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SEQUENCE-SCHEDULE OF AN INTERACTIVE G-CAPP FOR 2.5D PRISMATIC PART USING MATHEMATICAL AND SIMULATION APPROACH

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KEYWORDS:

Computer Aided Process Planning, sequence, schedule, interactive and generative-CAPP

ABSTRACT

This paper reports on the development of 3'C-CAPP for an interactive-generative computer-aided process planning system for 2.5D part machining. However, the input details are obtained from a 3'CAM technique. Sequencing has been implemented based on operations. The operations like drilling and circular interpolation and corner milling can be identified automatically as for the order of operational preference given to a feature. Further, a scheduling based on a drill; mill (End) and mill (corner) have been developed for optimizing the time. However, a single sequencing and scheduling is perhaps not sufficient for all operations in all situations. So, there must be a change manufacturing environment with the multiple objectives number of operations, time consideration for each operation for optimization in tool and parameters change. Most of the works were carried out in determining the operation sequence on a single milling machine that can be extended to multi machines. The selection of efficient machining parameters is of great concern in manufacturing industries. The program has been developed by .Net software at backend and Visual Studio IDE at the front end.

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1. INTRODUCTION

The eminent interface between computer-aided design (CAD) and computer-aided manufacturing (CAM) is Computer-aided process planning (CAPP) in computer-integrated manufacturing (CIM) network. Due to the linear approach in traditional process planning system the multiple planning tasks are not possible. However, the traditional process planning is neither a feasible idea nor optimal approach. This circumstance has created many gaps in

CAPP researches. Therefore, it has been identified as the Computer aided process planning (CAPP) provide more integrated manufacturing environments developed on the basis of modern software architectures and information technologies. In addition to that, the highly competitive environs and milieu being forced the modern manufacturing industries to produce a smaller cycle, with shorter lead time and at reduced costs. Flexibility pays a major role in contemporary manufacturing activities. Process plan includes standard process operations. However, to retrieve and to synchronize various operations into feasible and optimal methods an effective process planning task is much needed. As process planning is a complex task, it is needful to take into consideration the affecting factors. Therefore, it has been proved that an efficient CAPP system plays a major contribution to integrate the design and manufacturing. The CAPP system consider as available resource for reducing cost and time of a product being machined. It has been observed that almost 15% of the process planner's time is spent on decision making in fact 15% remaining time is spent on gathering data, calculating and document preparation. Investigation shows that efficient CAPP systems could result in a total reduction of the manufacturing cost in the range of 25%-30%, and the manufacturing cycle time (MCT) and altogether the overall production time is reduced by up to 50% [1].

The Computer Aided Process Planning (CAPP) is not the much aged proposal. In the early 1960's the first idea CAPP system was developed by prominent scientist Niebel. Since then various manufacturing industries try to explore on a development of CAPP system from research-industrial trial product to company-commercial packages. Being customized various planning issues and offering prosperity of dissimilar solutions. Presently, there are three general approaches to computer aided process planning variant, generative and hybrid. The variant deals the process plan for a similar features and jobs with little bit modifications whereas the generative is unique process planning for each job. As the name implies, the hybrid is the combination of both variant and generative. Each one has been implemented with specific technique.

A new Concentric Contrasting Circles Approach Methodology (3'CAM) technique has been introduced for recognition and extraction of various symmetric features from 2.5D prismatic part. The necessitated coordinates are imported from a standard IGES file as an input from creo2.0 designed part and recognition of features along with their geometric dimension as output has been successfully achieved. In general, the extraction of features plays a major role to build a CAPP module for machining a part. The geometric information of the 2.5D part that features to be extracted uses 3'CAM technique instead of Boundary representation (B-rep) or Constructive Solid Geometry (CSG). However, the recognition and extraction of a 2.5D part is demonstrated by a simple case study. The extraction of features is developed by using Visual Studio IDE at front end, supported by SQL-Server/.Net and C# software at back end respectively [2]

An efficient approach of machining plan has been presented using 3'C-CAPP approach. This is a simple, user friendly approach than some of those which had been proposed previously. All the modules that have been discussed here are basically output from so called 3'CAM technique and input to the 3'C-CAPP for an interactive G-CAPP system. The necessary data is collected from 3'CAM and other required inputs to generate well-organized machining plan for a proposed model. The most important four topics discussed in brief. The approach proposed here, the machining operations selection is done by 3'CAM. Not like the preceding publications we have not used an arduous task to generate operation sequences for machining ascertain feature to minimize the cost. In the present approach, the thumb rules developed along the constraints for selection of features and machining operations [3]

In the last four decades an enormous research work has been carried out in CAPP system. The overall research work is not only limited but also dealt like prismatic part, sheet metal part, cylindrical part, assembly part and foundry systems included the geometric modelling techniques. Generic Algorithm (GA) is a sharp search technique requires domain detailed information to solve an issue.GA has been productively applied to a variety of optimization issues since beginning. [4]. the decision-making in process planning takes place in an environment in which goals and constraints are fuzzy. This generates the need of approximation to obtain a reasonable model of a real system. Fuzzy theory deals with this type of problems by transforming human knowledge to mathematical formulae [5]

The use of computer technology for process planning was initiated four decades before. Since then, there has been a large amount of research work carried out in the area of computer-aided process planning (CAPP). One of the reasons for this is the role of CAPP in reducing throughout time and improving quality. The process planning activities includes interpretation of design data, selection, and sequencing of operations to manufacture the part/product, selection of machine and cutting tools, determination of cutting parameters, choice of jigs and fixtures, and the calculation of the machining times and costs. From these two basic approaches, the variant approach continues to be used by some manufacturing companies. Nowadays, the trend is toward a generative approach however, A hybrid CAPP system has been developed as a so-called pro-planner for an efficient heuristic algorithm to find near optimal operation sequences from all available process plans in a machine setup[6].

An investigated the integration of CAD CAPP/CAM based on machining features [7]. A different approach has been discussed as a part of their distributed process planning (DPP) system [8]. An approach to develop a road map method based on knowledge. It has been proved that the road-map method can introduce flexibility and dynamics in the manufacturing processes and also simplifies the decision-making process in production planning. Next to that a hybrid approach to combine knowledge-based rules and geometric reasoning rules for the purpose of sorting out the sequence of interacting prismatic machining features was proposed. [9] Fuzzy set theory/logic approach for the solution of process sequencing problem by creating a prototype process planning system that uses a hybrid of fuzzy and generic has been discussed[10].

A decision space of process routing based on process constraints were constructed with improved search efficiency of generic algorithm was projected. A genetic algorithm for operation sequencing in process planning has estimated [11]. An idea in a different way categorized process planning systems into non-linear, closed-loop and distributed process planning systems. In nonlinear process planning systems, which generate and rank all possible alternatives, plans for a part prior to production independent of the resource status on the shop floor; then at the time of production, the scheduler works its way through the alternatives until one is found which meet the current constraints of production. Closed-loop process planning generates a plan for a job in real-time at the time of production based on the feedback from the shop floor with respect to the status of the resources at that time and distributed process planning involves performing planning and scheduling in parallel [12].

In 80's decade researchers in the development of CAPP have put their efforts on a higher level. While the researchers in industry focused on introducing variant CAPP systems into a real manufacturing environment, the researchers in academia focused on introducing AI concepts into the development of generative CAPP systems. Simultaneously, some other research institutions focused their attentions on integrated CAPP systems in conjunction with manufacturing functions. By the end of the 1980s, many intelligent and integrated process planning systems had appeared. The International Institution for Production Engineering (CIRP) hosted an international seminar on the main themes of CAPP in Pennsylvania State University, USA in the year 1987. More than hundred technical papers presented with referring CAPP systems include FLEXPLAN [13]. Aside from general CAPP reviews, there were also surveys in a more specific area, such as CAD and feature-based process planning, neural network-based process planning, expert system-based process planning [14].Global competition and rapidly changing customer requirements have led to major changes in production styles and manufacturing strategies. Traditional, centralized and sequential process planning mechanisms are found insufficient to respond to the changing production styles and high-mix, low-volume production environments. Agent technology offers a possible tool to address such problems, and to design and implement efficient distributed manufacturing systems [15].

Using Fuzzy set theory/logic, an approach for the solution of process sequencing problem by creating a prototype process planning system that uses a hybrid of fuzzy and generic approaches has been presented. An introduction on a fuzzy inference system for the purpose of choosing appropriate machines as an alternative way to integrate the production capability during scheduling has been published [16].

An approach to integrate key product realization activities using neural data representation was presented, the approach as very useful for direct distributed applications, which passes the data in the form of XML streams proved with a case study [17]. A neural network method was utilized by for the development of a learning agent of the multi agent-based system approach. A mult-agent system consisting of three autonomous agent global manager, design, and optimization proposed and presented for the integration of process planning and scheduling [18]. An algorithm was developed to enable concurrent process planning and scheduling environment in manufacturing of tuned parts [19].The developed algorithm is based on GA, which performs strategic resource optimization for process planning development and also handles unplanned events. Next to that an optimization agent in a multi agent-based system for the integration of process planning and scheduling was presented [20].

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2. PROPOSED MODEL FOR THE APPLICATION OF RESEARCH METHOD

Component designed model is imported from AutoCAD software to Autodesk Design Review, and various required nodes are marked under standard DWF format dimensional view of the part is as shown in fig. 24. Node list is prepared, which consists of all required nodes as per constraints and requirements as shown in the fig. 26. Maximum distance in X, Y, Z is taken as block dimensions L, B, and T, respectively: L=100 mm, B=100 mm, T=−40 mm.

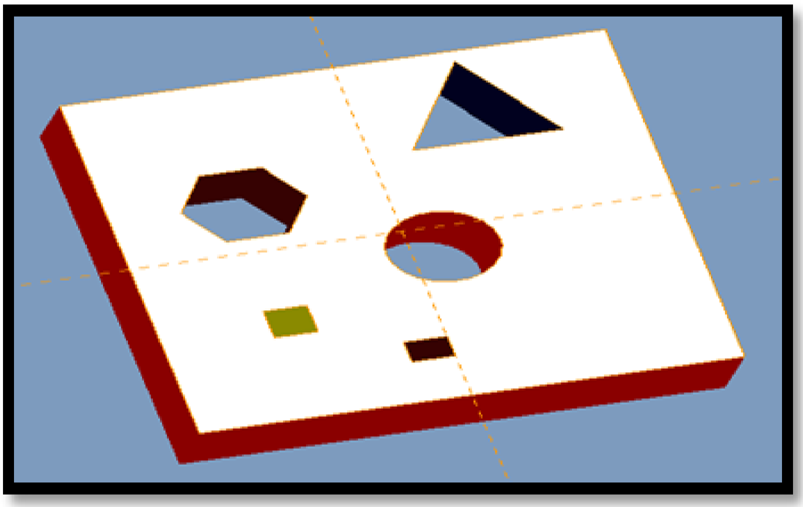

Figure 1. Isometric view of prismatic part model

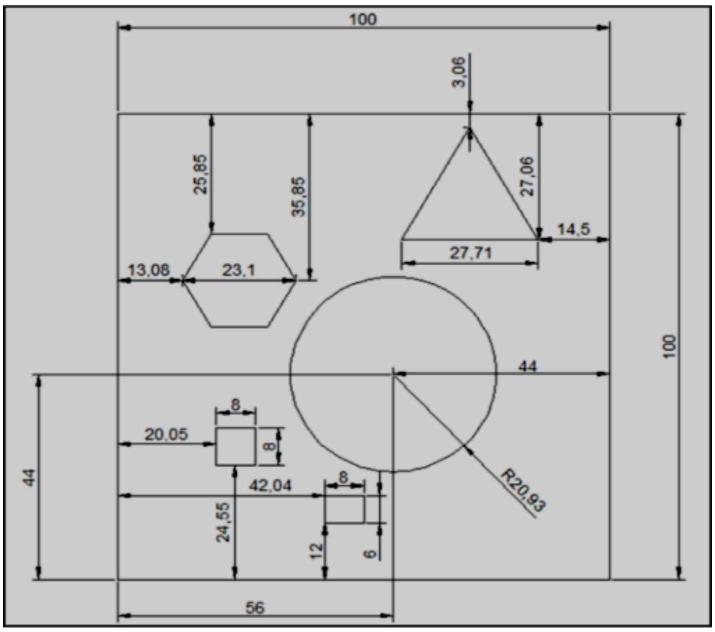

Figure 2. Two Dimensional view of the Part

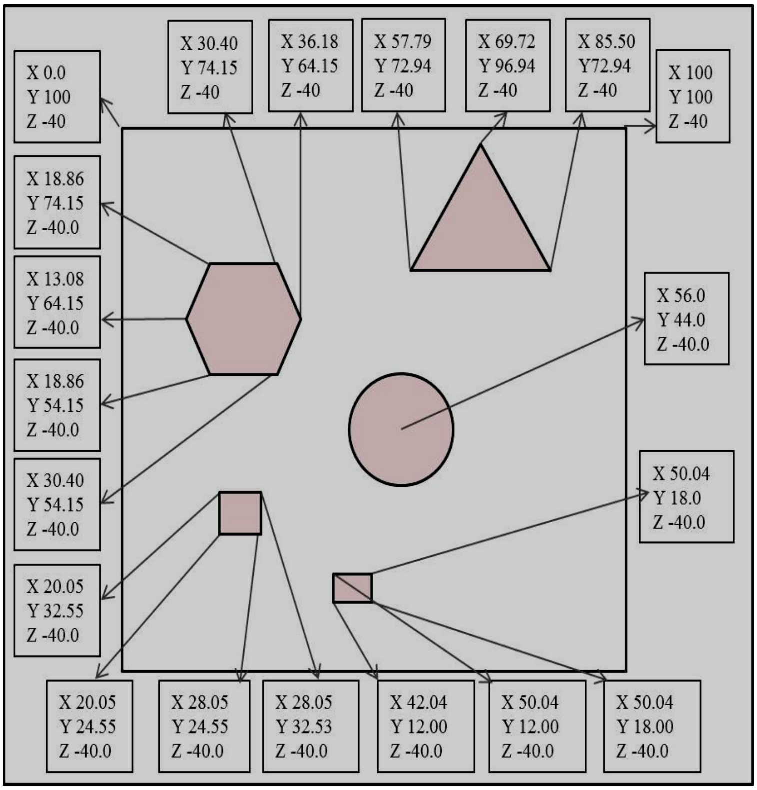

Figure 3. Required nodes Edge-rep

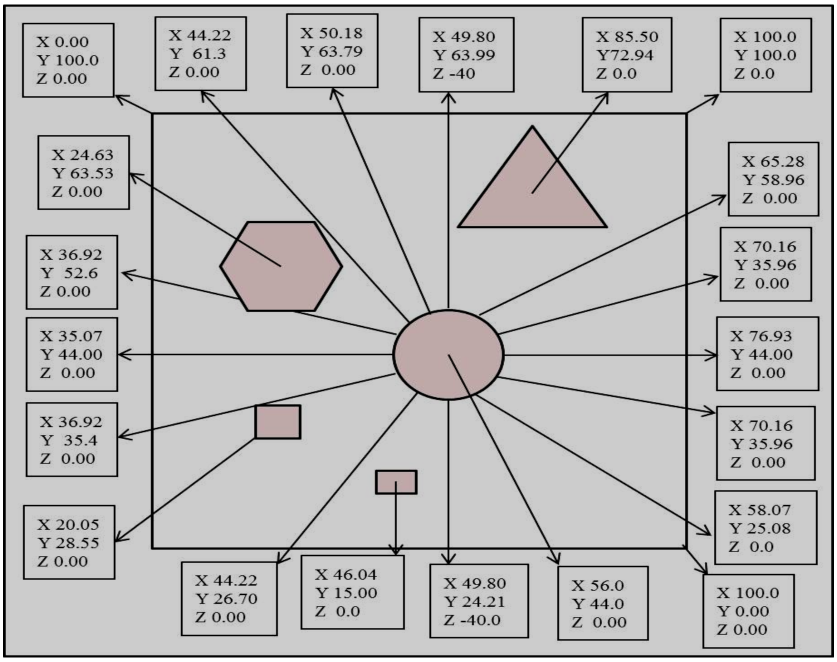

Figure 4. Centroid and circle nodes Edge-rep

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3. HIERARCHY OF SEQUENCING& SCHEDULING

	C0	C1	C2	C3	C4
R0	S.No	Feature title d_r	Feature location in XY-plane	Circumcenter location	Depth of pocket
R1	1	Square pocket	(20.05,24.55,0) (28.05,32.55,0) (28.05,24.55,0) (20.05,32.55,0)	(24.05,28.55,0)	-40
R2	2	Rectangular pocket	(42.04,18.00,0) (50.04,18.00,0) (50.04,12.00,0) (42.04,12.00,0)	(46.04,15.00,0)	-40
R3	3	Cylinder	Diameter = 40mm	(56.00,44.00,0)	-40
R4	4	Hexagon	(18.86,54.15,0) (18.86,74.15,0) (30.40,74.15,0) (30.40,54.15,0) (36.18,64.15,0) (13.08,64.15,0)	(24.63,64.15,0)	-40
R5	5	Triangle	(69.72,96.94,0) (85.50,72.94,0) (57.79,72.94,0)	(71.00,80.94,0)	-40

Table 1. Executing function ID: FET_[Rf, Cß], table call code FET

From the output of 3'CAM technique the above data is obtained with columns (C) and rows (R). The circum centre location can be taken into account for the each feature as a start position of the cutting tool. The feature coordinates are helpful to guide the cutting tools to perform machining within the limit of the boundary coordinates. Number of features can be extracted from a given job along with their geometrical structure and dimension that is used as the basic information to develop a CAPP system.

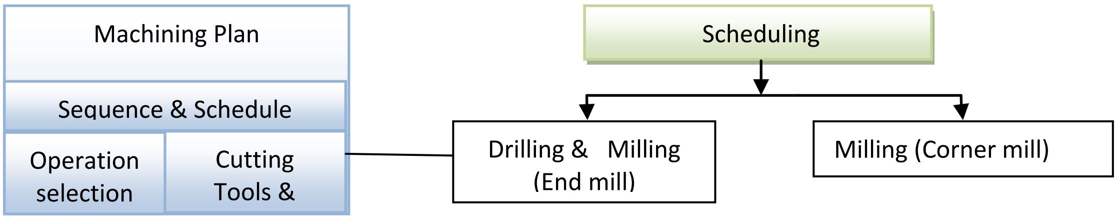

Figure 5. Tree of scheduling activity

The machining plan deals with the sequence and schedule of machining that include the type of operation selection, cutting tools and parameters. The sequence and schedule further deals with the two machining operations they are drilling and Milling. The drilling sometimes integrated along with milling (corner mill) and the milling (end mill) followed by corner mill, depends on the type of feature being machined.

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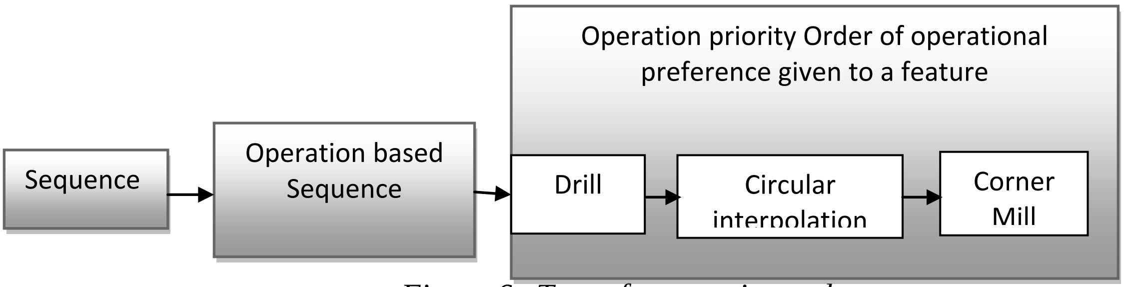

Figure 6. Tree of sequencing order

Machining sequence of features is specified, based on operation priority such that drilling is given as first priority, circular interpolation is second priority and last priority is given to corner milling. Each and every feature is selected as per the given priority i.e., a feature is selected in first cum first order as per feature extraction table [FET]. So, that if there are any drilling features then all the drilling operation required features are machine with respective drill bits followed by all the circular interpolation required features are machined and finally corner milling operation will be selected.

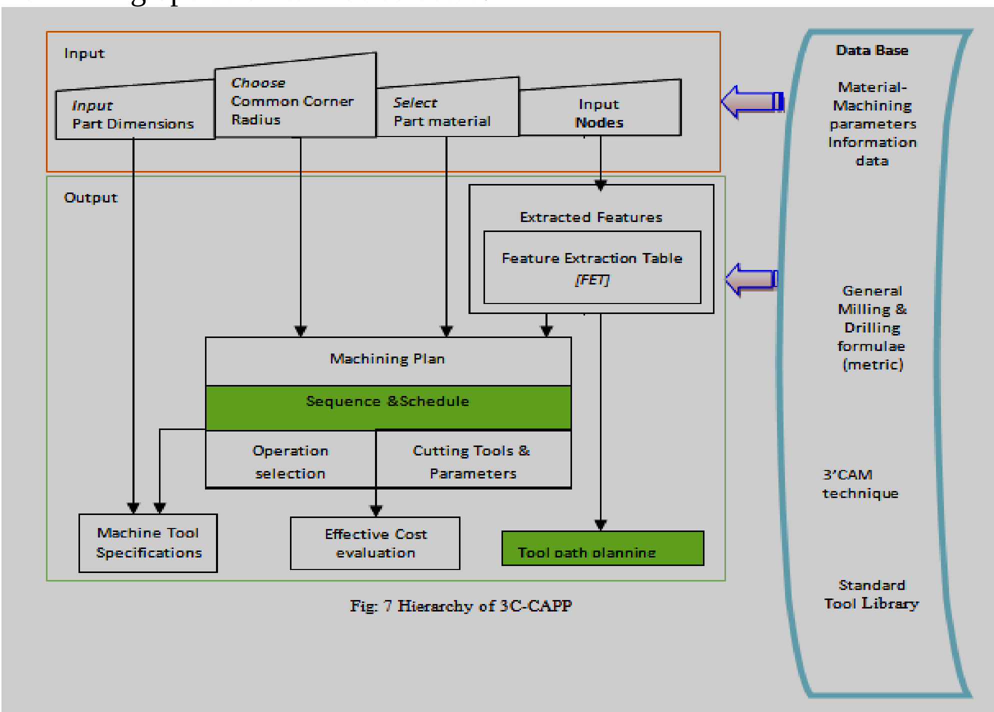

Figure 7. Hierarchy of 3C-CAPP [2] [3]

4. SEQUENCING & SCHEDULING OF DRILLING& CIRCULAR INTERPOLATION

C_0	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	
S.No	Machining feature	Drill Bit type	Drill material	Drill diameter *mm*	Feed *mm/min*	Feed *mm/rev* D_z	Speed *RPM* N_s	Drilling time min	R0
1									R1

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Table 2. Drill bit schedule table: Code DBTT DBTT_[Rf, C1...C6]

C0	C1	C2	C3	C4	C5	C6	C7	C8	C9
S.No	Machining feature	milling cutter type	Milling cutter material	mill diameter *mm*	No. of flutes	Speed RPME_s	Feed *mm/min* E_z	Depth of cut mm	Milling time min
1									

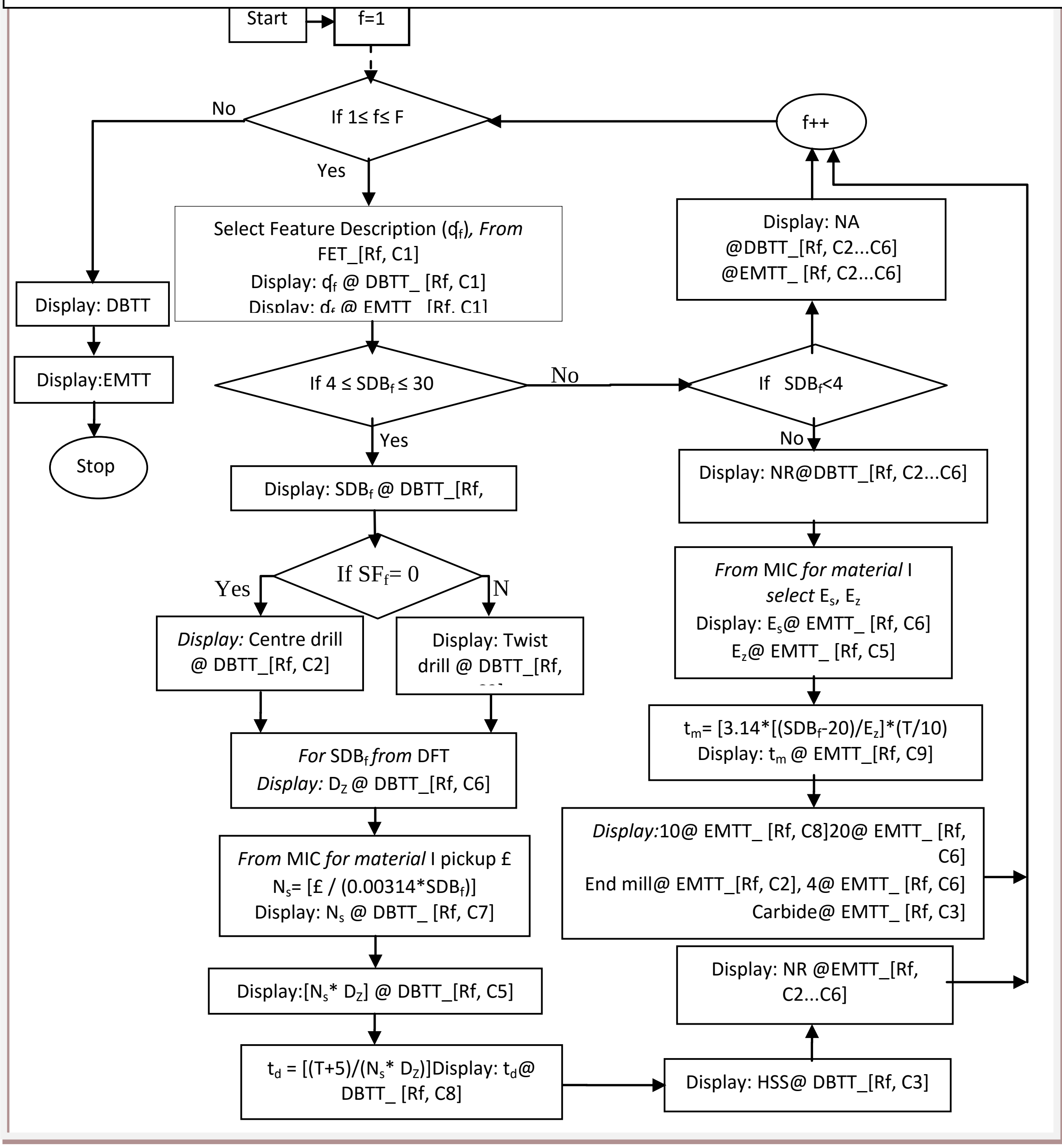

Figure 8. Flow chart of sequence & Schedule

5. ALGORITHM FOR SEQUENCING & SCHEDULING FOR *DRILLING AND CIRCULAR INTERPOLATION*

f=1, Step#1, If $1 \leq f \leq F$
Go to Step#2, Else;
Display: DBTT & EMTT, Stop;
Step#2
Select Feature title = ɖ$_f$ *From* FET_[Rf, C1], Display: ɖ$_f$ @ DBTT_ [Rf, C1], Go to Step#3
Step#3
If$4 \leq SDB_f \leq 30$, then Display: SDB_f @ DBT_[Rλ, C3] Go to Step#4, Else;Go to Step#8
Step#4
If SF_f= 0 then *Display:* Centre drill @ DBT_[Rf, C2], Go to Step#5 Else;
Display: Twist drill @ DBTT_[Rf, C2], Go to Step#5
Step#5
For SDB_f *from* DFT
Display: D_Z @ DBTT_[Rf, C6], Go to Step#6
Step#6
From MIC *for material* I pickup £
N_s= [£ / (0.00314*SDB_f)], Display: N_s @ DBTT_ [Rf, C7], Go to Step#7
Step#7, Display:[N_s* D_Z] @ DBTT_[Rf, C5]
t_d = [T/(N_s* D_Z)]
Display: t_d@ DBTT_ [Rf, C8], Display: HSS@ DBTT_[Rf, C3], Display: NR EMTT_[Rf, C2...C6]
Go for f increment f++, Go to Step#1
Step#8
If SDB_f<4, Go to Step#9, Else; Go to Step#10
Step#9:
Display: NA @DBTT_ [Rf, C2...C6]and @EMTT_ [Rf, C2...C6], Display: NR @DBTT_ [Rf, C2...C6]
Go for f increment f++, Go to Step#1
Step#10; *From* MIC *for material* I select E_s, E_z, Display: E_s@ EMTT_ [Rf, C6]
E_z@ EMTT_ [Rf, C5], t_m= [3.14*[(SDB_f-20)/E_z] + (T/E_z)]
Display: t_m@ EMTT_[Rf, C8]
Display: 10@ EMTT_ [Rf, C8]20@ EMTT_ [Rf, C6], End mill@ EMTT_[Rf, C2] 4@ EMTT_ [Rf, C6]
Carbide@ EMTT_ [Rf, C3], Go for f increment f++, Go to Step#1.

For initial value, The selection of first feature represents f=1, the f value enters into the decision $1 \leq f \leq F$ if the condition is not satisfied the prepared Drill Bit Timing Table (DBTT) & End mill Timing Table are displayed. If the above condition is satisfied, then SDBM is called from data base and the following condition is checked 'If $4 \leq SDB_f \leq 30$ is satisfied', SDB_f @ DBTT _ [Rf, C3] is displayed if not and consequently Drill bit table for a particular row (f), is prepared then row increments by 1. Some parameters and tools are suggested as constants those are depth of cut for circular interpolation is 10mm, end mill diameter 20mm & material as carbide with 4 flutes, for drilling tool material is HSS.

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Input: Manually selected work piece Material. For pre-selected work piece Material, feed & speed charts [MIC] are required for cutting tools from data base. Feature Extraction table [FET] and Standard drill bit module [SDBM] output from 3'CAM technique. Skeleton of Drill bit time table [DBTT] and End mill time table [EMTT]

Output: The prepared Drill bit time table [DBTT] and End mill time table [EMTT] will be displayed.

The data flow Process in the algorithm:
Condition 1: if $1\leq f\leq F$
Input:
Consider f=1[default] as initial input value of first iteration and for succeeding iterations, from the any of condition 3 or condition 4
Condition explanation: IFf (row value of FET) value is exceeded the no. of features (F).
Output:
If satisfied: The feature description will be displayed in [Rf, C1] in DBTT and EMTT simultaneously then further continues to condition 2.
If not satisfied: the final Drill bit time table [DBTT] and End mill time table [EMTT] will be displayed.

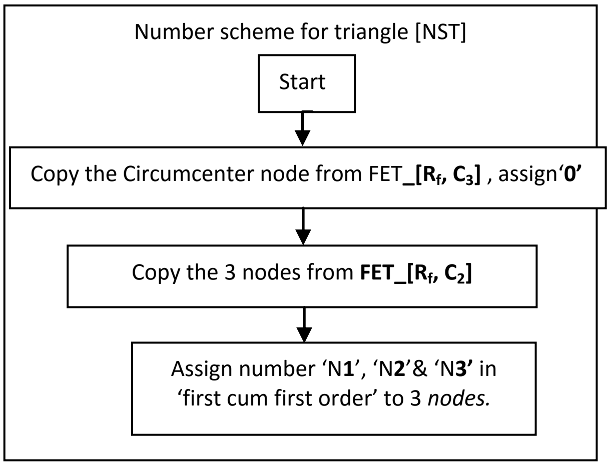
Condition 2: if $4 \leq SDB_f \leq 30$
Input: from the condition1. If satisfied.
Condition explanation: it checks whether, the SDB_f falls within closed interval[4-30] (by default)
Output:
If satisfied: SDB_f will be displayed in the [Rf, C4] at DBTT and then further continues to condition 4.
If unsatisfied: Go to the condition 3.
Condition 3: if $SDB_f < 4$
Input: from condition 2.If not satisfied.
Condition explanation: it checks whether, the SDB_f is less than 4.
Output:
If satisfied: Treat SDB_f as not applicable value and proceeds to feature increment (f++) from there to condition1
If not satisfied :proceeds with display NR @DBTT_[Rf, C2...C6],From MIC for material I select E_s, E_z
E_s@ EMTT_ [Rf, C6], Ez will be displayed at[Rf, C5] of EMTT, Compute the formula i.e., time elapsed for circular interpolation$t_m = [3.14 * [(SDB_f - 20)/E_z] + (T/E_z)]$Display: t_m@ EMTT_[Rf, C8]

Display the following: 10@ EMTT_ [Rf, C8], 20@ EMTT_ [Rf, C6], End mill@ EMTT_[Rf, C2], 4@ EMTT_ [Rf, C6]Carbide@ EMTT_ [Rf, C3] and proceeds to f increment f++. Then finally go to condition1.

*Condition 4:*If $SF_f= 0$

Input: from condition 2. If satisfied.
Condition explanation: it checks whether the selected feature is cylindrical pocket are not. (If the Diameter of in-circle = circum-diameter for a feature then it must be a cylinder)
Output:
If satisfied: display 'Twist drill' in the [Rf, C2] at DBTT
If not satisfied: display 'centre drill' in the [Rf, C2] at DBTT

If the output from condition 4 is either satisfied or not in both cases,
Display the following:
For SDB_f from MIC select drill feed *Display:* D_Z @ DBTT_[Rf, C6]
From MIC *for material* I pickup £ (surface speed), compute N_s= [£ / (0.00314*SDB_f)] &Display: N_s @ DBTT_ [Rf, C7],Display:[N_s* D_Z] @ DBTT_[Rf, C5],Compute t_d = [T/(N_s* D_Z)] & Display: t_d@ DBTT_ [Rf, C8],Display: HSS@ DBTT_[Rf, C3], Display: NR EMTT_[Rf, C2...C6] and then Go for f increment f++. Finally go to condition 1.



6. ALGORITHM FOR NUMBERING SCHEME FOR TRIANGLE

Step#1; Copy the Circumcentre node from FET_[R_f, C_3]and assign '0', Go to Step#2
Step#2: Copy the 3 nodes from FET_[R_f, C_2], Go to Step#3
Step#3: Assign number 'N1', 'N2'& 'N3' in 'first cum first order' to 3 *nodes.*

In order to provide sequential point to point machining information assignment of numbering to the nodes are necessary. Since triangle consists only three nodes numbering in first cum first preference order. For square, a numbering scheme is required the process of assignment is in first cum first order number 1 is given to first node, the farer node from this node is given number 2 and number 3 & 4 is assigned in first cum first order. For hexagon, a numbering scheme is required the process of assignment is in first cum first order number 1 is given to first node.

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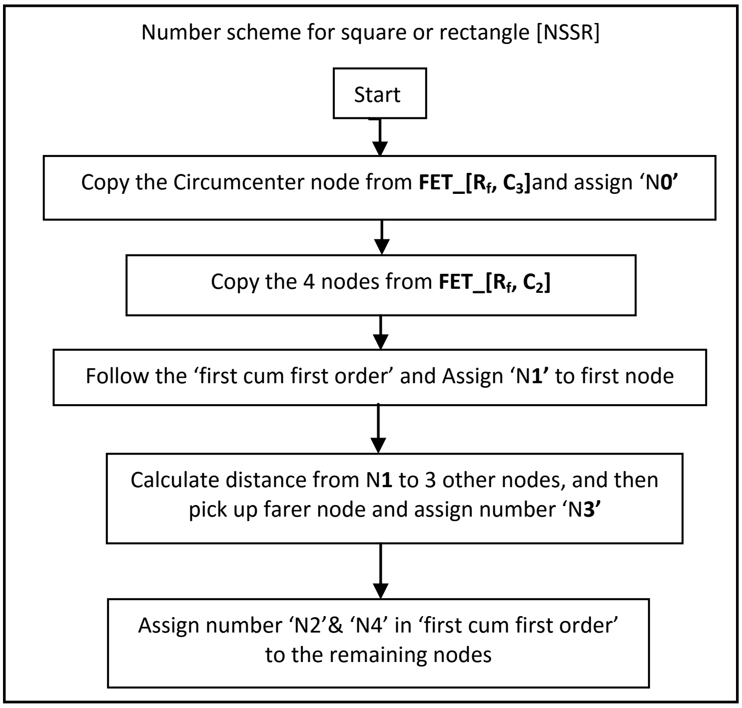

Figure 10. Number scheme for square or rectangle

7. ALGORITHM FOR NUMBERING SCHEME FOR SQUARE OR RECTANGLE [NSSR]

Step#1: Copy the Circumcentre node from FET_[R_f, C_3]and assign 'N0': Go to Step#2
Step#2
Copy the 4 nodes from FET_[R_f, C_2]; Go to Step#3
Step#3
Follow the 'first cum first order' and Assign 'N1' to first node; Go to Step#4
Step#4
Calculate distance from N1 to 3 other nodes, and then pick up farer node and assign number 'N3'
Go to Step#5
Step#5; Assign number 'N2'& 'N4' in 'first cum first order' to the remaining nodes

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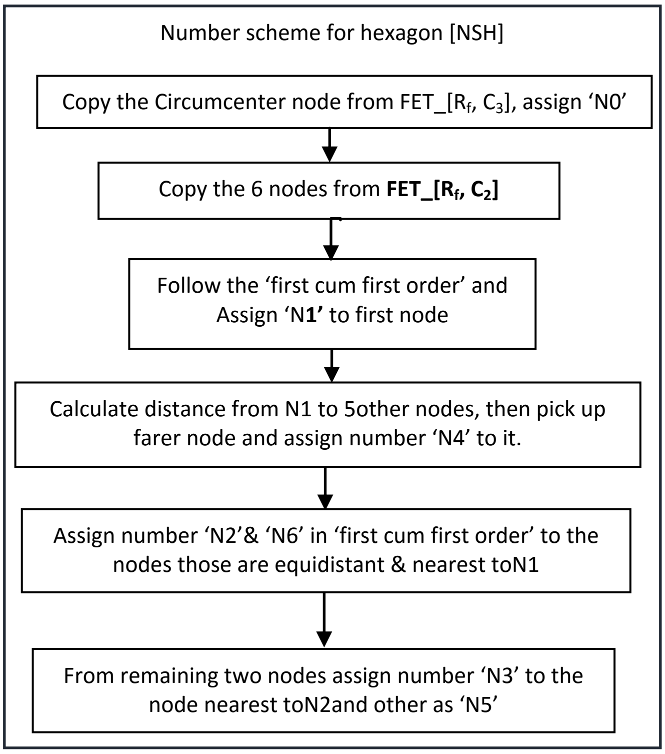

Figure 11. Number scheme for hexagon

8. ALGORITHM FOR NUMBERING SCHEME FOR HEXAGON [NSH]

Step#1; Copy the Circumcenter node from FET_[R_f, C_3] and assign 'N0'; Go to Step#2
Step#2; Copy the 6 nodes from FET_[R_f, C_2]; Go to Step#3
Step#3; Follow the 'first cum first order' and Assign 'N1' to first node; Go to Step#4
Step#4; Calculate distance from N1 to 5other nodes, then pick up farer node and assign number 'N4' to it.; Go to Step#5
Step#5; Assign number 'N2'& 'N6' in 'first cum first order' to the nodes those are equidistant & nearest toN1; Go to Step#6
Step#6; From remaining two nodes assign number 'N3' to the node nearest toN2and other as 'N5'

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9. SEQUENCING & SCHEDULING OF MILLING (CORNER MILL)

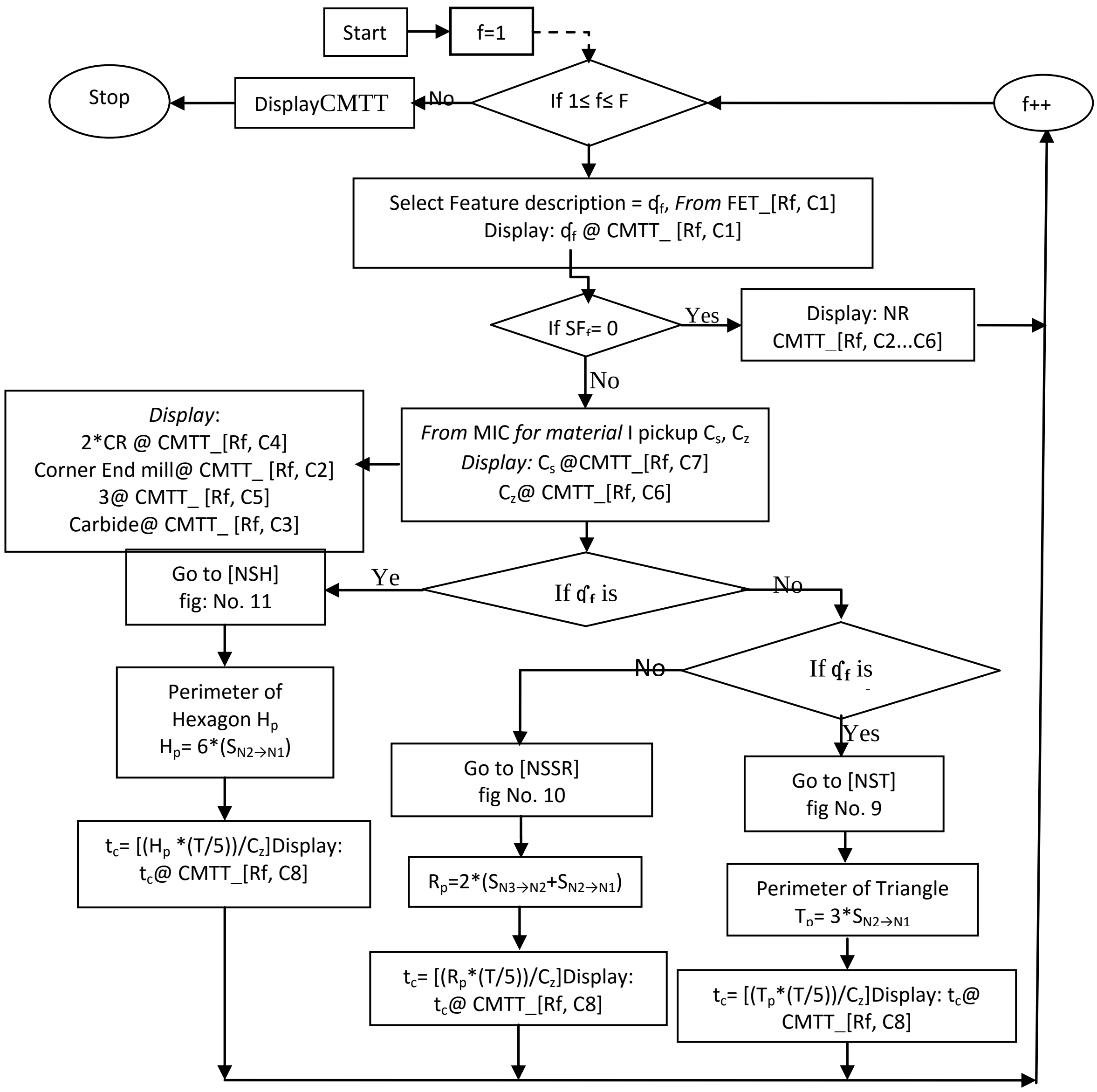

Figure 12. Sequencing & scheduling of Milling (Corner mill)

Corner mill schedule table:

	C0	C1	C2	C3	C4	C5	C6	
R0	Sr.No	Machining Feature	milling cutter type	Milling cutter material	mill diameter *mm*	No. of flutes	Feed ***mm/min*** C_z	Speed *RPM* C_s
R1	1							

Table 4. Operating function ID: CMT_[R1, Cß], table call code CMT.

10. ALGORITHM FOR SCHEDULING OF CORNER MILL

f=1; Step#1; If $1 \leq f \leq F$; Go to Step#2; Else; Display: CMTT

Step#2; *From* FET_[Rf, C1] select Feature title = $ɖ_f$; Display: $ɖ_f$ @ CMTT_ [Rf, C1]; go to Step#3

Step#3; If $SF_f \neq 0$, then go to Step#4 Else;; Display: NR CMTT_ [Rf, C2...C6]; go to Step#1

Step#4; Display: Corner End mill@ EMTT_ [Rf, C2] 3@ EMTT_ [Rf, C5]; Carbide@ EMTT_ [Rf, C3]

From MIC *for material* I pickup C_s, C_z; Display: C_s @CMTT_[Rf, C7]; C_z @CMTT_[Rf, C6]

Display: 2*CR @ CMTT_[Rf, C4]; Go to Step#5

Step#5: If $ɖ_f$ = Hexagon; Go to Step#7; Else; Go to Step#6

Step#6; If $ɖ_f$= Triangle; Go to Step#8; Else;; Go to Step#9

Step#7; Numbering scheme for Hexagon [NSH]; Perimeter of Hexagon $H_p= 6*S_{1\div2}$

$t_c= [(H_p *(T/5))/C_z]$; Display: t_c@ CMTT_[Rf, C8]; Go to Step#10

Step#8; Numbering scheme for Triangle [NST]; Perimeter of Triangle $T_p= 3*S_{1\div2}$

$t_c= [(T_p*(T/5))/C_z]$; Display: t_c @CMTT_ [Rf, C8]; Go to Step#10

Step#9; numbering scheme for square or rectangle [NSSR]

Perimeter $R_p =2*(S_{1\div2}+S_{2\div3})$; $t_c= [(R_p*(T/5))/C_z]$; Display: t_c@ CMTT_[Rf, C8]; Go to Step#10

Step#10; Go for f increment f++; Go to Step#1

Corner milling is employed for milling of corners of non-cylindrical pockets. Some parameters and tools are suggested as constants those are carbide corner end mill, as milling cutter and with 4 flutes. The *"Perimeter of a feature in the XY plane'* is multiplied by 'T/d_c' is magnitude of the length of path for the helical interpolation, which is to be travelled by the corner mill up to depth of the pocket. *'Length of path over feed'* gives time elapsed for milling of corners of the feature.

11. EXPLANATION OF THE SEQUENCE & SCHEDULE OF CORNER MILLING ALGORITHM:

Input: Manually selected work piece Material and corner radius (CR). For pre-selected work piece Material, feed & speed charts [MIC] are required for cutting tools from data base. Feature Extraction table [FET] output from 3'CAM technique. Skeleton of Corner mill time table [CMTT]
Output: The prepared Corner mill time table [CMTT] will be displayed.

The data flow Process in the algorithm:
Condition 1: if $1\leq f\leq F$
Input:
Consider f=1[default] as initial value of first iteration and for succeeding iterations from the any of condition 2/condition 3/ condition 4.
Condition explanation: checks whether 'f'(row value of *FET*)value is exceeded the no. of features (F).
Output:
If satisfied: The feature description '$ɖ_f$' will be displayed in [Rf, C1] at CMTT then further go to *condition 2*.
If unsatisfied: the prepared Corner mill time table [CMTT] will be displayed.
*Condition 2:*If $SF_f \neq 0$
Input: From condition 1. If satisfied.
Condition explanation: It checks whether the selected feature is cylindrical pocket are not. (If the Diameter of in-circle = circum-diameter for a feature then it must be a cylinder)
Output:
If satisfied: The feature description will be displayed in [Rf, C1] at CMTT,*Display*: 2*CR @ CMTT_[Rf, C4], Corner End mill @ CMTT_ [Rf, C2], 3@ CMTT_ [Rf, C5], Carbide @ CMTT_ [Rf, C3]
From MIC *for material* I select C_s, C_z&*Display:* C_s @CMTT_[Rf, C7], C_z @ CMTT_[Rf, C6]then further continues to *condition 2*.
If unsatisfied: Display NR in the[Rf, C2...C6]at CMTT. Go for f increment (f++). Go to condition 1.
Condition 3: If $ɖ_f$ is Hexagon
Input/output: From condition 2. If satisfied.
Condition explanation: Checks whether the selected feature is triangular pocket are not.
Output:
If satisfied: Numbering scheme for Hexagon [NSH], Perimeter of Hexagon H_p, Compute the $H_p= 6*(S_{N2\rightarrow N1})$ and compute the Perimeter $t_c= [(H_p *(T/5))/C_z]$ & Display t_c@ CMTT_[Rf, C8]Go for f increment (f++) then Go to condition 1.
If unsatisfied: go to condition 4.
Condition 4: If $ɖ_f$ is Triangle
Input Output: From condition 2. If satisfied.
Condition explanation: Checks whether the selected feature is triangular pocket are not.
Output:
If satisfied: Go to Numbering scheme for Triangle [NST], compute the Perimeter $T_p= 3*S_{N2\rightarrow N1}$and
$t_c= [(T_p*(T/5))/C_z]$ then Display: t_c@ CMTT_[Rf, C8].Go for f increment (f++), Go to condition 1.
If unsatisfied: Numbering scheme for square or rectangle [NSSR], compute
$R_p=2*(S_{N3\rightarrow N2}+S_{N2\rightarrow N1})$,
$t_c= [(R_p*(T/5))/C_z]$ Display: t_c@ CMTT_[Rf, C8].
Go for f increment (f++), Go to condition 1.

12. CALCULATIONS OF OPERATIONS AND FEATURES INDENTIFICATION

Feature [Hexagon]:
T+5 = [Thickness of work piece + clearance (5mm)] (Overall length) mm = 45
N_s= Spindle speed for drilling (rev/min) =2022
D_Z= drilling feed (mm/rev) = 0.2
SDB_f = drill bit diameter (mm) = 12
C_z= Feed for corner mill
$S_{N2\rightarrow N1}$= distance between node1 and node2
t_d= time elapsed for drilling
Drilling:
$t_d = [(T+5)/(N_s * D_Z)] = (40+5)/ (2022* 0.2) = 0.111$min
Corner mill:
H_p=Perimeter of Hexagon
$H_p = 6*(S_{N2\rightarrow N1}) = 6*12=72$mm
$t_c= [(H_p *(T/5))/C_z] = 72*(40/5)/1270= 0.68$min
Feature [Cylinder] (end milling cutter)
E_z= Feed for milling (mm/min) =497.53
t_m= time elapsed for milling
$t_m= [3.14*[(SDB_f-20)/E_z]*(T/10) = 3.14*[40-20)/497.53]*[40/10]= 0.505$ min

13. RESULT

Machining sequence and schedule for each feature

S.No	Machining feature	Drill Bit type	Drill material	Drill diameter *mm*	Feed mm/min	Feed *mm/rev* D_z	Speed *RPM* N_s	Drilling time min
1	Square pocket	Twist Drill	HSS	6	404.5	0.1	4045	0.111
2	Rectangular pocket	Twist Drill	HSS	4	606.7	0.1	6067	0.0741
3	Cylinder	NA	NA	NA	NA	NA	NA	NA
4	Hexagon	Twist Drill	HSS	12	404.4	0.2	2022	0.111
5	Triangular	Twist Drill	HSS	11	441.2	0.2	2206	0.101

Table 5. Drilling schedule sheet

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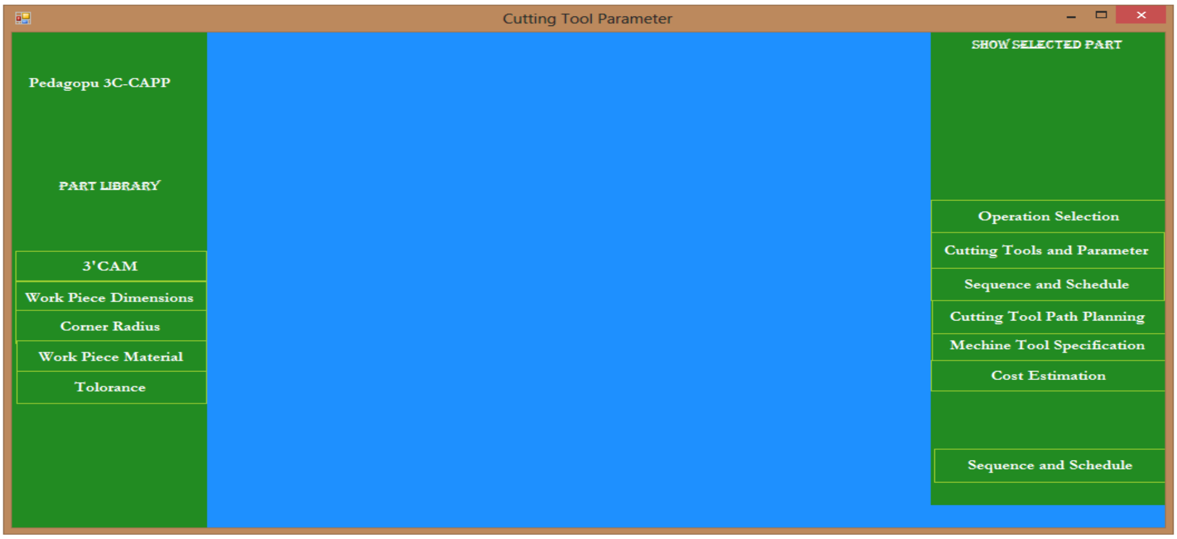
S.No	Machining feature	milling cutter type	Milling cutter material	mill diameter *mm*	No. of flutes	Speed RPM E_s	Feed *mm/min* E_z	Depth of cut mm	Milling time min
1	Square pocket	NA	NA	NA	NA	NA	NA	NA	NA
2	Rectangular pocket	NA	NA	NA	NA	NA	NA	NA	NA
3	Cylinder	End mill	Carbide	20	4	2449	497.53	10	0.505
4	Hexagon	NA	NA	NA	NA	NA	NA	NA	NA
5	Triangular	NA	NA	NA	NA	NA	NA	NA	NA

Table 6. End mill schedule sheet

S.No	Machining Feature	milling cutter type	Milling cutter material	mill diameter *mm*	No. of flutes	Feed *mm/min* C_z	Speed *RPM* C_s	Milling time t_c min
1	Square pocket	Corner mill	Carbide	6	3	1270	8304	0.302
2	Rectangular pocket	Corner mill	Carbide	6	3	1270	8304	0.264
3	Cylinder	NA	NA	NA	NA	NA	NA	NA
4	Hexagon	Corner mill	Carbide	6	3	1270	8304	0.68
5	Triangular	Corner mill	Carbide	6	3	1270	8304	0.8

Table 7. Corner end mill schedule sheet



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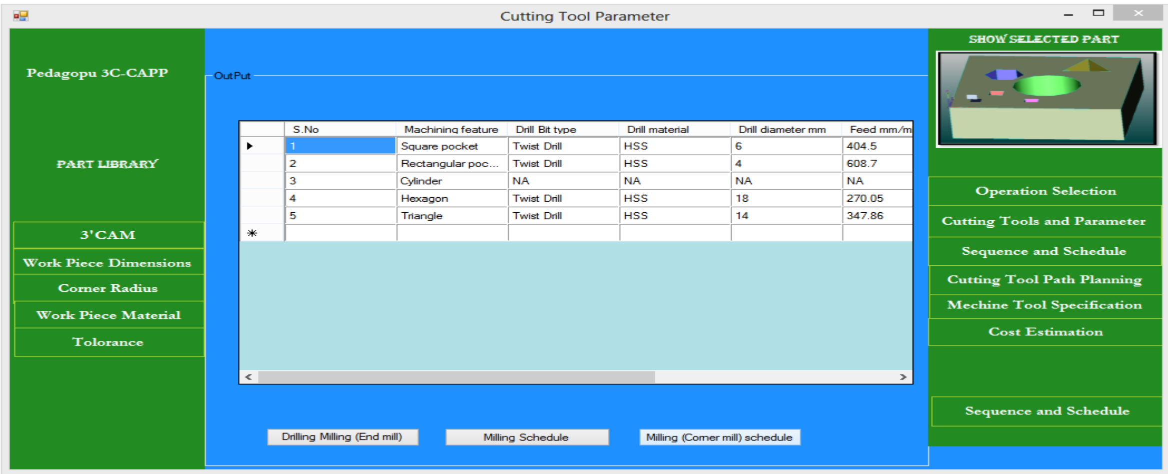

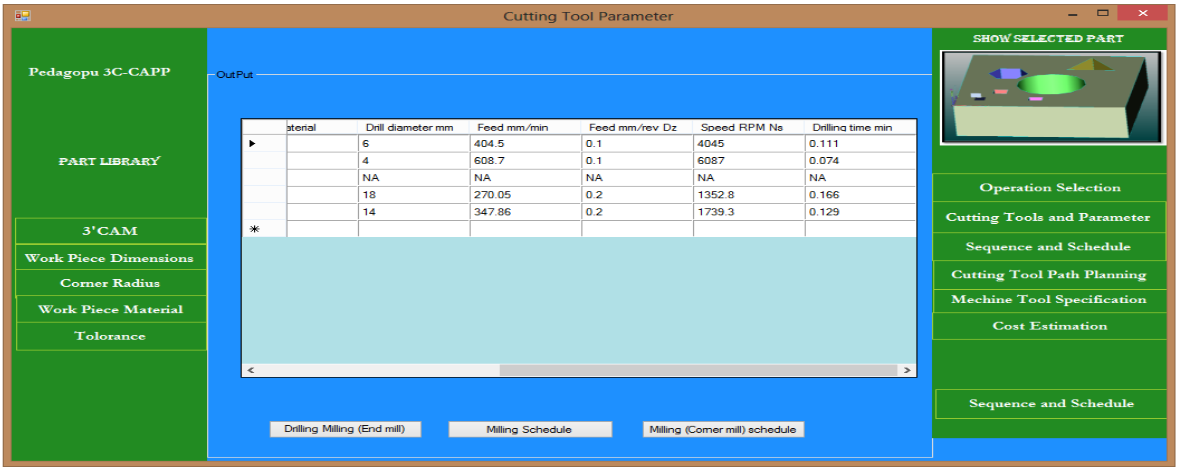

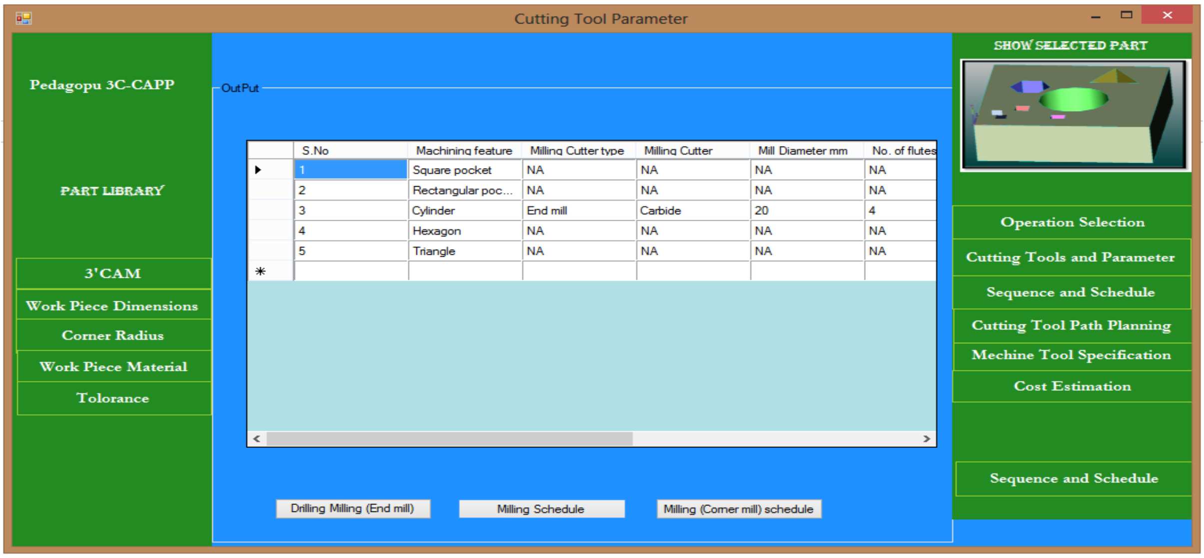

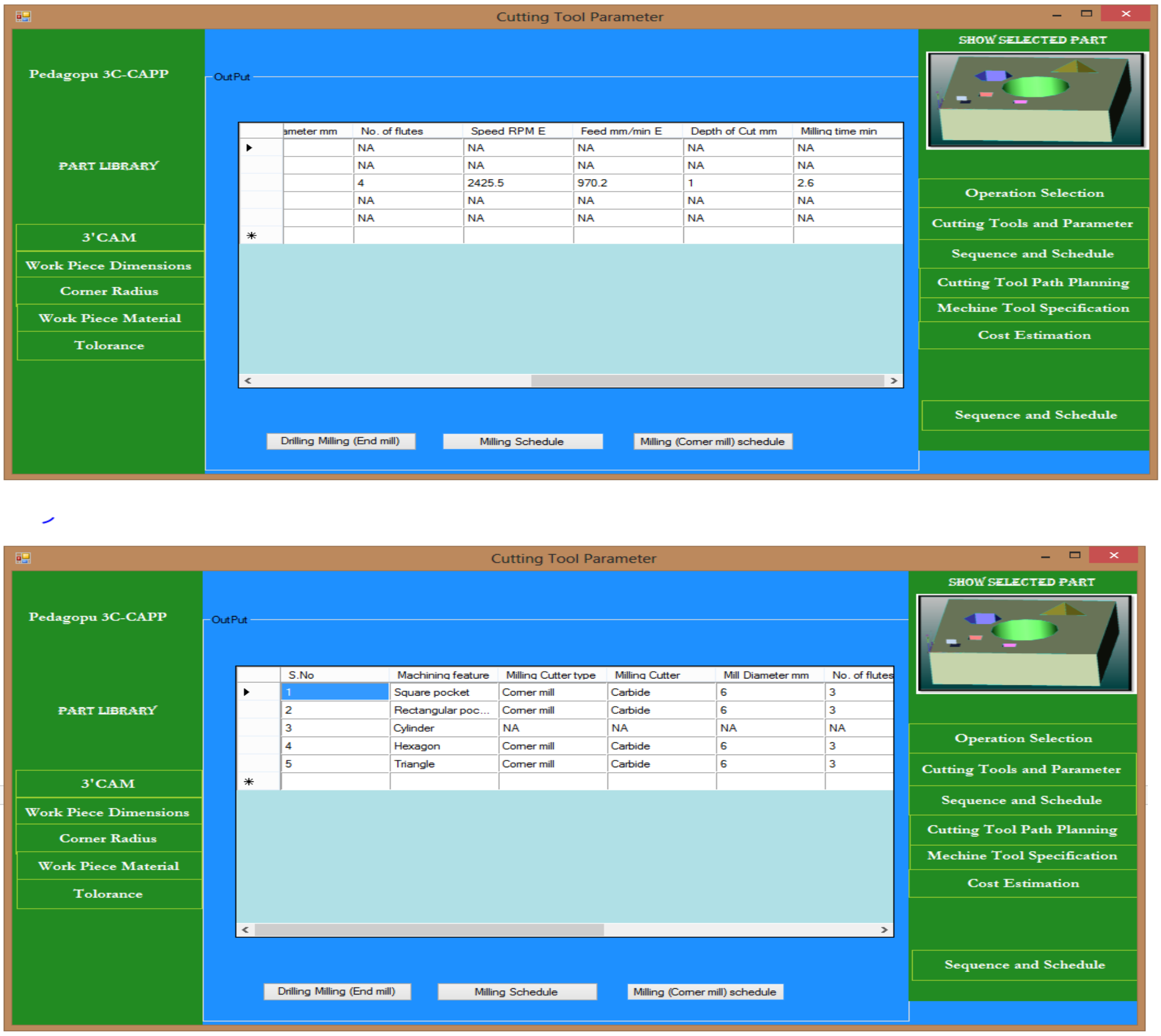

Figure 13. Simulation result of the entire process

14. CONCLUSION

In this paper, an efficient approach of machining plan has been presented using 3'C-CAPP approach. This is a simple, user friendly approach than those had been proposed previously. All the modules that have been discussed here are basically output from so called 3'CAM technique and input to the 3'C-CAPP for an interactive G-CAPP system. The necessary data is collected from 3'CAM and other required inputs to generate well-organized machining plan for a proposed model. The most important three topics discussed in brief. The approach proposed here, the machining operations sequence selection, scheduling for each operation and feature .The entire work has been carried out by selection is done by 3'CAM. An arduous task has been used to generate the integration of 3'CAM technique and 3C-CAPP approach in order to minimize the cost of machining. Finally, the two approaches have been applied, verified and approved for a selected part.

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ABBREVIATIONS AND ACRONYMS

- - ►	A single turn active link
N_s	Revolution per Minute
£	Surface speed per minute [m/min]
D_Z	Drill feed per revolution [mm/rev]
E_f	Milling feed
E_s	Milling feed
d_c	depth of cut for corner milling
CD_f	Variable assigned for circum-diameter module
CDM	Circum diameter module
CC_f	Variable assigned for Circumcenter module
CCM	Circumcenter module
DB_f	Variable assigned for Drill bit module
DBM	Drill Bit Module
I	an identity denotes the selected material
CMTT	Corner Mill time Table
EMTT	Corner Mill time Table
DBTT	Drill bit time table
C_s	Corner end mill speed [RPM]
C_z	Corner end mill Feed [mm/min]
SDBM	Standard drill bit module
SDB_f	Variable for standard drill bit module
f	Operating variable for feature selection [1….f….F]
F	Total number of features (constant per work piece)
SF_f	Variable assigned for Scaling factor module
SFM	Scaling factor module
Rf	Row variable [1…..f…..F]
Cß	Column variable [1…ß……F]
MIC	Material information chart
FET	Feature extraction table
T	Thickness of work piece
ʠ	Variable for feature description
T_p	Perimeter of triangle
R_p	Perimeter of Rectangle or square
H_p	Perimeter of Hexagon
t_c	Time elapsed for machining a feature with corner mill
t_m	Time elapsed for machining a feature with End mill
t_d	Time elapsed for machining a feature with drill
NSSR	Numbering scheme for Square or rectangle
NST	Numbering scheme for Triangle
NR	Not Required
NA	Not Applicable
NSH	Numbering scheme for Hexagon
Ↄ	Number of drill bit