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Feature - Based Approach to Automatic Fixturing System Planning For Uniform Polyhedra Workpiece

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Abstract

This paper demonstrates the design of an algorithm to represent the design stages of fixturing system that serve in increasing the flexibility and automation of fixturing system planning for uniform polyhedral part. This system requires building a manufacturing feature recognition algorithm to present or describe inputs such as (configuration of workpiece) and built database system to represents (production plan and fixturing system exiting) to this algorithm. Also knowledge – base system was building or developed to find the best fixturing analysis (workpiece setup, constraints of workpiece and arrangement the contact on this workpiece) to workpiece.

Keywords: Fixturing System Planning, Fixturing System Analysis, Computer Aided Fixturing System Planning.

Introduction

A key concern to a manufacturing company is the ability to manufacture high quality products in a short time as possible. Quick release of a product into the market place, ahead of any competitors, is crucial to securing a higher percentage of the market place [(1)]. Fixtures play an important role within many manufacturing processes such as machining, inspection and assembly [(2)]. They accurately locate and secure a workpiece during machining such that the part can be manufactured to design specifications. Thus fixtures have a direct effect upon machining quality, productivity, and the cost of products [(3, 4)].

Fixtures are used to locate and constrain a workpiece during a machining operation, minimizing workpiece and fixture tooling deflections due to clamping and cutting forces are critical to ensuring accuracy of the machining operation. Traditionally, machining fixtures are designed and manufactured through trial-and-error, which prove to be both expensive and time-consuming to the manufacturing process. The fixture design process can be divided into [(5)]:

- **Fixture planning** is to determine the number of setups, the orientation of workpiece in each setup, the machining surface in each setup, and determine a set of locating and clamping points on workpiece surfaces such that the workpiece is completely restrained.
- **Fixture construction** is to select fixture elements, and place them into a final configuration to locate and clamp the workpiece.
- **Fixture assembly** is to assemble fixture components in strict accordance with the previously stage.

To ensure a workpiece is manufactured according to specified dimensions and tolerances, it must be appropriately located and clamped, making it imperative to develop tools that will eliminate costly and time-consuming trial-and-error designs. Proper workpiece location and fixture design are crucial to product quality in terms of precision, accuracy and finish of the machined part. Theoretically, the 3-2-1 locating principle can satisfactorily locate all Uniform Polyhedra shaped workpiece. This method provides the maximum rigidity with the minimum number of fixture elements. To position a part from a kinematics point of view means constraining the six degrees of freedom of a free moving body (three translations and three rotations). Three supports are positioned below the part to establish the location of the workpiece on its vertical axis. Locators are placed on two peripheral edges and intended to establish the location of the workpiece on the x and y horizontal axes [5, 6, 7 & 8].

The goal of this paper is describe the stages of fixturing system planning for uniform Polyhedra workpiece this stage begin from extraction and recognition manufacturing features from CAD package and building database system for represent production plan and fixturing system exiting. Secondly, built knowledge-base system for fixturing system plan to represent type of fixturing, number of fixturing need and positioning of fixturing. Finally, determine fixturing system analysis is using same knowledge-base system that contain determined part setup or orientation and determine the faces and features to locate, support and clamp it, also determined the point contact on the faces or features and arrangement element according to this points.

System Architecture

The system architecture **of *automatic fixturing system planning*** *(A.F.S.P)* is depicted in Fig (1).

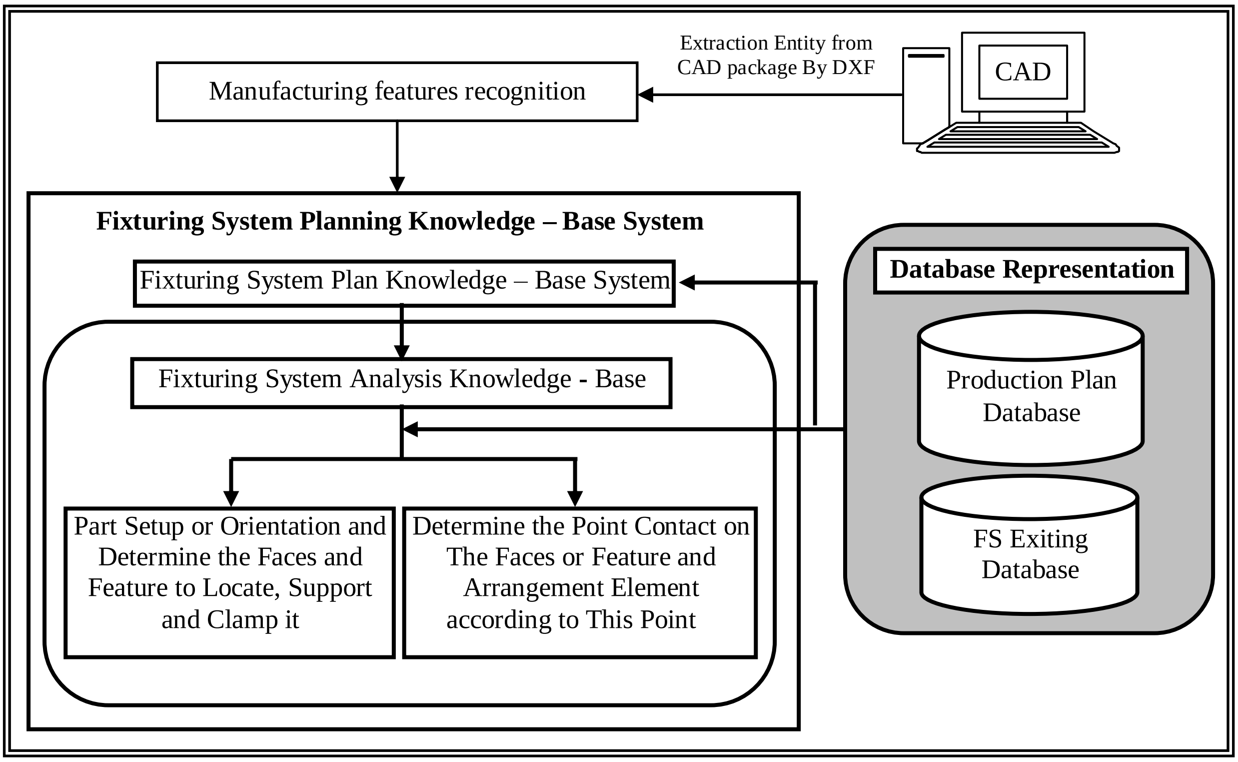

Fig.1. The (AFSP) System Architecture.

Manufacturing Feature

Feature technology can, in general, be classified into feature extraction, feature-based design, and feature conversion. Feature extraction (or feature recognition) is mainly concerned with identifying certain features from the various types of product representations such as boundary representations or solid models. Feature-based design, by contrast, aims at building a product model with a predefined set of design features. Feature conversion is the methodology that converts features defined in one domain to those of other domains (e.g., the conversion from design features to manufacturing features) [9]. The advantage of using features in engineering comes from the abstraction of information that the features provide. The features retain not only the geometric information but also much of the useful non-geometric information that is of interest in engineering applications. Since there are many different application areas, the definitions of features vary widely.

Feature is defined: -as special information about the semantics of part of the geometry and topology [10]. For process planning a feature is defined as a geometric form and a set of specification for which a process planning exists and this process is almost independent of the feature of the parts [9].

Automatic feature recognition techniques provides the capabilities for translating the part definition data between CAD & the feature needed to drive, for example, a process planning system. Applied to process planning a part, feature recognition system would distinguish features of a part based on the geometric and topological information stored in the CAD database. Once a feature and associated manufacturing information are identified, the information then can be passed to process planning to generate process plans [11]. The AFR technique is to take a general CAD model, which is available commercially to provide an automated interface to recognize and extract the manufacturing features from the model. Feature extractor will derive all the features of a part based on the geometric and topological information stored in CAD database. Feature recognition from solid model has been considered as one of the solutions for bridging CAD & CAM [9]. The AFR technique is developed by geometric operation on B-rep solid models. It automatically identifies and groups topological entities, such as faces of a B-rep model, into functionally significant features such as holes, slots, pockets, ribs, fillets, etc. It also extracts their size and positional parameters for use later on [10].

Process planning activities such as setup generation, process selection, tool selection, machining sequence, etc. are largely dependent on the types of features and their inter-relationships in the model. AFR outputs feature information that is useful to various processes planning activities [9, 10].

The proposed algorithm of features recognition supported by rules-condition facility, which is specific for processing the uniform polyhedral workpiece. This algorithm has the capability of recognizing the most prismatic features.

Generally, the algorithm is divided into many stages for recognition features represented in fig (4). First stage includes many tasks and starts from extraction of 3D data required stored in CAD database, processing, converting, and preparing these entities data for next stage. The second stage includes also many tasks which begin from representing and defining of the geometric entities parts by faces, edges and vertexes classifying predefined features and extraction and recognition of the manufacturing features and determining all parameters associated with all developed features such as orientation and location.

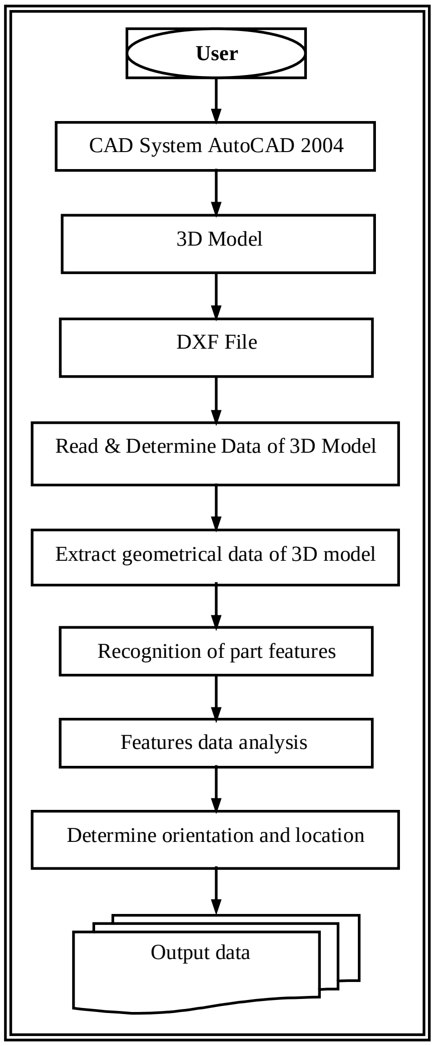

Fig.2. Algorithm for Recognition Features.

Uniform Polyhedra split to six faces (Top, Buttom, Left, Right, Front, Back) each two faces is opposite as show in fig (3).

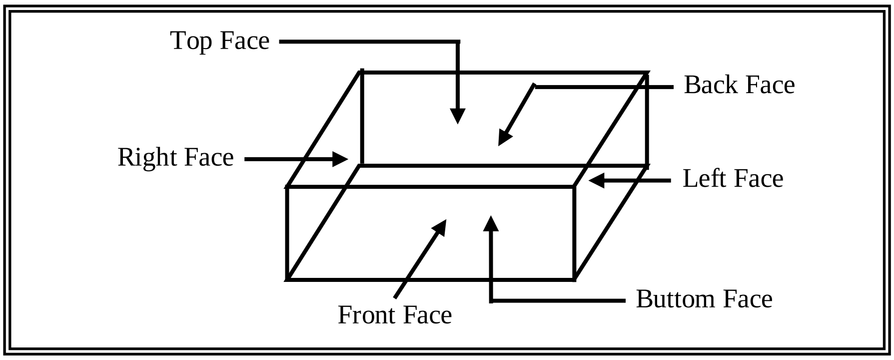

Fig.3. Determine Number and Name of Faces on the Uniform Polyhedra Workpiece.

Uniform Polyhedra workpiece divided into (12) edges used the distance between two edges in the same face to determine the location of machined (MF) and unmachined (features to be machined or required feature) feature (UF) as shown in fig (4).

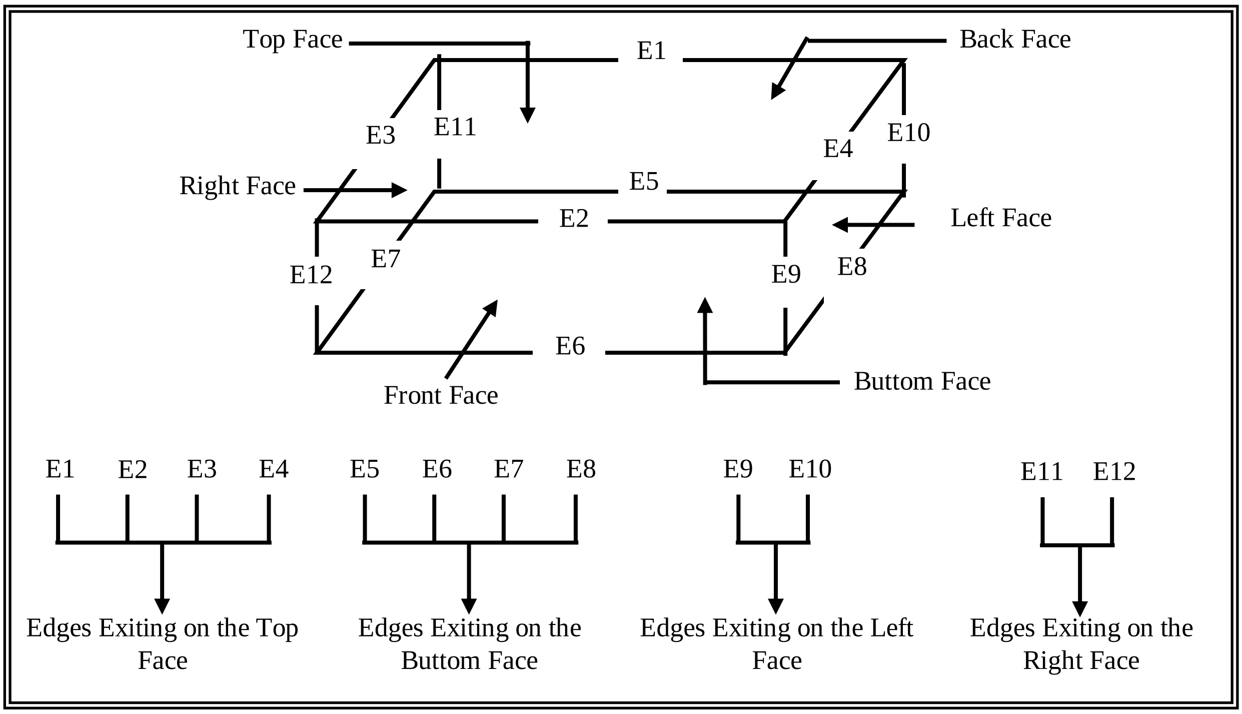

Fig.4. Relational Location of Machined Feature for Uniform Polyhedra Workpiece.

Fixturing System Planning

The objective of fixturing planning is to determine number of setups needed, the position and orientation of workpiece in each setup and to determine the locating and clamping surfaces and points contact on the workpiece. Fixturing planning consists of two main stages [6]:

1- Fixturing System Plan Knowledge–Base (FSPKB)

This stage contain specification type, number and position of fixturing system depend on the type of operation required produced, number of piece to be made or batch size and number of unmachined feature (UF) and location of this feature on the workpiece. Fig (5) shows this stage.

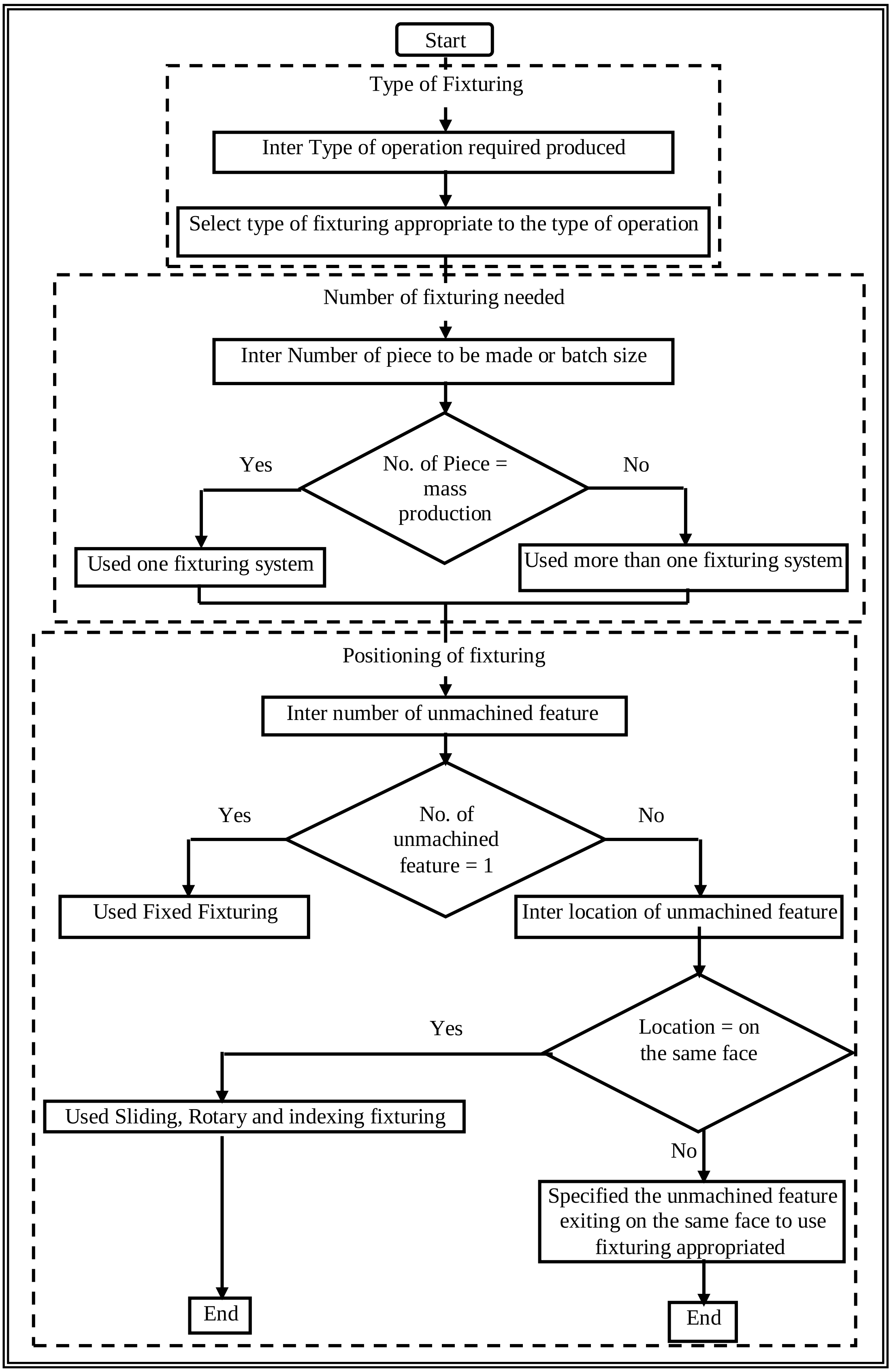

Fig. 5. Algorithm for Fixturing Plan.

Examples of rules used for finding Type, number and Positioning of fixturing system shown in table (1).

Table 1
Example of Rules Used For Fixturing Plan

Type of Fixturing System

[(**Rule 1:**
(IF (Type-Of- Operation = Drilling))
(Then (Type-Of-Fixturing-System = Drilling Jig)))
(**Rule2:**
(IF (Type-Of-Operation = Milling))
(Then (Type-Of-Fixturing-System = Milling Fixture)))]

Number of Fixturing System

[(**Rule 1:**
(IF (Number-Of-Piece-To-Be-Made = Mass Production)
OR (Batch-Size = Mass Production))
(Then (Number- Of-Fixturing-System = More Than One)))]

Positioning of Fixturing System

[(**Rule 1:**
(IF (Number-Of-Required Feature = One))
(Then (Positioning-Of-Fixturing-System = Fixed Fixturing System)))
(**Rule2:**
(IF (Number-Of-Required Feature = More Than One)
AND (Location-Of-Required-Feature = On The Same Face))
(Then (Positioning-Of-Fixturing-System = Sliding, Rotary and Indexing Fixturing System)))
(**Rule3:**
(IF (Number-Of-Required Feature = More Than One)
AND (Location-Of-Required-Feature = On The Different Face))
(Then (Positioning-Of-Fixturing-System = Cannot Find Positioning)))]

2- Fixturing System Analysis Knowledge-Base (FSAKB):

This stage can be classified into two main parts:

2-1 Workpiece Setup (Machining References, Locating and Clamping Face):

Determine workpiece setup one of the important task to success fixturing design due to stability and securing of the workpieces under certain force application and limit kinematics freedom. For each setup, must ensuring the fixturing configuration will provide a force closure on the workpiece and enable reach to feature to be machined without interfere with tool path.

Generally, determine the workpiece setup depend on representation or description the details geometric workpiece and using rule- based system to processing this details to get on the best and minimum number of workpiece setup.

In this paper, used one setup operation after specify number of unmachined feature (UF) and location of this feature. If the location of this feature exiting on the one face used one setup operation. But, if location of this feature exiting on the more than one face will select large number of this feature exiting on the one face to get on one setup operation. Also, after specified the number of setup required. The machining references, first and second locating face and clamping face are determined. In Uniform Polyhedra workpiece, the machining references represent the opposite face to the clamping face that unmachined feature (UF) exiting it and determine first and second locating face that ensuring full constraint to the prismatic workpiece. Example, if the unmachined feature (UF) exiting on the top face, top face represent as clamping face, buttom face as machining references, right face as first locating face and back face as second locating face as shown in Fig (6).

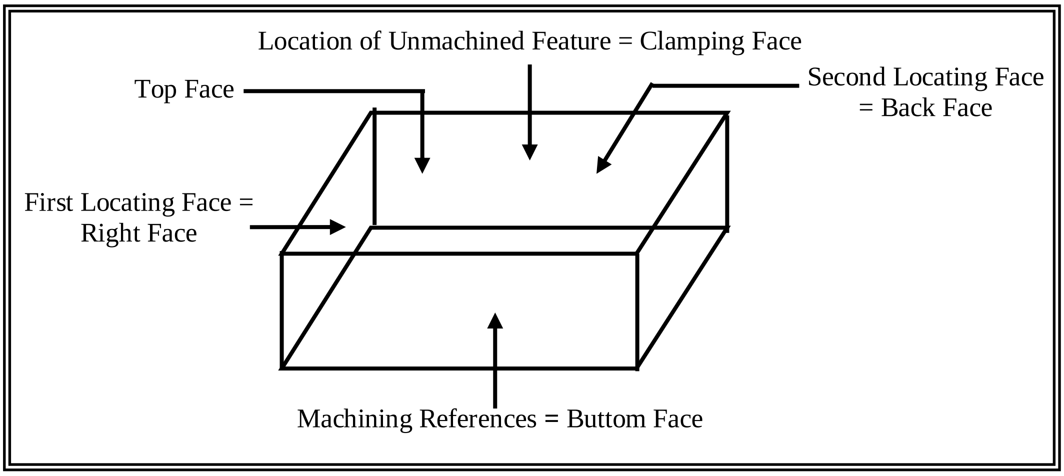

Fig.6. The Rule Used in Constraint Uniform Polyhedra Workpiece.

2-2 Determine Contact on the Faces Selected:

After pinpointing the faces that locating and clamping it, contact important to get on the best equilibrium to the workpiece must be determined. This part begins **Firstly**, in definition the machined feature (MF) exiting on the faces selected. **Secondly**, specify the number and type of clamping contact on the clamping face.

In Uniform Polyhedra workpiece, using point contact and face contact according to type of feature or operation machining required. If the unmachined feature is hole, used face contact to easy use drill bushing and prevent the movement resulted from the drilling moment and formatted according to the machined feature (MF) exiting on the clamping face. But, if the unmachined feature is slot or other type used point contact specified depend on the location of machined and unmachined feature exiting on the clamping face with ensuring not interfere with tool and feature and definition this point according to the method using in determine the feature for Uniform Polyhedra workpiece presented previously.

Thirdly, select the locating and supporting point contact on machining references. In Uniform Polyhedra workpiece, use three-point contact on the machining references. If hole feature is founded or selected, one locating point contact and two supporting contact is used. But, hole feature is no selected, three supporting point contact is used.

Fourthly, select the locating and supporting contact on the first, second locating and support faces. In Uniform Polyhedra workpiece, use two locating or supporting point contact in first locating face and use one support point contact on the second locating face. Uniform Polyhedra workpiece arrangement the point contact on the face used in locating and supporting depend on the design consideration to this element. Fig (7) illustrated the step of the procedure used in the fixturing analysis.

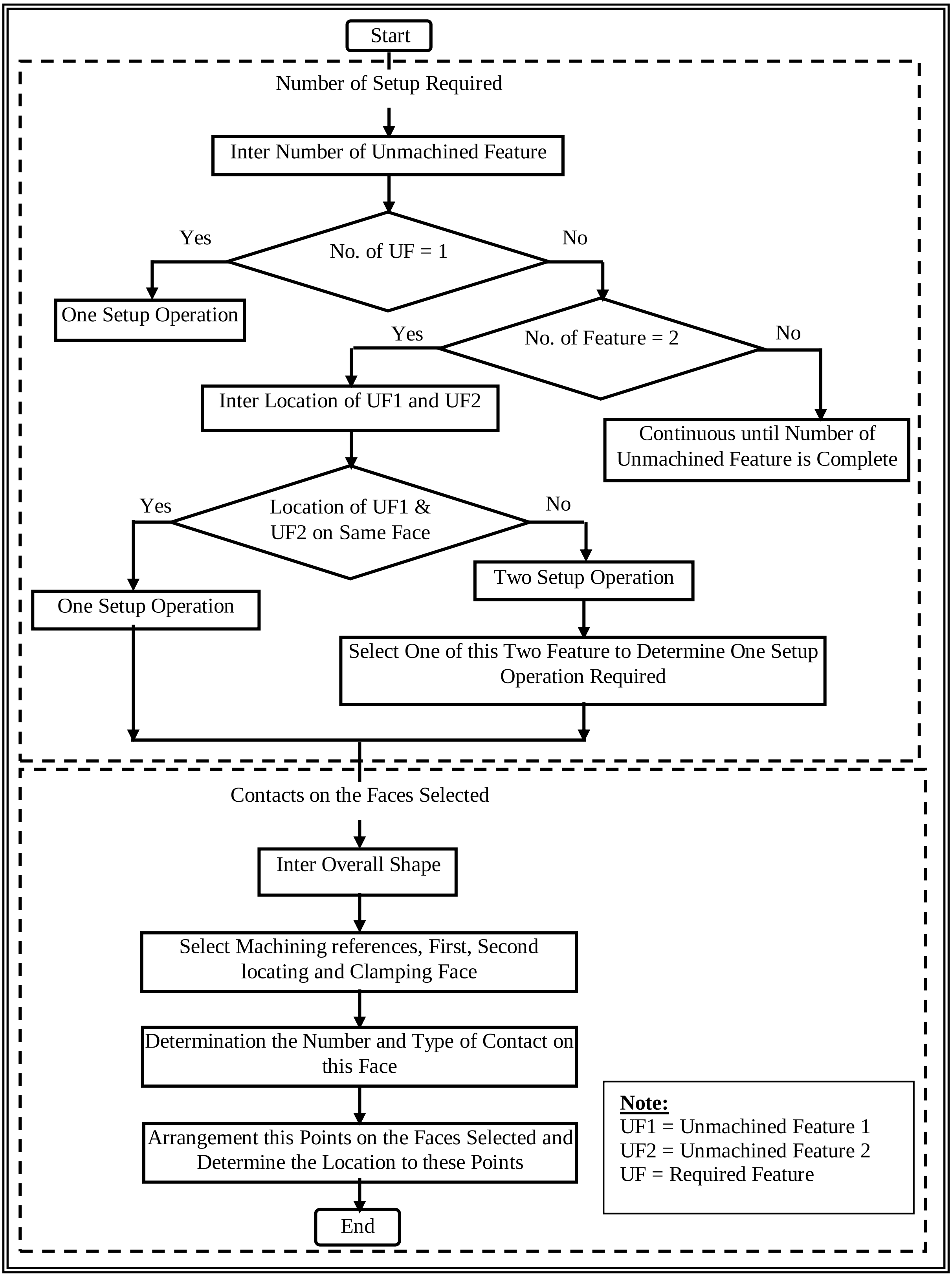

Fig.7. Flowchart for Fixturing Analysis.

Fig. (8) shows examples of rules used for determining number of setup operation, rules used for determining the faces used locating, supporting and clamping, and Some of rules used in this step.

Number of Setup Operation

[(**Rule 1:**
(IF (Number-Of-Required Feature = One))
(Then (Positioning-Of-Setup-Operation = One Setup Operation)))
(**Rule2:**
(IF (Number-Of-Required Feature = More Than One)
AND (Location-Of-Required-Feature = On The Same Face))
(Then (Positioning-Of-Fixturing-System = One Setup Operation)))
(**Rule3:**
(IF (Number-Of-Required-Feature = More Than One)
AND (Location-Of-Required-Feature = On The Different Face))
(Then (Positioning-Of-Fixturing-System = More Than One Setup operation)))]

Find the Faces for Locating, Supporting and Clamping It

[(**Rule 1:**
(IF (Overall-Shape = Uniform Polyhedra)
AND (Location-Of-Required-Feature = On The Top or Buttom Face))
(Then (Face-Selected = Machining References, First and Second Locating Face and Clamping Face)))

(**Rule2:**
(IF (Location-Of-Required-Feature = On The Top Face))
(Then (Machining-Reference = On The Buttom Face)
(Locating-Face = On The Right and Back Faces)
(Clamping-Face = On The Top Face)))
(**Rule3:**
(IF (Location-Of-Required-Feature = On The Front Face))
(Then (Machining-Reference = On The Back Face)
(Locating-Face = On The Left or Right Face and On the Top or Buttom Face)
(Clamping-Face = On The Front Face)))]

Number and Type of Contact on Clamping Face

[(**Rule1:**
(IF (Number-Of-Machined-Feature = Non)
AND (Number-Of-Unmachined-Feature = Existing)
OR (Type-Of-Unmachined-Feature = Hole))
(Then (Number-Of-Contact = One)
(Type-Of-Contact = From Face)
(Arrangement-Contact = On The Overall Size Of Face)))]

Number and Type of Contact on Machining References

[(**Rule1:**
(IF (Number-Of-Machined-Feature = Non))
(Then (Number-Of-Contact = Three)
(Type-Of-Contact = From Point)
(Arrangement-Contact = Near To The Center Of Workpiece)))]

Fig. 8. Example of Rules Used For Fixturing Planning.

Number and Type of Contact on First and Second Locating Face

[(**Rule1:**
(IF (Number-Of-Machined-Feature = Non)
AND (Number-Of-Machined-Feature = One)
Or (Number-Of-Machined-Feature = More Than One))
(Then (Number-Of-Contact = One)
(Type-Of-Contact = From Face)
(Arrangement-Contact = On The Overall size Of Face)))
(**Rule2:**
(IF (Type-Of-Machined-Feature = Hole))
(Then (Number-Of-Contact1 = One)
(Number-Of-Contact2 = One)
(Type-Of-Contact1 = From Hole)
(Type-Of-Contact2 = From Face)
(Arrangement-Contact1 = Same Location Of Hole)
(Arrangement-Contact2 = Overall size Of Face)))]

Fig. 8. Examples of Rules Used For Determining Fixturing Planning.

The full description to the practical application and other input to the ***automatic fixturing system planning (AFSP)*** system show in Fig (9) and table (2).

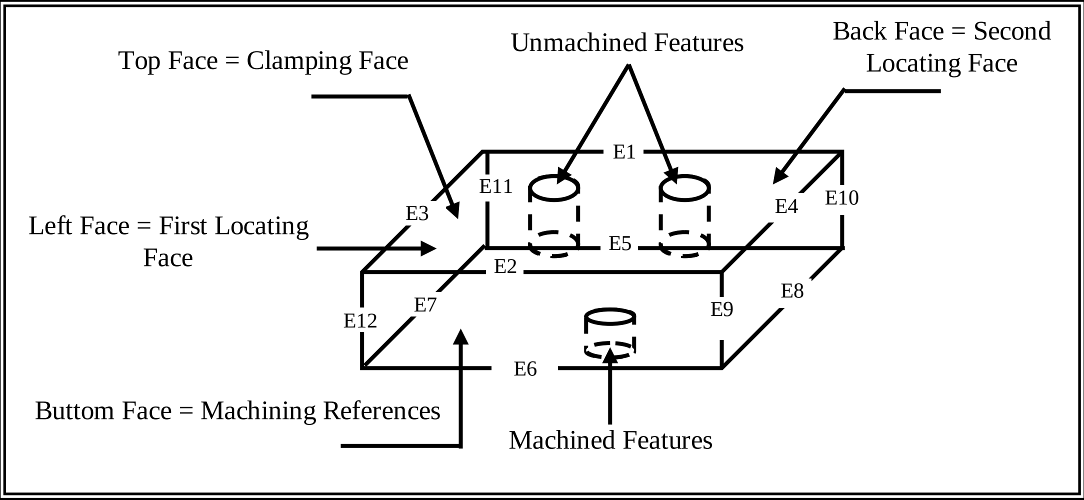

Fig. 9. Drawing of Practical Application.

Table 2
Practical Application Configuration.

No. of M.F.	List of M.F.	Location of Machined Feature (M.F).	Length	Depth	Width	Diameter	Other	Position
1	Hole	On The Bottom Face		18.8		2.5		(20 and 8)mm between hole center and (E7, E6)
No. of R.F.	**List of R.F.**	**Location of Required Features (RF)**	**Length**	**Depth**	**Width**	**Diameter**	**Other**	**Position**
2	Hole	On The Top Face		1.6		6.25		(15 and 8) mm between hole center and (E3, E1)
	Hole	On The Top Face		1.6		6.25		(23 and 8) mm between hole center and (E3, E1)

The windows that representing the automating algorithms of fixturing system planning shown in Figs. (10, 11, 12, 13, 14 and 15).

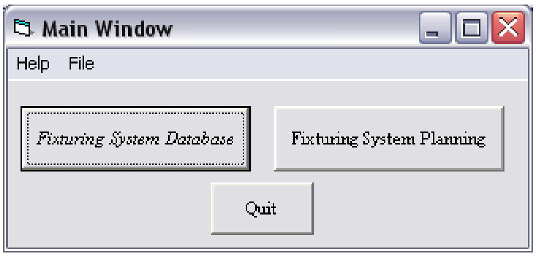

Fig.10. Main Window for System.

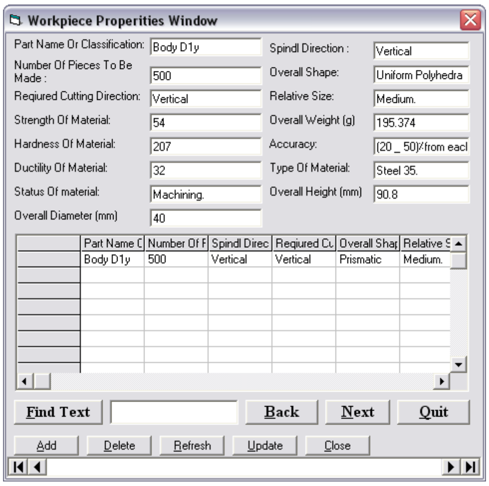

Fig.11. Workpiece Properties Window Database.

The system in this stage through interaction with the user performs extraction and recognition tasks of the manufacturing features from processing the geometric entities data and converts it from low level into high level representation called features. The window illustrate in figure (12) represents a link between CAD and system through automated information design by extraction and recognition of the manufacturing features. The feature recognition window consists of main procedures related of part analysis, which contain all data required for the next steps.

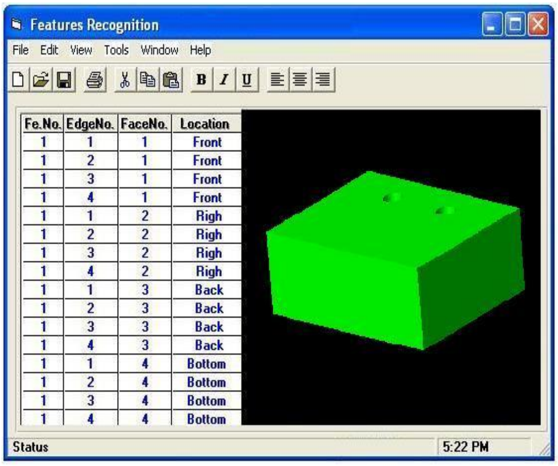

Fig.12. Workpiece Configuration Window Database.

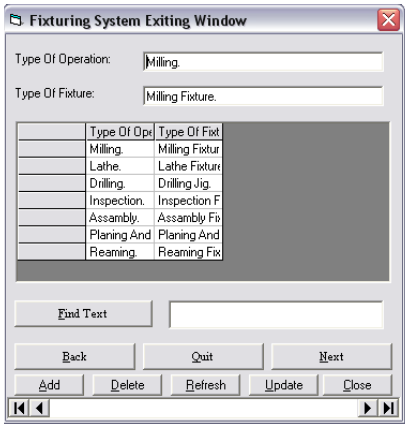

Fig.13. Fixturing System Exiting Window Database.

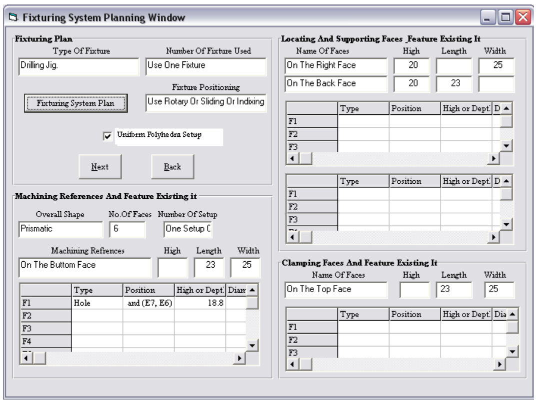

Fig.14. Fixturing Planning Window.

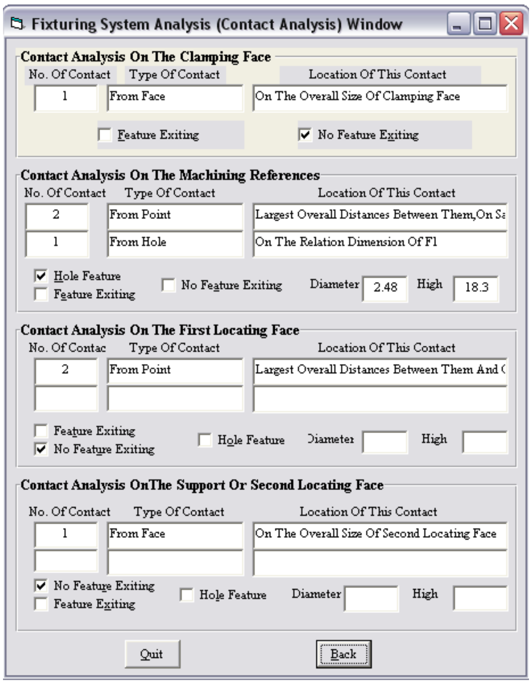

Fig.15. Fixturing System Analysis (Contact Analysis) Window.

Conclusion

In manufacturing, tooling includes selection, design, and fabrication of cutter tool, fixturing system, inspection devices and molds. Fixturing system is an important aspect of manufacturing process and has become one of the bottlenecks in implementation of CIM (Computer Integrated Manufacturing). The cost of designing and fabricating fixturing system can amount to (10% - 20%) of the total manufacturing system cost, also the time and effort spanned by designer to design fixturing system is very important therefore, it is important use the computers and AI (Artificial Intelligence) techniques to increase the efficiency of design fixturing systems. this system applied to various types of Uniform Polyhedra work pieces (various sizes and types) and use database system leads to simplifying the ability of the user to enter, change and expand data, also the ease of searching between these data to find the data required and reduces the time and effort required to describe the workpiece. Applying knowledge–based (rule-based) system to fixturing system analysis has proved a powerful tool and very useful to get the efficient results for the number of workpiece setup and finds faces or feature for clamping, locating and supporting it also arrangement contact on this faces that realization best equilibrium to the workpiece. The workpiece selected in this research is one of some of workpiece are used to test system that getting from some of papers related to this research.

The fixturing plan results show below:

Type of fixturing system	Drilling jig
Number of fixturing system	One
Number of part faces	6
Number of setup operation	One setup operation

Buttom face using as machining references contain hole feature as machined feature. Position of this feature is determined between the edge (E7 and E6). Right face present first locating face and back face as second locating face and determined the dimension for this face. The clamping face using as clamping face.

The result for fixturing system analysis also shows below:

Contact analysis on	Number of contact	Type of contact
Clamping face	1	From face
Machining references	2	From point
	1	From hole
First locating face	2	From point
Supporting or second locating face	1	From face

The position and the dimension fro this contact is determined.

By studying results of the previous application the following points, can be noticed:

1- Depending on the location of required feature to specify number of workpiece setups helps the user to get on the minimum of setup operations and also the use of location of these features leads to best decision for fixturing system position.
2- Finding the faces for locating, clamping, and supporting depends on the rules constraint of rotational workpiece that results in getting the

best equilibrium and constraint to this application.

3- Using faces to support or locate this application instead of using a point, gives lager stability to application and removes the complexity because the large number of machined features exist on the faces of application.

4- Basically Using screw force for clamping element reduces time, effort and wear of these elements, it also gives maximum clamping force for rotational applications.

5- Use locating and supporting element such as (Locating Rest Pad) lead to minimum number of elements selected.

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تصميم خوارزميه لاتمته تخطيط انظمه التثبيت لقطعه العمل المتعددة السطوح المتناسقه

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الخلاصة

هذا البحث يقدم تصميم خوارزميه لتمثيل مراحل تصميم انظمه التثبيت و التي تساهم في زيادة مرونه و اتمته تخطيط انظمه التثبيت للاشكال المتعددة السطوح المتناسقه. هذا النظام يتطلب بناء خوارزميه لتوليد السمات التصنيعيه ك -(شكل قطعه العمل) و كذلك بناء قاعده البيانات لوصف المدخلات لهذا النظام مثل (خطه الانتاج و انواع انظمه التثبيت الموجودة). كذلك بناء قاعدة المعرفه لايجاد افضل تحليل للتثبيت (نصب و تقييد قطعه العمل و ترتيب التلامس على قطعه العمل) لقطعه العمل.