AN AUTOMATIC FIXTURE DESIGN SYSTEM FOR CREATING PRISMATIC PARTS

A. Al-Ahmari[1], A.A. Khan[2*], E.A. Nasr[3] & A. Kamrani[4]

[1,2,3]Industrial Engineering Department
College of Engineering, King Saud University
Saudi Arabia
[2]kawais@ksu.edu.sa

[3]Faculty of Engineering, Mechanical Engineering Department
Helwan University, Cairo, Egypt

[1,2]FARCAMT, Advance Manufacturing Institute
King Saud University, Saudi Arabia

[4]Industrial Engineering Department
University of Houston, College of Engineering
Houston, TX, USA

ABSTRACT

A modular fixture system is a flexible alternative to a dedicated fixture. In this paper, an automatic modular fixture design system is suggested for creating prismatic parts. The system contains fixture planning, fixture modelling, and fixture assembly. The part geometrical database and process plans are considered as inputs to the system. A rule-based method is applied to assign the feasible locating scheme and the locating and clamping datum. The search strategy is designed to determine the most suitable locating and clamping points. The final fixture assembly is made with the standard fixture components using the CATVBA Editor inside CATIAV5. The proposed methodology is successfully validated with a case study.

OPSOMMING

‘n Aanpasbare hegtingsisteem is ‘n buigsame alternatief vir ‘n toegewyde hegstuk. ‘n Outomatiese aanpasbare hegstuk ontwerpsisteem vir die skep van prismatiese onderdele word voorgestel. Die sisteem bevat hegstuk beplanning, hegstuk modellering en hegstuk samestelling. Die onderdeel geometriese databasis en proses planne word as insette gebruik. A reëlgebaseerde metode is toegepas om die opsporings en vasklem verwysingspunte toe te ken. Die soekstrategie is ontwerp om die mees geskikte verwysings- en klempunte te bepaal. Die finale hegstuk samestelling is gemaak van die standaard hegstuk komponente van die CATVBA Editor van CATIAV5. Die voorgestelde benadering is suksesvol gevalideer deur middel van ‘n gevallestudie.

* Corresponding author

1 INTRODUCTION

Fixtures, which are important in both traditional manufacturing and modern flexible manufacturing systems (FMS), directly affect the machining quality, productivity, and cost of products. The time spent on designing and fabricating fixtures contributes significantly to the production cycle in relation to improving current products and developing new products. Greater attention has therefore been paid to the study of fixturing in manufacturing. The manual fixture design requires the consideration of a number of factors such as the primary requirements of the design, meeting specific demands, the use of automated and semi-automated clamping devices, and safe operation. The application of these fundamental principles to an individual fixture design depends primarily on the designer's experience. The collection and representation of this knowledge, which is based on the designer's experience, plays a crucial part in computer-aided fixture design [1].

A fixture is a device for locating, holding, and supporting a work-piece during a manufacturing operation. Fixtures are essential elements in production processes, and are required in most automated manufacturing, inspection, and assembly operations. Fixtures must correctly locate a work-piece in a given orientation with respect to a cutting tool or measuring device, or with respect to another component (e.g., in assembly or welding). The location must be invariant in the sense that the devices must clamp and secure the work-piece in that location for the particular processing operation [2].

Modular fixturing systems use a group of individual components, which are assembled on a base plate, to fit the work-piece that requires fixturing. Modular fixturing systems are typically used for prototype tooling, for short-run production tools, for limited part quantities, or as a backup work-holder to replace dedicated tooling that requires repair. The advantages of using modular fixture systems include flexibility, a reduction in fixture construction time, a reduction of storage space, and the ability to re-use the fixture components. By using a number of standard parts, the fixture can be constructed in about 20 per cent of the time required for dedicated fixtures. Modifications also take much less time to perform. There are two types of modular fixture systems: T-slot based and dowel-pin based [3, 4].

In this paper, the process and setup planning data is taken as an input in a fixture design system. The system comprises fixture planning, fixture modelling, and fixture assembly modules. The developed rule-based method is used to obtain the fixture planning data. The fixture modelling is obtained by a search strategy based on fixture rules, geometrical and dimensional constraints, and a graphical fixture database. The modular fixture assembly is produced inside CATIA V5, using a graphical database.

This paper is organised as follows: Section 2 reviews the fixture design literature; then the proposed methodology is presented in Section 3. Section 4 uses a case study to demonstrate the implementation steps of the developed methodology. Conclusions are presented in Section 5.

2 LITERATURE REVIEW

A fixture design process starts from the fixture planning phase, which consists of fixture type, complexity, orientation of work-piece, determination of locating scheme, and clamping faces. The fixture layout determines the position and types of locating, supporting, and clamping devices. In the fixture assembly, the fixture body design is completed by developing the fixture layout with the designed elements [5]. Several techniques have been developed in the literature to develop the fixture design process; some of these techniques are presented here.

Knowledge-based engineering (KBE) methods build a structure of knowledge (e.g., geometrical information, machining process, fixture design elements, and fixture resources)for every phase of the fixture design process. These methods are coupled with interpretation rules to obtain the solution for machining fixtures. Rios et al. [6] developed and presented KBE applications for fixturesin high-speed milling. Hunter et al. [7] and Alarcon et al. [8] presented a functional design approach in which the functional requirements and constraints were considered as an input to the fixture design process. The fixture design solution was created at two levels: functional and detailed. The functional level was based on fixture functional elements, while the detailed level was based on fixture commercial elements.

The case-based reasoning (CBR) method is a variant fixture planning approach. By using CBR methods, past problem-solving experience and cases can be re-used and learned. The most popular CBR process includes four steps: retrieve, re-use, revise, and retain. Li et al. [9] presented a case-based agile fixture design for re-configurability, re-scalability, and re-usability. Liqing [10] and Liqing and Kumar [11] developed an internet-enabled computer-aided fixture design using a distributed case-based reasoning approach. Case representation for fixture design was composed of three parts: part representation, fixture representation, and setup representation. They were described in eXtensibleMarkup Language (XML) using Unified Modelling Language (UML) notation. A feature-based similarity measure was adopted for case indexing and case retrieval in this system. The two major considerations for the part are geometric shape and material. Wang and Rong [12] presented a case-based reasoning approach for welding the fixture design by referencing the previous design cases, and proposed a quick fixture solution.

Virtual reality (VR) is a technology that simulates the real world in a virtual computer-generated environment. Qiang[13] developed an interactive VR system for fixture design named Virtual Reality Fixture Design and Assembly System (VFDAS). This system allows fixture designers to complete the whole design process for modular fixtures (e.g., fixture element selection, fixture layout design, assembly, analysis, etc.) within the virtual environment (VE). Gaoliang et al. [14] presented a VR-based system for interactive modular fixture configuration design. The authors used a multi-view based modular fixture assembly model to assist with information representation and management. The multi-view model exploited the advantages of the hierarchical structure model and the assembly relationship model.

Many geometrical and analytical methods are implemented, based on the literature for modular fixture design and verification. Ma et al. [15] presented an analytical approach for automated fixture planning based on work-piece geometry and operational information. The surface accessibility, accuracy, and fixturing stability were the major parameters used in the design of their fixture planning system. Wu et al. [16,17]developed a geometrical analysis approach for automated modular fixture planning. The proposed method was used to determine the fixture surfaces and points. This system analysed the fixture's accessibility, accuracy, and clamp planning. Zheng and Qian [18] developed a set of algorithms that were used to automatically select the optimal fixture points on the baseplates, and accurately locate and firmly clamp the object. Methods for measuring the location error and for adjusting the fixture points to improve the localisation accuracy were also presented.

In rule-based methods, fixture knowledge is represented in the form of rules to govern the fixture design process. The rules are represented as 'if' and 'then' logical statements. Jeng and Gill [19] presented a fixture design problem in a hierarchical design structure. The automatic computer-aided fixture design system that was developed could automatically generate the fixture configuration for each setup orientation. The process plan was the input to the system. On that basis, a rule-based approach was used to select the locating and clamping surfaces, and an algorithm-based search strategy was developed to generate the fixture configuration automatically for the building of modular fixtures. Modular fixture elements were selected by considering the required function and geometric limitation. Nee and Kumar [20] presented a rule-based expert system for an automatic fixture design in which geometric and textural information was extracted using a solid modeller. Geometric and textual information was extracted from the solid modeller to determine the type of operation and number of setups required. Locating, supporting, and clamping planes and points were identified using rule-based and mathematical analysis.

The above literature review has highlighted that different fixture design solutions are available; but a realistic and automatic fixture design solution that uses standard available modular fixture components is still required. An object-oriented approach is used to integrate and automate the fixture design process in an independent environment. The work in this paper is restricted to block-shaped prismatic parts.

3 RESEARCH METHODOLOGY

The methodology presented in this paper is based on fixture planning, fixture modelling, and fixture assembly modules. The fixture planning module determines the locating scheme and the locating and clamping data for the prismatic part. The locating scheme and the locating and clamping datum for the specific setup of the part is established by developing the suitable rules, based on process/setup plan data and the part geometrical database. The fixture modelling determines the suitable locating and clamping positions. The specific search strategy is designed to determine the locating and clamping positions for the final fixture assembly. The designed search strategy determines the locating and clamping points based on fixture rules, part geometrical and dimensional constraints, and the modular fixture database. The final fixture assembly is created inside CATIA V5 by using the CATVBA program. The graphical database is established from commercial fixture component manufacturers such as Fixture Works and Carrlane. Visual C++ is used to integrate and automate the various fixture design modules and graphical database. The proposed methodology is presented in Figure 1.

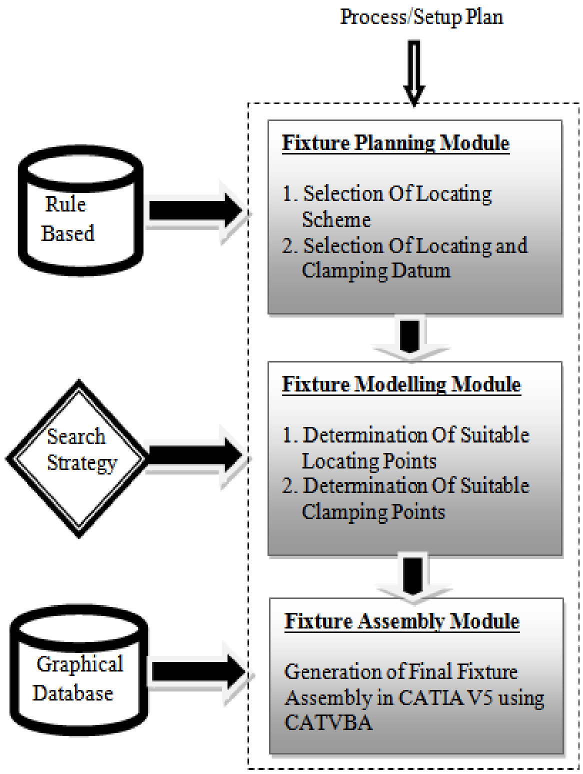


Figure 1: Fixture design process

3.1 Fixture planning module

3.1.1 Locating scheme

A work-piece, such as any free solid body, has six degrees of freedom: three linear displacements along the mutually orthogonal co-ordinate axes, and three angular displacements with respect to the same axes. During a setup, it is necessary to restrict certain degrees of freedom so as to locate and orient the technological feature surfaces with respect to the cutting tools. For prismatic-shaped work-pieces, the most common locating schemes that restrict all six degrees of freedom are 3-2-1, base 2-1, and 4-2-1[19]. There are many variations when determining the locating scheme, due to the shape, the primary datum surface, and cutting tool penetration problems.

Shape, orientation, and cutting tool penetration

The work presented in this paper is restricted to block-shaped prismatic parts. Further classifications of these parts are based on the Optiz GT classification scheme [19]. According to this scheme, the prismatic parts are defined as cube, flat, and long. This classification is based on the length, width, and height of the component in each setup/orientation of the part.

1. Cube $A/B <= 3$ and $A/C < 4$ for the cubic component.
2. Flat $A/B <= 3$, $A/C >= 4$ for the flat component.
3. Long $A/B > 3$ for long component.

where A = length, B = width, and C = height of the work-piece.

Cube is further classified for the cubic work-piece as small and large cube:
Small cube: $A/B <= 3$ and $A/C < 3$ Large cube: $A/B <= 3$ and $3 < A/C < 4$

To select the best orientation of the work-piece to simplify the geometric reasoning, the primary datum must be selected first. If the feature is present on the XY top surface and the tool access direction (TAD) is (0, 0,-1), then the work-piece is oriented so that the bottom surface will become the primary datum surface. The cutting tool path in the primary datum face will also help to determine the correct locating scheme. The feature TAD in the primary datum surface indicates the cutting tool penetration.

Considering the above conditions, the following rules are formulated to determine the correct locating scheme for each type of the work-piece orientation:

If work-piece is small cube
And primary datum is XY bottom
And cutting tool is penetrating in the primary datum surface
Then
3-2-1 locating scheme is feasible

3.1.2 Locating and clamping faces

The potential locating faces should be along three mutually perpendicular planes. The clamping should be positioned to direct the clamping force and support the work-piece. There are two common clamping types: overhead and side clamps. The overhead clamp applies a force perpendicular to the fixture base plate, and the side clamp applies a force parallel to the fixture base plate. Since an overhead clamping scheme is preferred to a side clamping scheme for locating accuracy, a fixture configuration with overhead clamps is preferred[19](Figure 2).

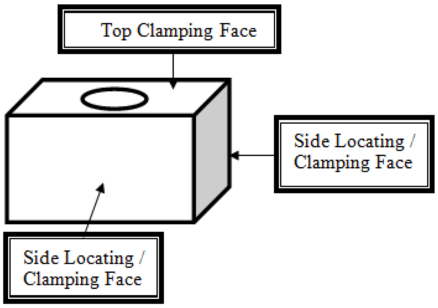


Figure 2: Candidate locating and clamping faces

The primary locating surface is always the datum surface of the work-piece. This depends on the work-piece's orientation with respect to the machine tool. The larger side of the locating surface will be considered as the secondary surface, and two locators will be placed on this surface. The smaller side is the tertiary locating surface, and therefore only one locator is required on this face (3-2-1 rule). If multiple faces are found for the secondary or tertiary location, then the face with the greater area will be selected. The set of rules used for selecting the secondary and tertiary locating faces are as follows:

IF
If a machining feature mf1 is to be machined in this setup,and F1 is the side location surface of mf1,and
F2 is the primary reference surface,and
F1 is perpendicular to F2, and F1 is machined and has fine roughness

THEN
F1 is suitable for the secondary locating surface

IF
If a machining feature mf1is to be machined in this setup,and F1 is the side locating surface of mf1,and
F2 is the primary reference surface, and F3 is the secondary locating surface,
and F1 is perpendicular to F2 and F3, and F1 is machined and has fine roughness

THEN
F1 is suitable for the tertiary locating surface

3.2 Fixture modelling module

The fixture modelling process should satisfy the following fixturing requirements:

1. An accurate locating method should be adopted.
2. There should be no interference between the modular fixture components and the machine cutter.
3. The work-piece should be held rigidly to prevent any deflection during the machining.

The top clamping is normally preferred for rigid and accurate clamping action. The minimum number of clamps is suggested to avoid redundancy. If the locating requirements are satisfied, then normally two clamps are sufficient to fasten the part against three supports in a 3-2-1 locating scheme.

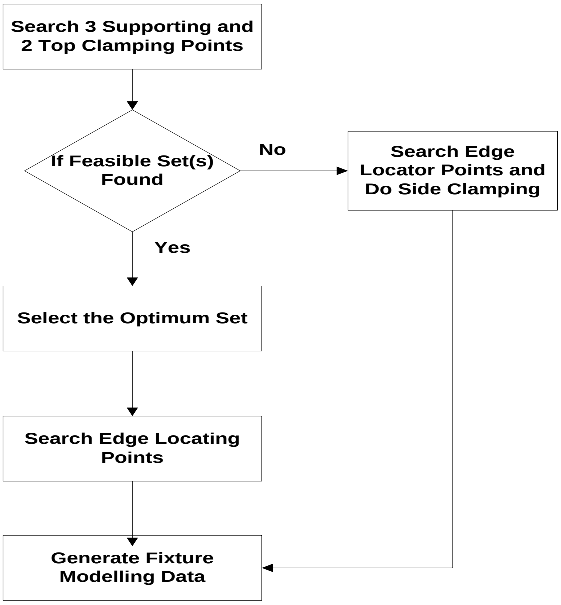


Figure 3: Fixture modelling for the 3-2-1 locating scheme

The optimum set for supports and clamps is based on the largest supporting triangle that contains the centre of mass and corresponding maximum distant clamping points.

3.2.1 Search strategy for fixture modelling

Part-baseplate assembly

The position of the part on the base plate should be such that there is enough space available from all sides of the part for the assembly of the modular fixture components. The origin (0,0,0) of the base plate is fixed in the centre of the plate. For the part origin, two cases are possible:

Case1: If the origin (0,0,0) of the part is in the centre

In this situation, the part will be assembled in the centre of the base plate, as represented in Figure 4(a). The only condition that must be checked is whether the hole's coordinate (x, y, or z value) contains 0 to ±diameter/2 of the base-plate hole's value. The base plate will move at a distance equal to the centre-to-centre distance between the base plate holes in the direction of that coordinate(s).

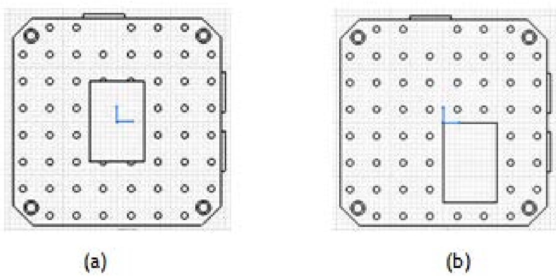
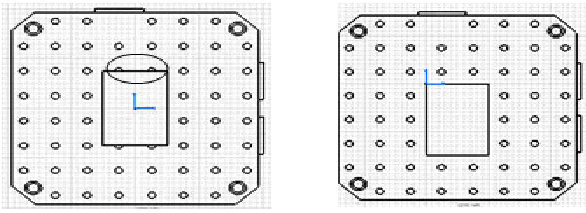


Figure 4: Initial assembly of the part-plate

Case 2: If the origin (0,0,0) of the part is in the corner

In this situation, the part will be assembled at one of the sides of the base plate, as represented in Figure 4(b). In this case, the plate should be moved so that it is equal to L/2, W/2 of the part, in order to bring the part to the same position as presented in Figure 4(a).

In the next step, we have to check if the boundary line of the part crosses any of the base plate's holes, as shown in Figure 5(a). The check is made from the base plate's hole database. The condition that must be checked is whether the hole's coordinate (x, y, or z value) contains 0 to ±diameter/2 of the baseplate hole's value. The base plate will move again at a distance equal to the centre-to-centre distance between the base plate's holes in the direction of those coordinates. Now, the part is in the required, feasible position on the base plate, as represented in Figure 5(b).



(a) (b)

Figure 5: The feasible position of the part-plate

Support assembly

The supports need to be inserted on the base plate holes that are inside the boundary of the primary locating face of the part. The primary locating face ID is extracted from the fixture planning file. The candidate supporting points should be within the boundary of the primary locating face, as presented in Figure 6.

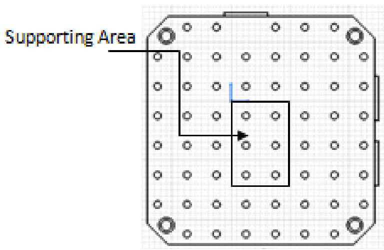


Figure 6: Supporting area

To ensure that the work-piece is stable and that there is adequate resistance to the cutting force, the supports should be placed at the maximum distant holes. The centre of the part must be located within the projected bounding region formed by the supporting components. The centre of a non-self-intersecting closed polygon defined by *n* vertices (x_0,y_0), (x_1,y_1), …, (x_{n-1},y_{n-1}) is the point (C_x, C_y), where

$$C_x = \frac{1}{6A}\sum_{i=0}^{n-1}(x_i + x_{i+1})(x_i y_{i+1} - x_{i+1} y_i) \quad (1)$$

$$C_y = \frac{1}{6A}\sum_{i=0}^{n-1}(y_i + y_{i+1})(x_i y_{i+1} - x_{i+1} y_i) \quad (2)$$

and where A is the polygon's area, which is determined by

$$A = 1/2 \sum_{i,j=0}^{n-1}\left((X_j + X_i)(Y_j - Y_i)\right) \quad (3)$$

To select the feasible hole combinations for the assembly of supports, the following conditions should be ensured:

The search will be made by checking each candidate supporting triangle. The strategy is defined in the following steps:

1. Generate all combinations of supporting triangles from the candidate supporting points.
2. Find the centre of mass of the component.
3. Apply a ray crossing algorithm to check the centre of mass inside the triangle(s).
4. Any triangle that does not contain the desired centre of mass will be removed from the list.
5. Calculate the area of the selected triangle(s).
6. The triangle(s) with the largest area will be selected.

Clamp assembly (top clamping)

Top clamping is always preferred to side clamping because the direction of the force exerted by the top clamps is perpendicular to the base plate, whereas in side clamping the force direction is parallel to the base plate. The candidate top clamping points will be generated around the part, as shown in Figure 7.

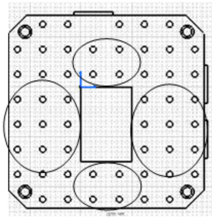


Figure 7: Candidate top clamping holes

The search for suitable clamping points in order to avoid machining collision is accomplished by checking each clamping hole around the work-piece. The fixturing point outside the top or side clamping region will be removed from the list. The strategy is defined in the following steps:

1. Generate clamping points separately for each side of the component.
2. Extract the external edge loop(s) of the top clamping face(s).
3. Extract edge curves separately for each side of the part.
4. Define the clamping range by finding the difference between the minimum and maximum changing coordinate value (x,y,z).
5. Compare each hole's coordinate value with the clamping range.
6. Remove the holes from the list of candidate clamping points that are outside the clamping range (see Figure 8).
7. Extract the internal edge loop(s) of the top clamping face(s) (see Figure 8).
8. Define the internal loop range from the edges of the loop.
9. Compare the internal loop range with the clamping points inside the part.
10. If the clamping point inside the part is found within the internal loop range, the point will be excluded from the list of candidate clamping points.
11. The feasible clamping points inside the part are compared with the candidate triangles formed by the supporting elements.
12. The maximum distant clamping points and related supporting triangle will be selected as suitable clamping and supporting points.

Edge locator assembly

The edge locators should be placed on the secondary and tertiary locating face of the part. The secondary and tertiary locating face IDs are extracted from the fixture planning file. The hole coordinates adjacent to the secondary and tertiary locating faces are extracted for the selected base plate, as presented in Figure 9.

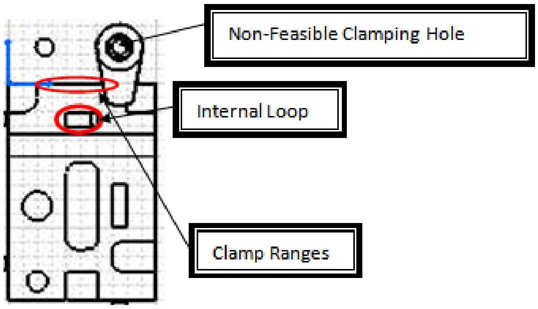


Figure 8: Internal loop and clamp ranges

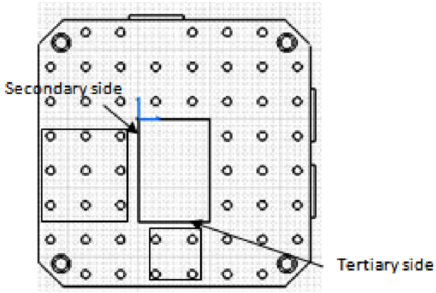


Figure 9: Candidate edge locator holes

These hole's coordinates are then divided into rows and columns on the basis of the same x, y, or z values. The distance of these rows and columns is calculated from the part face, and this value is compared with the locating range. The row and column within this range is selected for the placement of the edge locator assembly.

To select the ideal height of the edge locator, the height of the component and the height of the selected support cylinder (if present) are extracted. The feasible height of the edge locator should be around 1/3 to 2/3 of the height of the component. The ideal height is at the centre of the work-piece. To select the suitable edge locator from the locator database, the ideal height value should be calculated first, and then this value should be compared with the database values.

The ideal height of the edge locator = 1/2 (height of component)+ height of support cylinder (if present).

If no edge locator is found at the ideal height, then select the locator from the feasible height values that are near the ideal height.

Feasible height of the edge locator = 1/3 (height of component) to2/3 (height of component) + height of support cylinder (if present)

The search is made by checking each candidate edge locating hole adjacent to the secondary and tertiary locating faces. The strategy is defined in the following steps:

1. Extract the height of the selected locator assembly.
2. Generate the edge locating points separately for each side by updating the H coordinate of the locating holes.
3. Extract the edge curve(s) that have a constant H value between the minimum and maximum of the face.
4. Find the edge locating points that are inside the range of these edge curves.
5. Compare each locating point H value (found in step 2) with these edge curves.

6. If the H value of the locating point is inside the feasible locating region, the point will be selected as the candidate edge locating point; otherwise it will be removed from the list of candidate points, as shown in Figure 10.
7. Select two maximum distant points on the secondary locating side.
8. Select one point at or near the centre of the tertiary locating side.

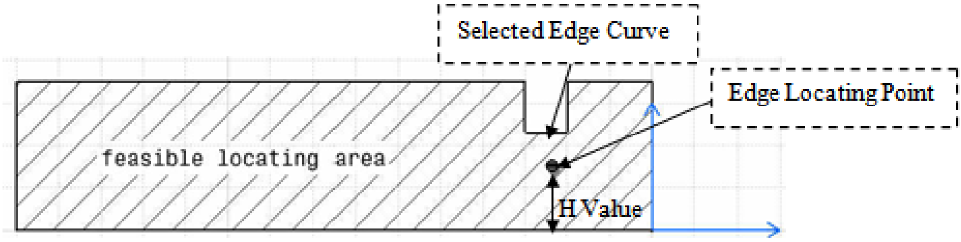


Figure 10: Feasible locating point

3.2.2 Selection of the fixture components

The selection procedure is based on satisfying the functional requirements and geometrical constraints for the final fixture assembly. The functional requirements, such as type of clamp, type of locator, etc., are established based on the part shape and geometric data obtained from the fixture planning program. Selecting suitable locators/clamps is accomplished by scanning the modular fixture component database, based on the selection rules.

3.3 Fixture assembly

The CATIA VBA editor is used to create the CATVBA file for the final fixture assembly. The modular fixture database is created using the standard fixture components from Fixture Works. The fixture database contains base-plates, supports, edge locators, and clamps. The base plate and clamp database are described below.

3.3.1 Base plate

The base plate element provides attachment surfaces for the other fixturing elements. For most applications, the base plate has numerous grid holes that accommodate the locators, supports, and clamping devices. Horizontal and angle base plates are the two types that are most frequently employed [2].The base plate database contains the unique base plate ID, its maximum area, the acceptable area for the part (presented as a dotted line), height, hole-to-hole distance, hole diameter, and hole coordinate values. This information is represented in Table 1 for a sample horizontal (square) base plate, as shown in Figure 11.

Table 1: Base plate database values (mm)

Base plate ID	Plate area	Safe area for part	Plate thickness	Hole diameter	Hole to hole distance	Hole coordinate ID	X	Y	Z	Manufac-turer
BJ040-4040-12	386X386	200X200	50	12	50	1	175	125	0	Fixture Works

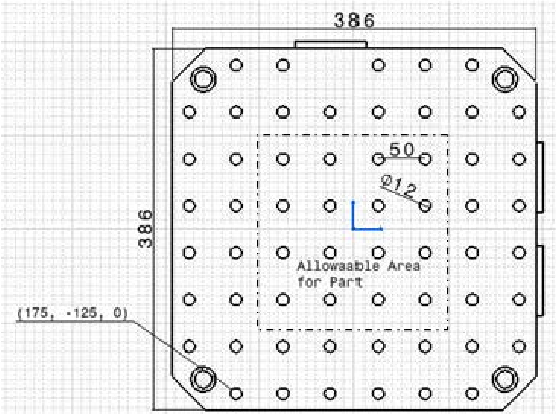


Figure 11: Base plate

3.3.2 Clamps

Clamping elements rigidly hold the work-piece against the supporting and locating elements and prevent the motion of the work-piece in any direction. There are three principal types: overhead, side, and down-support clamps. The overhead clamp is positioned on a surface that is parallel to the fixture base plate, and the side clamp is placed on a surface that is opposite the edge locators. The down-support clamp, as the name implies, is used as an overhead clamp and support. The clamp database contains the clamp ID, diameter, clamp height, arm extension value, clamp width, and clamp type. The information for an overhead swing clamp, shown in Figure 12, is represented in Table 2.

Table 2: Clamp database values (mm)

Clamp ID	Diameter	Height	Arm extension	Clamp arm width	Clamp type
BJ-130-12040	M12	39-64	40	25	Swing

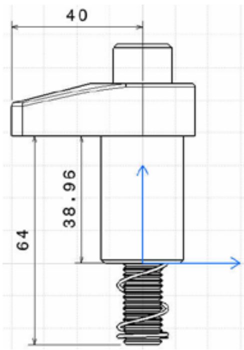


Figure 12: Swing clamp assembly

4 IMPLEMENTATION AND RESULTS

To demonstrate the application of the developed system, a case study is presented to illustrate the proposed methodology. The 3-D solid model, which was created in CATIA V5, is presented in Figure 13. There are 46 faces extracted in the part geometrical database. The process plan file indicates milling features with two setups. The fixture planning output for the locating scheme and the locating and clamping faces is presented in Table 3 for each setup. The fixture modelling data that is based on the search strategy is presented in

Tables 4and 5. The final fixture assembly that was made using CATVBA is shown in Figures 14 and 15.

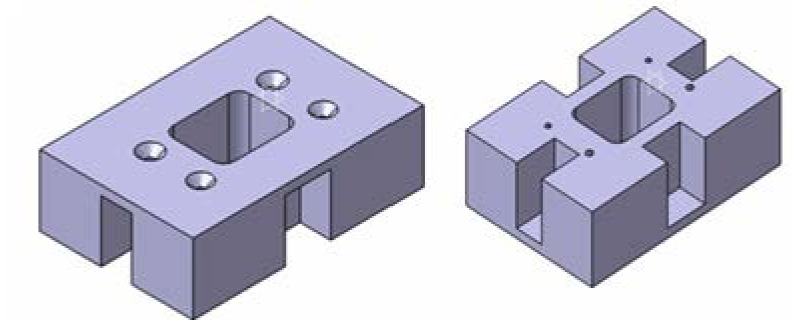


Figure 13: Case study

Table 3: Fixture planning output

Setup ID	Locating scheme	Primary locating faces	Secondary locating faces	Tertiary locating faces	Top clamping faces
1	3-2-1	26	27	28	4
Setup ID	**Locating scheme**	**Primary locating faces**	**Secondary locating faces**	**Tertiary locating faces**	**Top clamping faces**
2	Base 2-1	4	27	28	26

Table 4: Fixture modelling (setup 1)

Part dimensions	Base plate	Supports fixing points	Edge locators fixing points	Clamps fixing points
Length: 150 Width: 100 Height: 46	BASEPLATE: BJ040-4040-12	SUPPORT:BJ-300-12020 SUPPORT_1: 25, 75,0 SUPPORT_2: 125,75,0 SUPPORT_3: 125, 25,0	LOCATOR:BJ-211-12001 SECONDARY_POINT: 25, -25, 0 SECONDARY_POINT: 125, -25, 0 TERTARY_POINT: 175, 75, 0	CLAMP: BJ-130-12040-67 CLAMP_POINT_1: 25,125,46 CLAMP_POINT_2: 175,25,46

Table 5: Fixture modelling (setup 2)

Part dimensions	Base plate	Edge locators fixing points	Clamps fixing points
Length: 150 Width: 100 Height: 46	BASEPLATE: BJ040-4040-12	LOCATOR: BJ-211-12001 SECONDARY_POINT: 25, -125, -46 SECONDARY_POINT: 125, -125, -46 TERTARY_POINT: 175, -75, -46	CLAMP: BJ-130-12040-47 CLAMP_POINT_1: 125,25,0 CLAMP_POINT_2: -25,-75,0

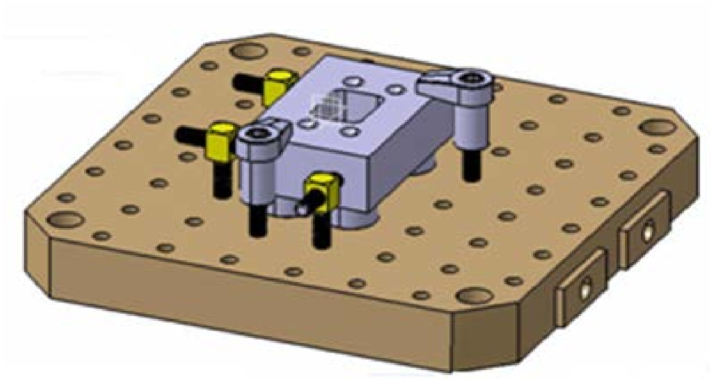


Figure 14: Fixture assembly (setup 1)

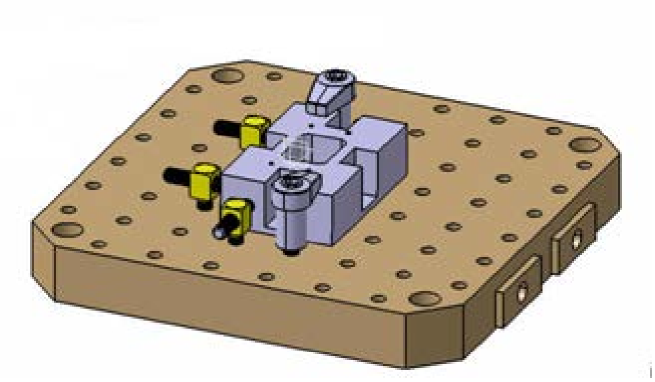


Figure 15: Fixture assembly (setup 2)

5 CONCLUSION

The suggested methodology was implemented using Visual C++,which interacts with existing CAD packages. The proposed methodology was successfully tested and validated for a selected case study. The process and setup plan data provided a basis for the modular fixture design system. The fixture planning phase determined the locating scheme and the locating and clamping data for the prismatic part. The correct locating scheme and locating and clamping datum for the specific setup of the part was established by developing the suitable rules, based on the process/setup plan data and part geometrical database. Different locating schemes were suggested for the selected case study due to the cutting tool penetration condition in the primary datum(Table 3).

The fixture modelling module determined the suitable fixture components and locating/clamping points. For this reason, a specific search strategy was designed to select the modular fixture components and determine the locating and clamping positions for the 3-2-1 and base 2-1 locating schemes. In the first setup, locating and clamping data was established by applying the search strategy for the 3-2-1 locating scheme (Table 4). In the second setup, the strategy established the locating and clamping points based on the base 2-1 locating scheme (Table 5). The fixture assembly was created inside CATIA V5 with standard modular fixture components, and used the CATVBA file to ensure a practical solution.

In future work, a fixture verification module will be added for functionality analysis based on the machining force. The developed methodology is also being adapted to be used for part locating and fixturing of complex, contour-shaped components.

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