters like feed, speed and depth of cut were noted from CAPSmill software database. For this operation 80 mm diameter with 45 deg face mill cutter was used with various depth of cut. The machine hour rate (MHR) was considered from Micromatic Machine Tool (MMT) group as per their standard estimation. If the depth of cut is more for a high speed, the life of tool is reduced and more bending and compression stress occur on work piece and also cutter lift the work piece from the machine vice while machining. To reduce this effect chose appropriate machining parameters like low depth of cut with high speed or high depth of cut with low speed and high DOC with low feed or low DOC with high feed. The amount of material removed in face milling operation is 200x100x5mm with different depth of cut as 0.5, 1, 1.5, and 2 mm. This results cost changing continuously along with the cycle time. By varying the Depth of cut by 0.5 mm for each test, the value of power, torque, cost and cycle time is found to be varying by 22% of previous test in side milling operation. These variation in the values are tabulated in the table.

The Table II shows the observed value of power, torque, cost and the cycle time for face milling. The feed rate along the XY axis and the machining parameters like feed, speed and depth of cut were noted from standard CNC Vertical Milling Center (MCV-450). The experiment has been done in a VMC by considering CAPSmill machining parameters. While performing face milling operation the value of power is keep on changing in a Sinumerik 828 D control panel, because of tool produces more force over the work surface. If the DOC is more the power also increases linearly. The observed value were compared with the calculated value, small variation were observed in both. These small variation as show through the graph.

This graph represents actual power with respect to depth of cut for calculated value and observed value. It is clearly seen that there has been a small increase in the Depth of cut about 0.5mm, while the actual power also increased by 0.2Kw. The actual power have been risen linearly along the Depth of cut as shown in Figure 3. The graph shows there is small variation between calculated value and observed value, because of wear in a spindle bearing, machine efficiency, temperature loss, insert wear, coolant quality and material homogeneousness. It was found out that the variation is less than 5%, therefore the money maker feature can be implemented to CAPSmill software.

The Figure 4 shows power with respect to torque for calculated value and observed value. It is clearly seen that there has been a small increase in the torque, while the power also increased by 0.2Kw. The power have been risen linearly along the torque, because of the torque is directly proportional to the power in terms of speed, depth of cut and width of cut. The power is depended on the machining parameters like width of cut, depth of cut, feed rate and specific cutting force.
The Figure 5 shows cost with respect to cycle time for calculated value and observed value. It is clearly seen that there has been a small increase in the cycle time, while the cost also increased by 10 Rs. The cost have been risen linearly along the cycle time, because the cost is directly proportional to cycle time. The machine hour rate is main parameter to find or describe each machining operational cost. For 1048 Sec cycle time, the value of cost is 73Rs and next point the cycle time is 529 sec, the value of cost is 36.52 Rs, there is a bit of variation between first cut and second cut as compare to next cuts. Because of insufficient coolant, insert wear, temperature loss, and mechanical vibration.

This Figure 6 represents cycle time with respect to Depth of cut for calculated value and observed value. It is clearly seen that there has been a small increase in the cycle time 200 Sec, while the DOC also increased by 0.5 mm. The Cycle time have been risen linearly along the DOC. because of DOC is directly proportional to the cycle time. The results of these graphs shows there is small difference between calculated values and observed value because of some error will occurs while performing a operations in a Vertical Machining Center.

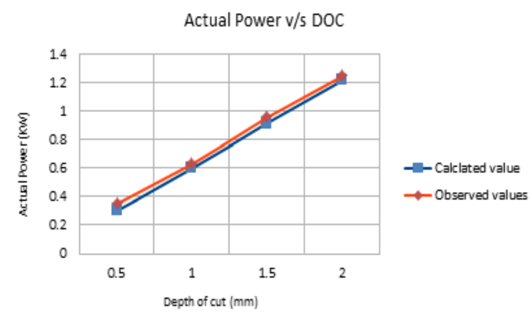

Figure 3.: Comparison between Actual power and Depth of cut

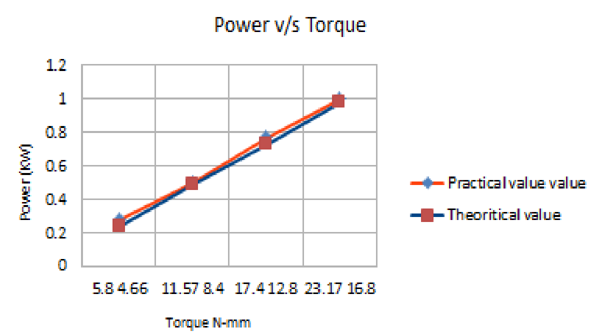

Figure 4.Comparison between Power and Torque

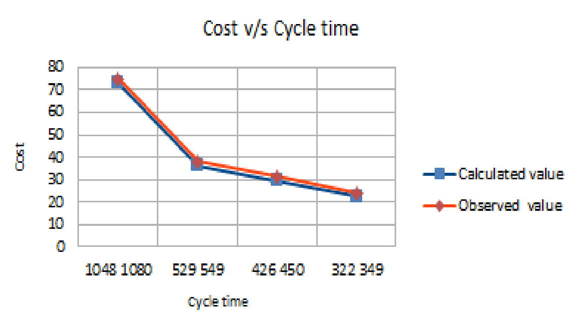

Figure 5 Comparison between Cost and Cycle time

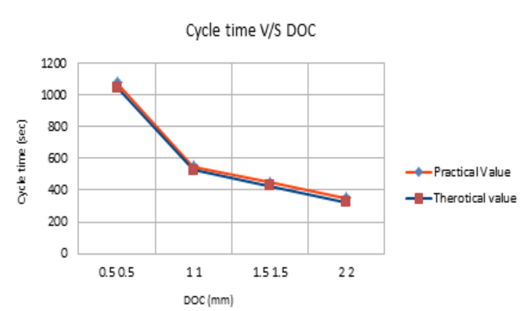

Figure 6 Comparison between Cycle time and DOC

VI. CONCLUSIONS

1. The main aim of this project is to reduced cycle time for different operations performed in milling machine. The work involves elimination of problem in machining operation by comparing values of power, torque, machining cost and cycle time in both theoretical and practically. By using standard formulas and Standard CNC vertical machining center (VMC)
2. After comparing the values of cycle time for different operations in CAPSmill and Vertical Machining Center, small difference was noted. Because of wear in a spindle bearing, machine efficiency, temperature loss, insert wear, coolant quality and material homogeneousness. It was found out that the variation is less than 5%, therefore the money maker feature can be implemented to CAPSmill software.

VII. SCOPE OF FUTURE PROJECT

1. The scope of the project is to improve cycle time for various operations performed on a vertical milling machine.
2. In CAPSmill software different types of work piece material are available like cast iron, nickel based super alloy, copper based alloys, iron based super alloys, stainless steel etc. Using the above same procedure to find the values of power, torque, and cost for different operations for cycle time reduction
3. The calculation may be repeated for other milling operations such as spot facing, reaming, boring, chamfring, side-slot milling, internal threading and counter sinking etc. to reduce the cycle time.
4. They are different controllers in CAPSmill software such as Fanuc, Mistrubishi, Fogor,etc using these controllers may perform the machining operations.

ACKNOWLEDGEMENTS

The authors are grateful to Mr. G. V. Dasarathi, Director (Application), CADEM Technologies Pvt. Ltd, Bangalore and Dr. V KRISHNAN, Professor in Department of Mechanical Engineering, Sir MVIT,), Ms. VijayaBhaskar (Senior Application Engineer), Micromatic Machine Tools,for providing the facilities for doing research and to the administrators of their respective institutions.

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