Military Technical College Kobry El-Kobbah, Cairo, Egypt.

16th International Conference on Applied Mechanics and Mechanical Engineering.

COMPUTER AIDED PROCESS PLANNING FOR PRISMATIC PARTS

S.E. Sarhan*, A. A. Afifi** and M.S. Abbas***

ABSTRACT

Computer aided process planning (CAPP) is the bridge between CAD and CAM. Therefore, the first step towards the total integration of CAD/CAM is the integration of CAD and CAPP systems.This paper deals with design and development of a generative computer-aided process planning (CAPP) system for prismatic components.

The input to this CAPP system is the created manufacturing features with required data, which have been extracted in a previously developed feature recognition module which deals with 2D and 3D CAD systems. The proposed CAPP system includes workpiece material database, type of fixation selection, machine tool selection, cutting tool selection, and generation of process plan sheet with minimum number of tool changes. The whole CAPP system is developed using Visual Basic 6.0. The main feature of the proposed CAPP system is its ability to handle a variety of prismatic components with large number of features like (external contour, internal contour, rectangular pocket, circular pocket, slot, holes…) and generate process plans for them. A case study has been included to highlight the potential of the CAPP system.

KEY WORDS

Computer Aided Process planning, CAPP, intelligent manufacturing systems, CIM.

---

* Lecturer assistant, Dept. of Design and Production, German University, Cairo, Egypt.

** Associate professor, Dept. of Design and Production, German University, Cairo, Egypt.

*** Professor, Dept. of Mechanical Engineering, Benha University, Cairo, Egypt.

INTRODUCTION

An efficient CAPP system has a key role to integrate the design and manufacturing or assembly systems properly considering available resources and design constraints. It has been found that 15% of the process planner's time is spent on technical decision making while remaining time is spent equally between gathering data, calculating and the preparation of documentation. Investigation shows that an efficient CAPP system could result in a total reduction of the manufacturing cost by up to 30% and time in the manufacturing cycle and the total engineering time could also be reduced by up to 50% [1].

CAPP is usually considered to be part of Computer-Aided Manufacturing (CAM). However, this tends to imply that CAM is a stand-alone system. In fact, a synergy results when CAM is combined with computer-aided design to create a CAD/CAM system. In such a system, CAPP becomes the direct connection between design and manufacturing. Process planning includes identification of the processes, machine tool, cutting tools, setups and fixtures to produce the desired product, along with geometric information Even today, the activities of process planning are partially based on the skill of experienced process planners, which results in time-consuming procedures. As process planning is very complex, it would be desirable to use computer-aided approaches to relieve the process planner from routine activities and reduce the time and cost of the task. Because of the need to respond quickly to highly variable market demands, the development of computer-aided process planning (CAPP) systems is necessary. [2].

According to the survey of the different CAPP systems (CADEXCATS, OPPS-ROT, MASCAPP, IPIM, PLM/CAPP, CADLOG, FBAPP, OSCAP, FAPPS, IDEF, GISCAPP systems developed by Juan Du and Xianguo Yan, M. Kanga, (2003)∗, J. Hanb, J.G. Moonc, Hyun Chan Lee (2007) *, Won Chul Jhee, Hee-Sok Park 2007) [3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14,and 15] it has been found out that there still exist certain points, which have not been covered sufficiently. Flexibility of the most systems is considerably low due to few numbers of predefined features.

The present work is a module from three modules included in global software. The three modules are future recognition module, Operation planning module, and the third one is computer aided part programming module. The topic of this research is the developing of generative operation planning module. In this software the 2D and 3D CAD models are used for the determination of the necessary machining steps required to manufacture the object by milling.

OPERATION PLANNING MODULE

The developed generative operation planning module includes a database for the system responsible for saving, modifying, updating, and removing data, required for the system. The operation planning module contains four sub modules; workpiece material database module, Machine tool module, fixation module, and tooling module.

Workpiece Material Database Sub Module

This workpiece material database contains the available workpiece materials and their specifications. Two applications are related to this database, the first one is the workpiece material input data, while the second is the choice of the workpiece material.

Workpiece material data

The user has to input all required data for any new material as shown in figure (1)

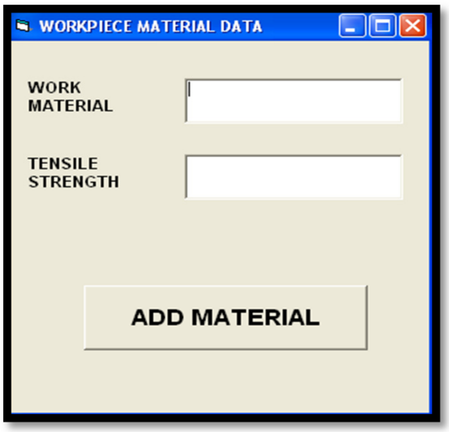
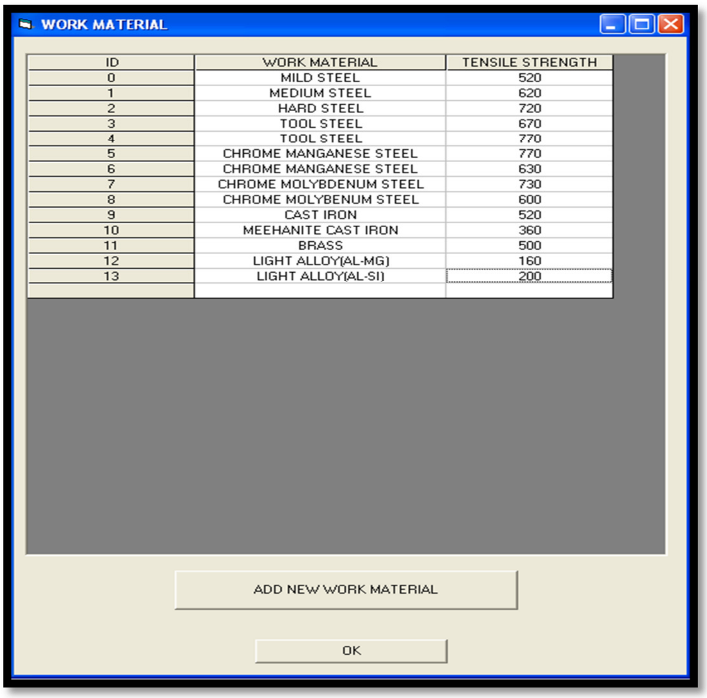


Figure (1). Workpiece material input data form.

Workpiece material selection

The second application is the choice of workpiece material. The workpiece selection form is shown in figure (2).



ID	WORK MATERIAL	TENSILE STRENGTH
0	MILD STEEL	520
1	MEDIUM STEEL	620
2	HARD STEEL	720
3	TOOL STEEL	670
4	TOOL STEEL	770
5	CHROME MANGANESE STEEL	770
6	CHROME MANGANESE STEEL	630
7	CHROME MOLYBDENUM STEEL	730
8	CHROME MOLYBENUM STEEL	600
9	CAST IRON	520
10	MEEHANITE CAST IRON	360
11	BRASS	500
12	LIGHT ALLOY(AL-MG)	160
13	LIGHT ALLOY(AL-SI)	200

Figure (2). Workpiece material selection.

Machine Tool Sub Module

This database of this module contains the available machines and their specifications. Two applications are related to machine tool module. The first one is the machine input data, and the second one is the choice of the most suitable machine according to the workpiece dimensions from the created database.

Machine input data

The first application in machine tool sub module is the machine input data, as shown in figure (3), the database has the ability to enter a new machine data, update any existing machine data, or to remove any existing machine data.

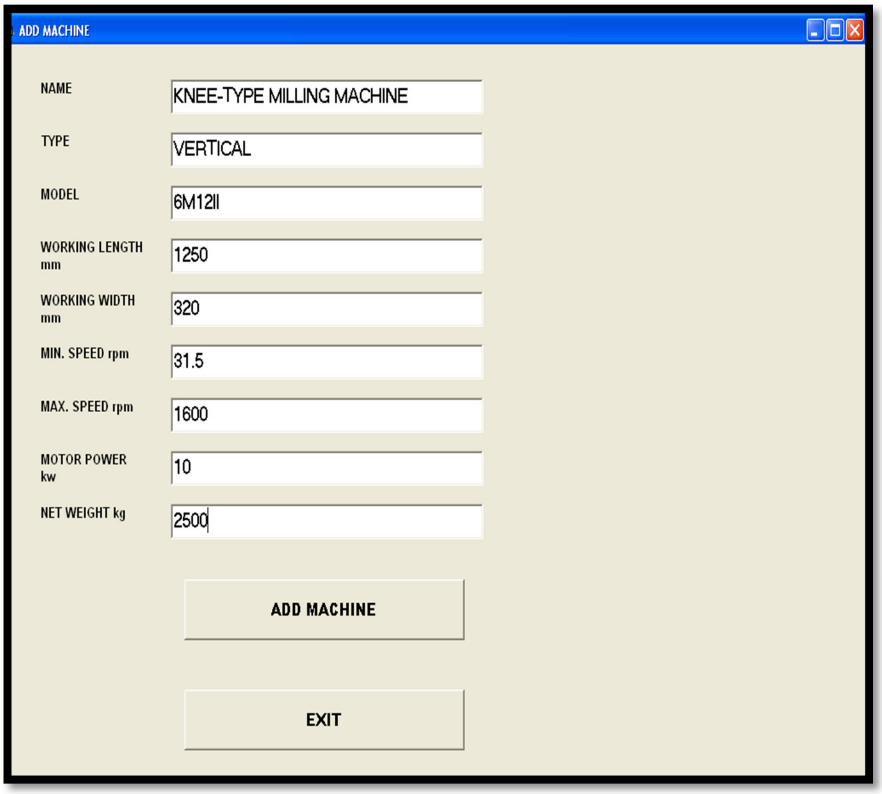


Figure (3). Machine input data form.

Selection of suitable machine

According to the dimensions and geometrical shape of the workpiece, the suitable machine will be chosen automatically. In case more than one machine satisfies the semi product dimensions, the software will display an information massage and display them as shown figure (4) and figure (5) and the user has to choose the most suitable one of them.

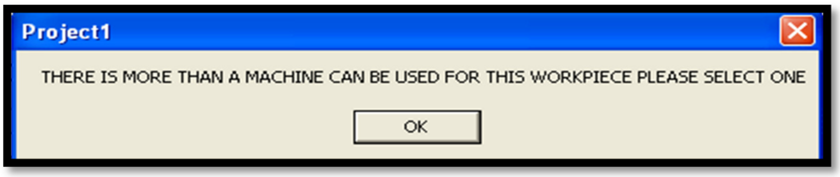


Figure (4).

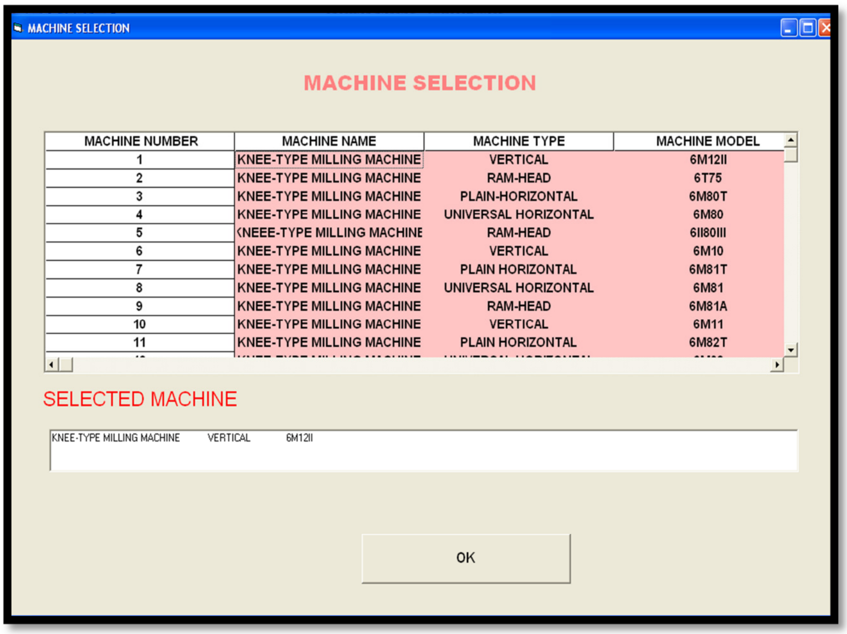


Figure (5). Selection of suitable machine.

In case of incompatibility of semi product dimensions with any machine tool, a warning massage will appear to warn the user and ask for adding new machine as shown in figure (6).

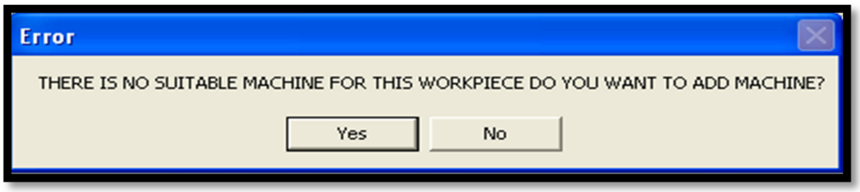


Figure (6). Warning message.

The created software has the ability to allow user to add a new suitable machine to be used for this semi product by click on YES button to show machine input data form.

Fixation feature sub module

In the developed system this module is used to extract features, which are suitable for clamping the workpiece.

Rules for choosing fixation features

The developed system has the ability to choose the suitable holding method as follow:

-Plain milling machine vice is used for holding workpiece which has parallel sides.

-The plain vice can be accompanied by swivel base which allow the vice to swivel in horizontal plane and this type is used for holding workpieces which have one of the following characteristics:

- Workpiece with group of holes on pitch circle and with indexing angle has an integer value

- Workpiece with number of flat sides on an indexing angle with integer value (hexagonal object…etc.)
- Workpiece has a row of holes inclined by angle with integer value
- Workpiece with inclined slot or group of slots on a pitch circle with indexing angle has an integer value

-Plain milling machine vice with V block jaws is used for circular work pieces.

-Indexing fixture or dividing head is used for a workpiece with the following characteristics:

- Workpiece with group of holes on pitch circle and with indexing angle has an real value
- Workpiece with number of flat sides on an indexing angle with real value (hexagonal object…etc.)
- Workpiece has a row of holes inclined by angle with real value
- Workpiece with inclined slot or group of slots on a pitch circle with indexing angle has an real value

-If the previous four rules are not suitable for a workpiece then we can use a special fixture.

The software will be developed in the future to include more types of fixation methods

Tooling Sub Module

This module contains a database for the available tools with its data and the methodology for tool selection. Two applications are related to this module. The first is the tool data input and the second one is tool selection as shown in figure (7).

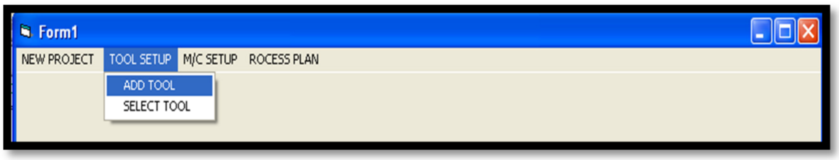


Figure (7). Tooling database.

Tool data input

The first task is the tool data input, as shown in figure (8). The developed software has the ability to enter a new tool data.

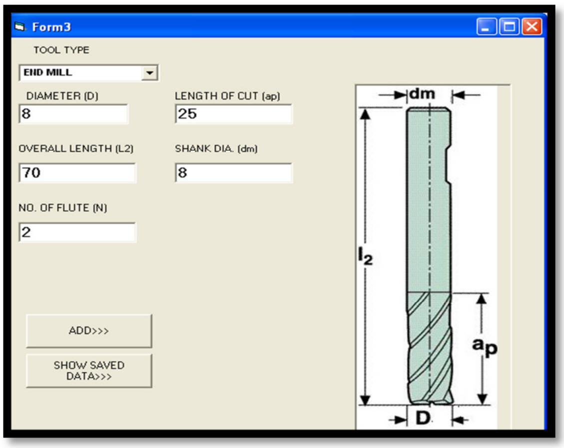


Figure (8). Tool input data form.

Tool selection

The form shown in figure (9) will be displayed in the screen when running the developed software to select all available tools in the user workshop or factory from the available database. This will be done by allow the user to choose the tools needed from tool library form and then select add button to add this tool in selected tool form as shown in figure (9).

The created software can choose automatically the suitable tool for each machining step from the selected tool list. The concept of choosing the tools will be according to the machining logic and rules defined by the machining experts.
If the created software cannot find the suitable tool to perform any operation the software will warn the user by a warning massage to add the suitable tool for this operation similar to what is done in the machine tool module as shown in figure (6).

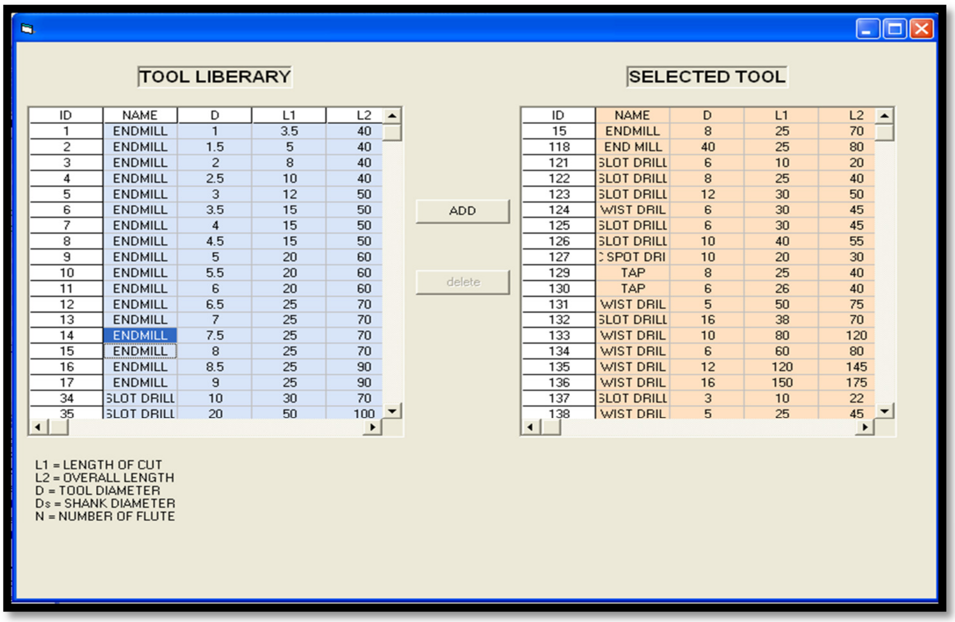


Figure (9). Tool selection.

OPERATION PLANNING MODULE

The first step of the planning module starts by making a full description of the part, and transform parts features from design base features (hole, rectangular pocket, slot,…etc.) by means of the feature recognition module.

The operation planning module starts its function to create the necessary operation plan according to the following steps:

- The developed software starts with the logical manufacturing rules to choose the suitable machine according to the rules explained in the machine tool module
- The clamping features are extracted according to certain rules as discussed before. Then the suitable machines are selected according to the semi product dimensions. General rules for milling operations are saved in the database.

- The suitable tool for each machining step will be chosen according to the rules discussed in the tooling sub module.
- Then the suitable plan will be generated according to the pervious steps and milling operation rules.

OPTIMIZATION OF USING TOOLS

The developed software has a smart loop to perform all features which uses the same tool before changing it with different tool conditioned with the sequence of this features satisfying logical machining rules.

Ex1: you cannot use twist drill before using centre drilling tool.
Ex2: you cannot use thread tool before using drilling tool.
Ex3: you cannot manufacture slot before doing the rectangular pocket as shown in figure (10).

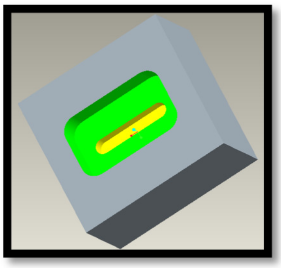


Figure (10).

CASE STUDY

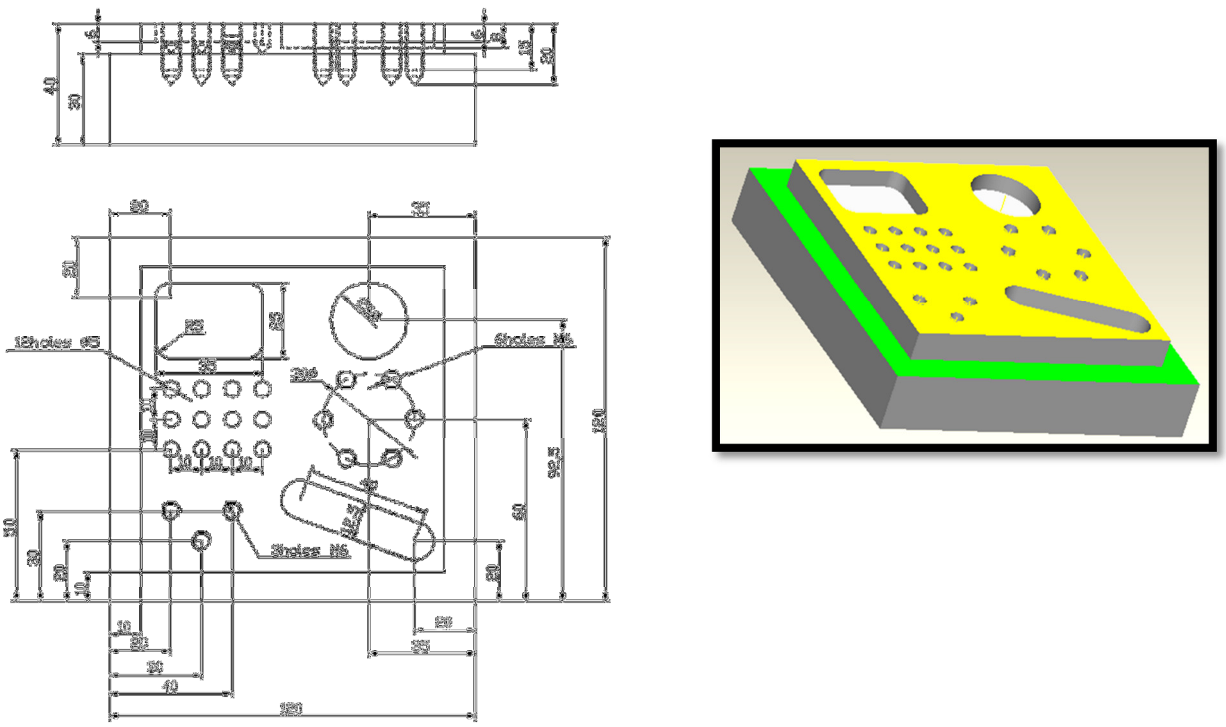


Figure (11). Case study.

Reading Data by the Software

In order to read a new part drawing data the user has to choose new project from DXF file or from IGS file as shown in figure (12).

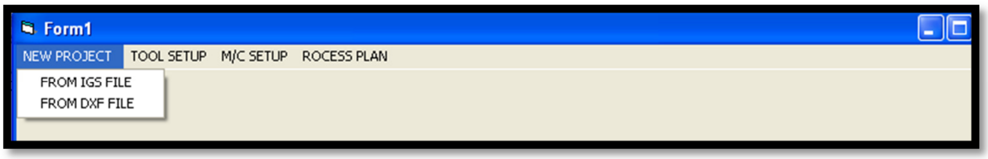


Figure (12). Selecting CAD file type.

Selection of the Data File

The following figure shows that this system permits the user to choose the drive, the folder, and hence the DXF or the IGS file position on the computer as shown in figure (13).

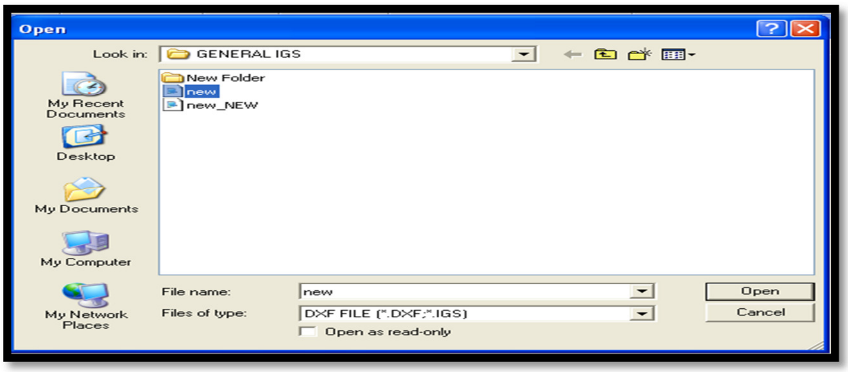


Figure (13) Selection of the data file

Display of Results of Extracted Data

The extracted data from DXF file or IGS file is displayed as in given figure (14) and figure (15). All extracted external contours, scattered holes, hole matrices, and group of holes on pitch circle are show in figure (14). All extracted internal contours, circular pockets, rectangular pockets and all types of slots are show in figure (15).

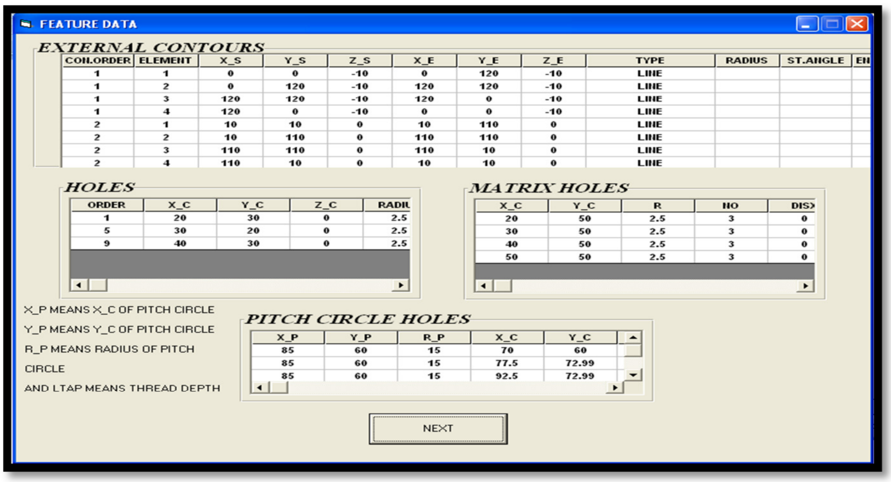


Figure (14). Extracted contours and holes.

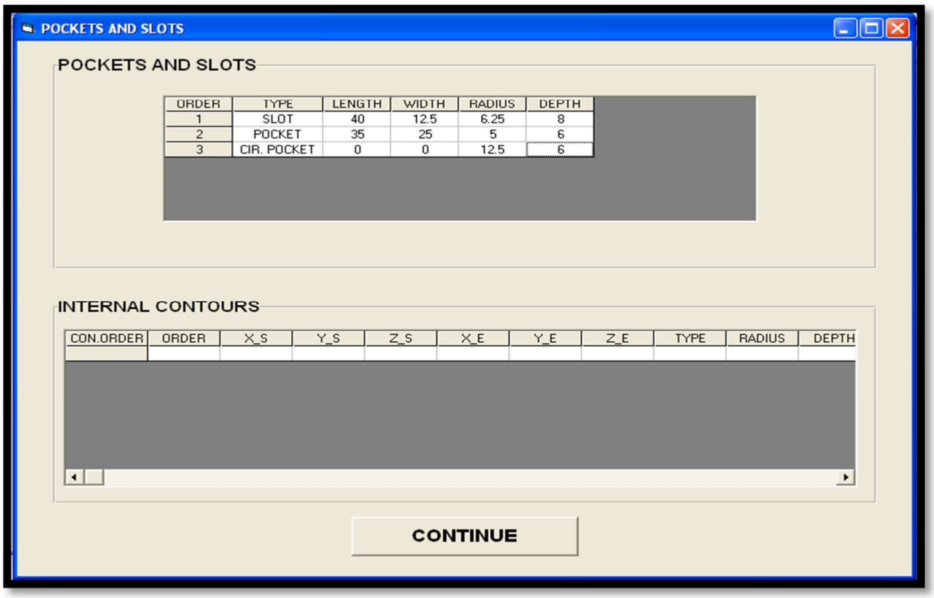


Figure (15). extracted pockets, slots and internal contours.

Machine Selection

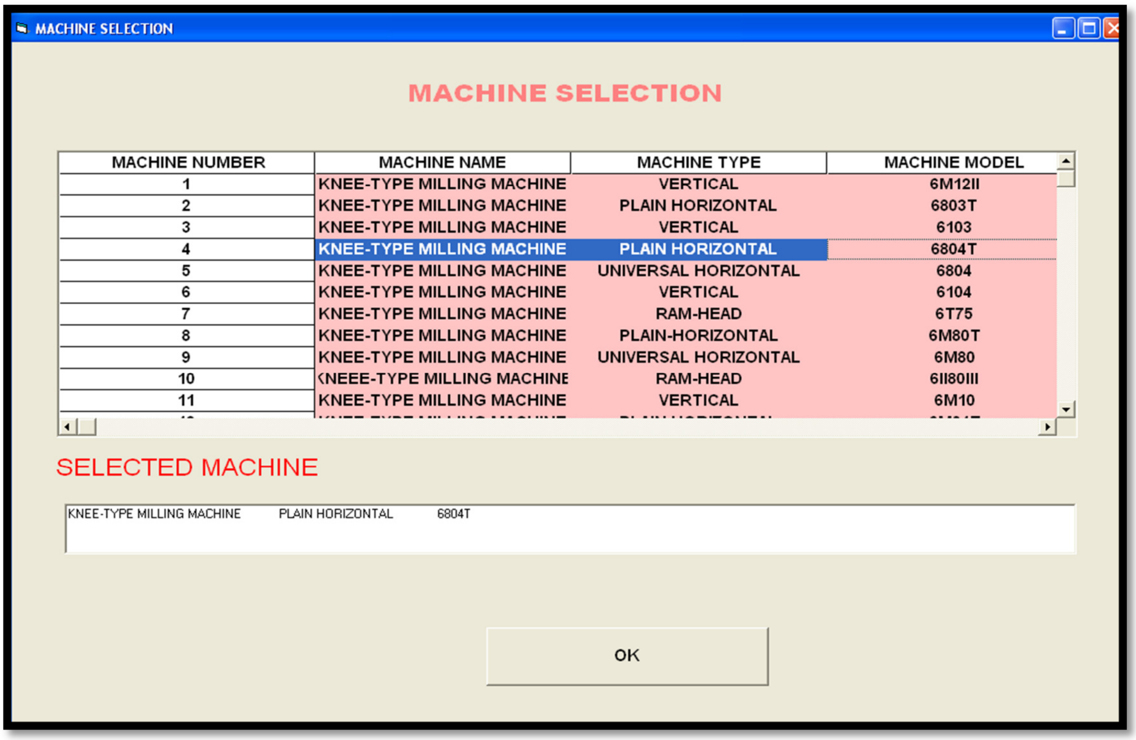


Figure (16) Machine selection

Workpiece Material Selection

In this step the software allows the user to choose the type of workpiece material as prescribed by the designer in the engineering drawing

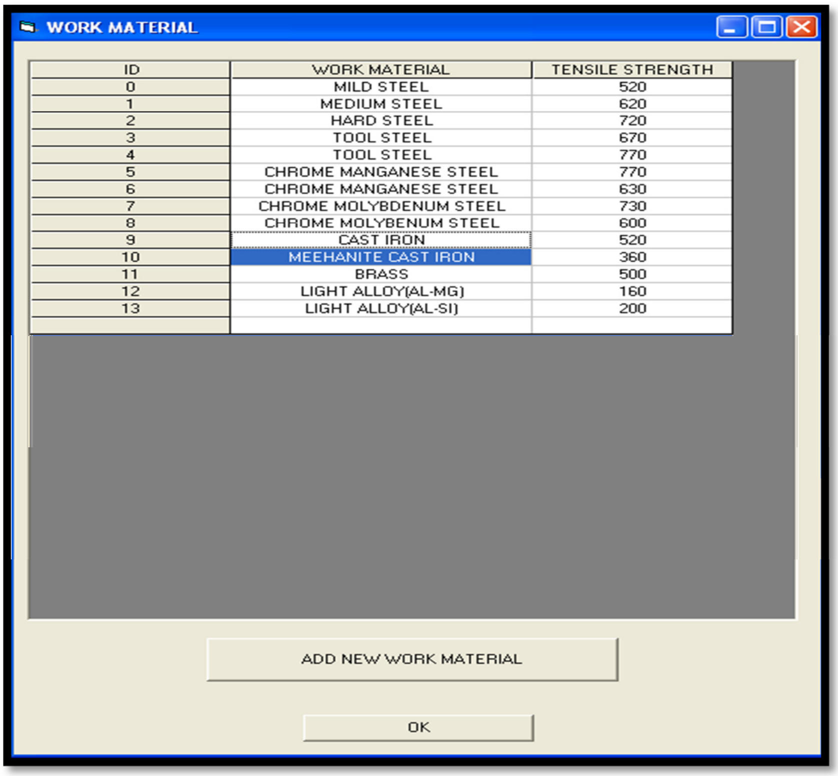


Figure (17). Selection of workpiece material.

Extraction of Features

The features are extracted and displayed as shown in the next form according to the predefinition of each feature shape. As shown in figure (18) the extracted feature data with dark colour consists of three categories.

- Contours: Face – External contours – Internal contours.
- Pockets and slots: Rectangular pockets – Circular pockets – Slots.
- Holes: Cantering – Drilling – Tapping of scattered holes or row of holes or holes on pitch circle.

Display of Operation Sequence

After the input of all required data, the software is ready to create the possible operation sequence according to the previously input, and extracted data as shown in figure (19).

The user can show details of any feature by double clicking on that feature to show a form with all wanted details of this feature as shown in these figures (20, 21, 22, 23, 24, 25. 26, and 27).

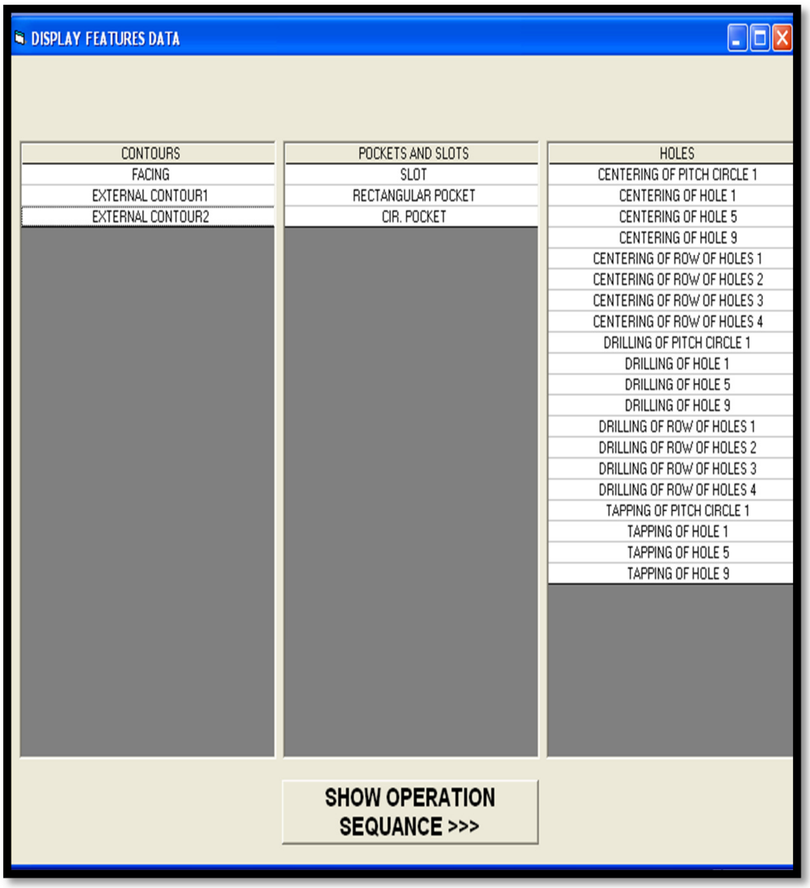
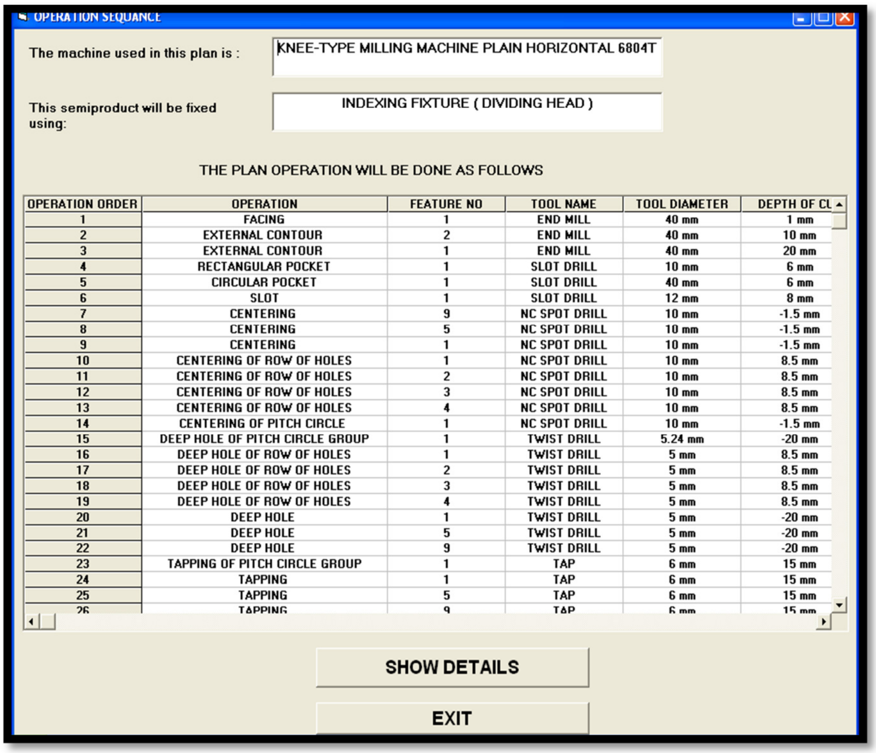


Figure (18). Extraction of features.



OPERATION ORDER	OPERATION	FEATURE NO	TOOL NAME	TOOL DIAMETER	DEPTH OF CU
1	FACING	1	END MILL	40 mm	1 mm
2	EXTERNAL CONTOUR	2	END MILL	40 mm	10 mm
3	EXTERNAL CONTOUR	1	END MILL	40 mm	20 mm
4	RECTANGULAR POCKET	1	SLOT DRILL	10 mm	6 mm
5	CIRCULAR POCKET	1	SLOT DRILL	40 mm	6 mm
6	SLOT	1	SLOT DRILL	12 mm	8 mm
7	CENTERING	9	NC SPOT DRILL	10 mm	-1.5 mm
8	CENTERING	5	NC SPOT DRILL	10 mm	-1.5 mm
9	CENTERING	1	NC SPOT DRILL	10 mm	-1.5 mm
10	CENTERING OF ROW OF HOLES	1	NC SPOT DRILL	10 mm	8.5 mm
11	CENTERING OF ROW OF HOLES	2	NC SPOT DRILL	10 mm	8.5 mm
12	CENTERING OF ROW OF HOLES	3	NC SPOT DRILL	10 mm	8.5 mm
13	CENTERING OF ROW OF HOLES	4	NC SPOT DRILL	10 mm	8.5 mm
14	CENTERING OF PITCH CIRCLE	1	NC SPOT DRILL	10 mm	-1.5 mm
15	DEEP HOLE OF PITCH CIRCLE GROUP	1	TWIST DRILL	5.24 mm	-20 mm
16	DEEP HOLE OF ROW OF HOLES	1	TWIST DRILL	5 mm	8.5 mm
17	DEEP HOLE OF ROW OF HOLES	2	TWIST DRILL	5 mm	8.5 mm
18	DEEP HOLE OF ROW OF HOLES	3	TWIST DRILL	5 mm	8.5 mm
19	DEEP HOLE OF ROW OF HOLES	4	TWIST DRILL	5 mm	8.5 mm
20	DEEP HOLE	1	TWIST DRILL	5 mm	-20 mm
21	DEEP HOLE	5	TWIST DRILL	5 mm	-20 mm
22	DEEP HOLE	9	TWIST DRILL	5 mm	-20 mm
23	TAPPING OF PITCH CIRCLE GROUP	1	TAP	6 mm	15 mm
24	TAPPING	1	TAP	6 mm	15 mm
25	TAPPING	5	TAP	6 mm	15 mm
26	TAPPING	9	TAP	6 mm	15 mm

Figure (19). Operation sequence.

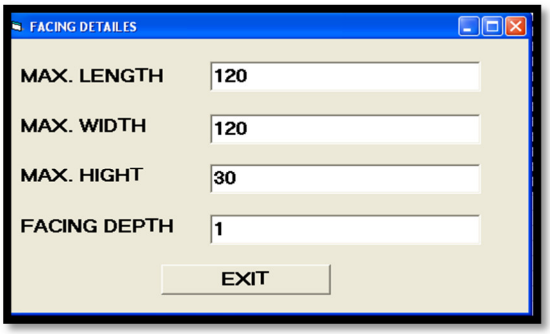
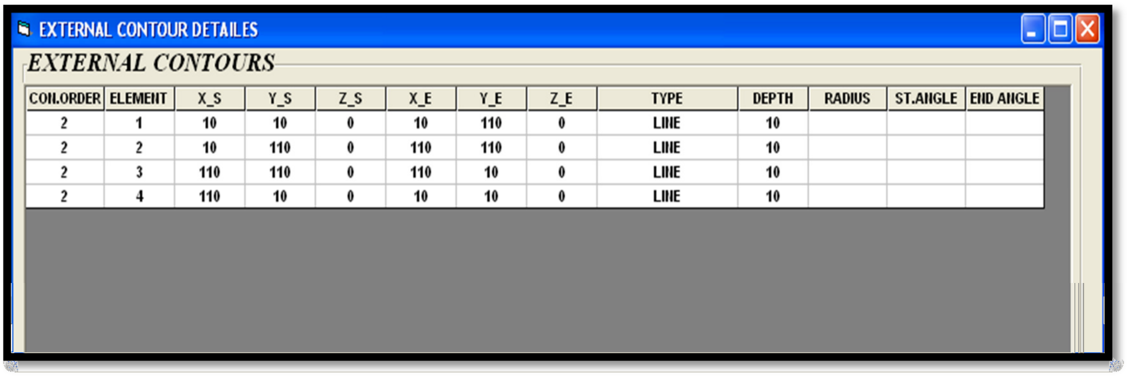


Figure (20). Facing details.



CON.ORDER	ELEMENT	X_S	Y_S	Z_S	X_E	Y_E	Z_E	TYPE	DEPTH	RADIUS	ST.ANGLE	END ANGLE
2	1	10	10	0	10	110	0	LINE	10			
2	2	10	110	0	110	110	0	LINE	10			
2	3	110	110	0	110	10	0	LINE	10			
2	4	110	10	0	10	10	0	LINE	10			

Figure (21). External contour details.

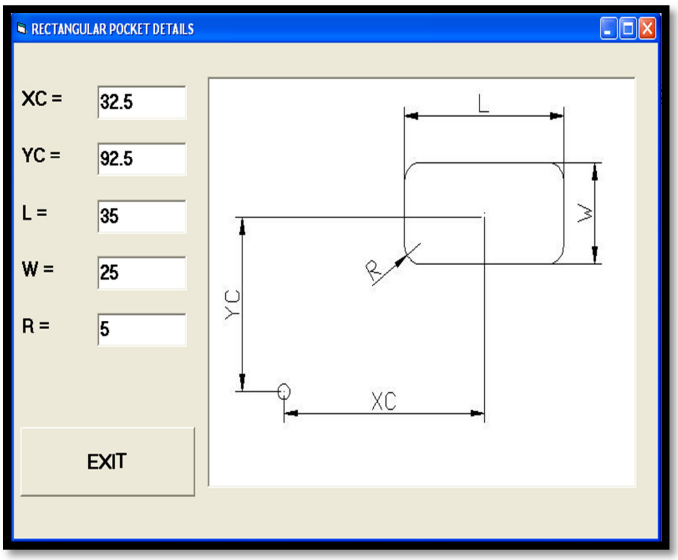


Figure (22). Rectangular pocket details.

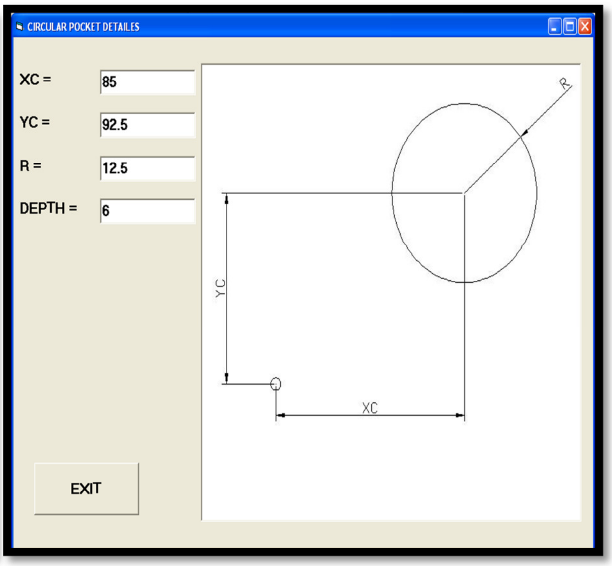


Figure (23) Circular pocket details.

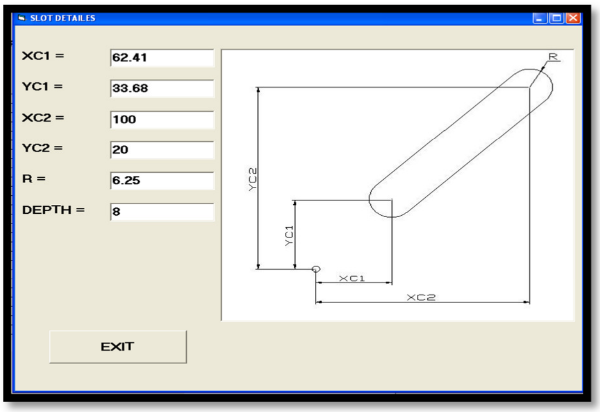


Figure (24). Slot details.

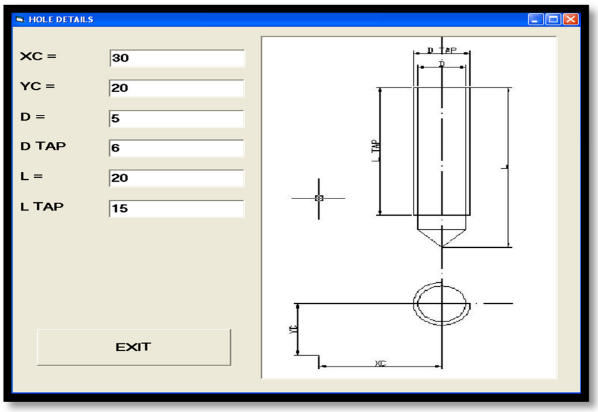


Figure (25). Scattered hole details.

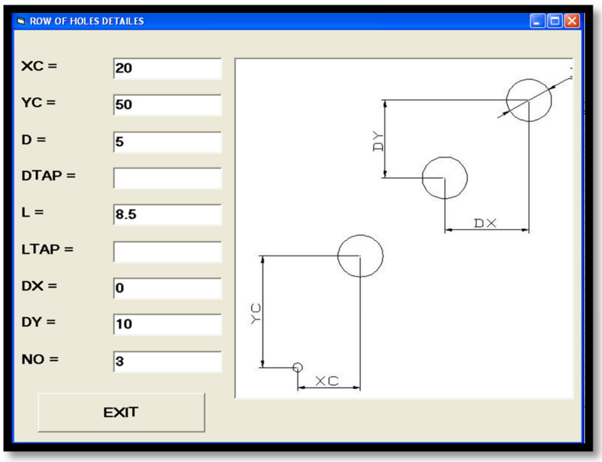


Figure (26). Row of holes details.

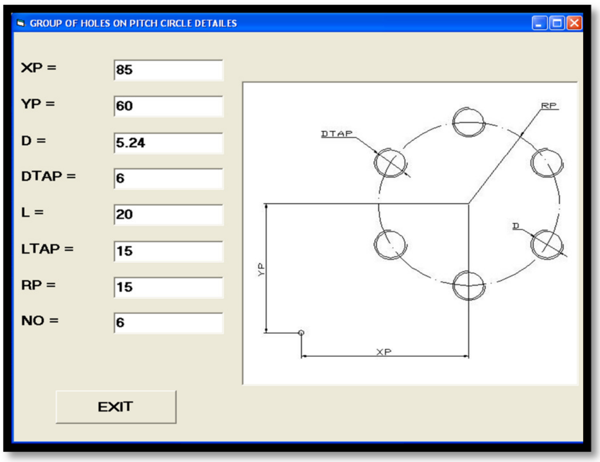


Figure (27). Group of holes on pitch circle details.

CONCLUSION

The present paper presents an operation planning module of a Computer aided process planning (CAPP) system for prismatic parts which includes 3 sub modules and a database for the system which is responsible for saving, modifying, and updating required data for the system. This module is capable of:

- Calculation of the size of the required raw material.
- Selection for standard work piece thickness.
- The ability of adding any new workpiece material.
- Selection of suitable machine according to semi product dimensions.
- The ability of adding any new machine to the developed software to be used.
- Identification of the clamping type of workpiece, according to semi product size and machine capability.
- Selection of the most suitable fixation method.
- The ability of adding any new tool to be used.
- The selection of suitable tool (type and diameter) for any machining operation.

- Selection of standard machining allowances.
- The creation of possible machining sequence for producing the required part.
- Displaying the detail data of each operation on the process sequence sheet.

REFERENCES

[1] N. Ahmad, A. F. A. Haque and A. A. Hasin, “CURRENT TREND IN COMPUTER AIDED PROCESS PLANNING”, International Conference The Institution of Engineers, Bangladesh Mechanical Engineering Division 25-27 October, 2001.

[2] P. V. Krishna, N.V.S. Shankar and B. S. Babu, “FEATURE BASED MODELING AND AUTOMATED PROCESS PLAN GENERATION FOR TURNING COMPONENTS”, Advances in Production Engineering & Management 6 (2011) 3, 153-162.

[3] Y. Zaho, K. Ridgway and A.M. Al-Ahmari, “Integration of CAD and a cutting tool selection system” August 2001.

[4] M. Kayacan, I. H. Filiz, A. I. Sijnmez, A. Baykasoglu and T. Dereli, “OPPS-ROT: An optimised process planning system for rotational parts’, Department of Mechanical Engineering, University of Gaziantep, 27310 Gaziantep, Turkey, 1996.

[5] A. Nassehia, S.T. Newmanb and R.D. Allena, “The application of multi-agent systems for STEP-NC computer aided process planning of prismatic components”, International Journal of Machine Tools & Manufacture 46 (2006) 559–574.

[6] X. Zhou, Y. Qiu, G. Hua, H. Wang and X. Ruan, " A feasible approach to the integration of CAD and CAPP A feasible approach to the integration of CAD and CAPP ", National Die and Mold CAD Engineering Research Center, Shanghai Jiao Tong University,(2007).

[7] B. Denkena, M. Shpitalni, P. Kowalski, G. Molcho and Y. Zipori, "Knowledge Management in Process Planning", Laboratory for CAD and LCE, Faculty of Mechanical Engineering,(2002).

[8] J. Y. Fuh, C.-H. Chang and M. A. Melkanoff, “The development of an integrated and intelligent CAD/CAPP/CAFP environment using logic-based reasoning”, Department of Mechanical, Aerospace and Nuclear Engineering, UCLA, Los Angeles, CA 90024, USA (1995).

[9] J. DONG, H. R. PARSAEI and H. R. LEEP, " MANUFACTURING PROCESS PLANNING IN A CONCURRENT DESIGN AND MANUFACTURING ENVIRONMENT", Department of Industrial Engineering, University of Louisville, Louisville, KY 40292, U.S.A. (1996).

[10] A. J. Joneja, "Geometric reasoning for optimizing backward growing-based feature recognition", Dept. of Industrial Engineering & Engineering Management Hong Kong University of Science & Technology, (1997).

[11] Y. Woo, E. Wang, Y. S. Kim and H. M. Rho," A Hybrid Feature Recognizer for Machining Process Planning Systems", School of Mechanical Engineering, Sungkyunkwan University, Suwon, Korea, (2004).

[12] J. Ciuranaa, M. L. Garcia-Romeua, I. Ferrerb and M. Casadesu," A model for integrating process planning and production planning and control in machining processes ", Robot Computer Integrated Manufacturing systems (2007).

[13] H. Lau and Bing Jiang, "A generic integrated system from CAD to CAPP: a neutral file-cum-GT approach", Robot Computer Integrated Manufacturing systems (1998).
[14] M. Kanga, J. Hanb and J. G. Moonc, “An approach for interlinking design and process planning”, Journal of Materials Processing Technology, 2003.
[15] H. C. Lee, W. C. Jhee and H.-S. Park, “Generative CAPP through projective feature recognition", Available online 15 June 2007.