REKABENTUK DAN FABRIKASI LEKAPAN MODULAR UNTUK MELENGKAPI SISTEM PEMASANGAN FLEKSIBEL

(DESIGN AND FABRICATION OF MODULAR FIXTURE TO ACCOMMODATE FLEXIBLE ASSEMBLY SYSTEMS)

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Alhamdulilllah, syukur to Allah, I have finished my final year report and report. Without their help and guide, maybe it is difficult for me to finished my report. Special thanks to my supervisor, Mr. Ahmad Baharuddin for his understanding and attitude of guiding me in making this final year report. Through his efforts I was given a means to support throughout the duration of my final year project.

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And last but not least, thanks to my family for giving moral support to me during completing of the project.

DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree

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ABSTRAK

Di dalam membangunkan sesuatu produk yang boleh dilaras penggunaannya, maklumat perincian diperlukan yang boleh dicantumkan dengan menggunakan perisian sistem CAD dimana ianya adalah penting kepada pereka bentuk dalam bidang ini. Permulaan untuk pencantuman produk mudah alih diperkukuhkan dengan kaitan geometri diantara komponen yang dipasang dengan bahan kerja yang dianalisis. Tesis ini menyatakan tentang kaedah yang digunakan dalam penyambungan atau pencamtuman sesuatu produk yang boleh dilaras penggunannya. Tujuan utama projek ini adalah untuk mendapatkan pemasangan dan penyambungan plug 3-pin dalam keadaan optimum iaitu melibatkan masa yang sedikit dan mempunyai produktiviti produk yang tinggi. Hasil daripada projek yang dijalankan, keputusan mendapati sistem lekapan modular ini dapat digunakan dalam pelbagai keadaan dengan hanya mengubah kedudukan atau tempat komponen-komponen tersebut dalam menepati sistem pemasangan bagi sesuatu produk. Dalam kes ini melibatkan 3 kes pemasangan yang dikaji iaitu plug 3-pin, tetikus dan jam loceng yang bersaiz kecil.

ABSTRACT

In the development of a modular fixture design system, it is essential to have a modular fixture specific information measurement that can be integrated with a CAD system, in addition to the other considerations such as fixture configuration, interference checking, etc., which are also important to fixture designers. The initial conditions for modular fixture assembly are established together with geometric relationships between fixture components and the workpiece to be analyzed. Of particular focus is the design of alternative locating points and components, together with examples of the 3-D fixture designs. Examples of fixture design generated by the system are also provided to illustrate the development. This thesis describes a method to create the fixture element database and model the fixturing towers like assembly of modular fixture. The main purpose for this project is to get the optimum of the modular fixture based on assembly process in order to make the product productivity and can reduce time in assembly and saving costs. The result in this case shows that the fixtures can be applied in many assembly situation such as assembly of 3-pin plug, optical mouse and alarm clock.

CHAPTER 1

INTRODUCTION

In the field of assembly technology, the unit construction principle as successfully applied in many branches of technology has made possible the construction of automated assembly systems without the necessity for a new development from the first principle. The principle of the equipment module, which is comprised of so-called basic and ad hoc modules, has proven to be advantageous for the construction of such equipment. Because the different technical solutions are always conceivable for every assembly programmed, it is necessary to possess good knowledge of the available modules.

The objective selection of the most suitable modules for the solution of a particular assembly problem under specified boundary conditions is an important and directly effective measure for the economic arrangement of assembly installations. As far as possible, the function of the modules is to undertake the handling and assembly operations in one unit. A fundamental knowledge of handling is a prerequisite for correct selection, especially in the field of material conveying technology.

In order to make the modular fixture design, there also should be seen to flexible manufacturing system (FMS). A flexible manufacturing system (FMS) is an arrangement of machines and interconnected by a transport system. This is important in order to make the productivity increased and reducing the time to assembly. [1]

1.1 Objective

The main objective of this project is to:

- To apply the modularity approach in design of modular fixture.
- To design and fabricate the modular fixtures.

1.2 Scope of the project

This project is to apply the modularity approach in design of modular fixture. The software used in design of the fixtures is AutoCAD 2003 and Solid Work 2003. Understanding of this program will make the design easier and perfect. To clarify the work, several case studies are used like 3-pin plug, optical mouse and alarm clock. This is wants to make the assembly easier and reduce the time of assembly and increased the productivity of the product.

CHAPTER 2

LITERATURE REVIEW

2.1 Flexible manufacturing system (FMS)

A flexible manufacturing system (FMS) is an arrangement of machines and interconnected by a transport system. The transporter carries work to the machines on pallets or other interface units so that work-machine registration is accurate, rapid and automatic. A central computer controls both machines and transport system. Flexibility is one of the benefits of small-batch manufacturing. FMS is defined as a manufacturing system consisting of automatically reprogrammable machines (material processors), automated tool deliveries and changes, automated material handling and transport, and coordinated shop floor control [2].(Refer to Figure 2.1)

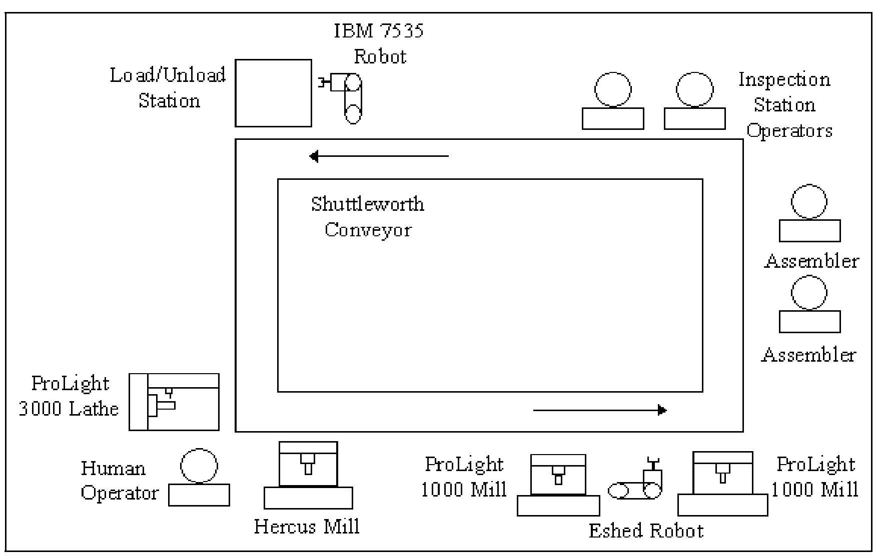


Figure 2.1: An example layout of FMS.

The key idea in FMS is that the co-ordination of the flow of work is carried out by a central control computer. This computer performs functions such as:

- Scheduling jobs onto the machine tools
- Downloading part-programs (giving detailed instructions on how to produce a part) to the machines.
- Sending instructions to the automated vehicle system for transportation
- The example of flexible manufacturing system is shown in Figure 2.2 below.

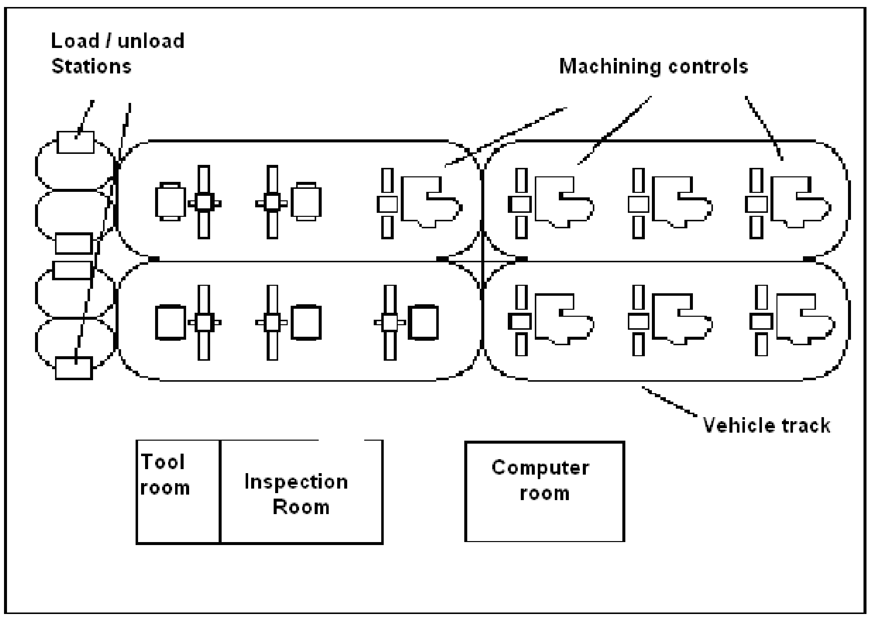


Figure 2.2: A Flexible Manufacturing System

Products to be produced are manually loaded onto pallet of fixtures at a load station, and the computer system takes over, moving the product to the various processing stations using automatic vehicles, which may be rail-guided, guided by wires embedded in the floor or free-roving. After having visited all necessary stations, usually only two or three, the job is taken back to the load station, where it is removed from the pallet and passed to the next process.

Writing FMS control software is not a trivial matter. The software is often custom-written, and is not straightforward programming task. There are complex, real-time interactions with remote hardware which require great expertise and experience on the part of the programmer, particularly for larger systems [3].

Advantages and disadvantages of FMSs implementation

➢ **Advantages**

- Faster, lower- cost changes from one part to another which will improve capital utilization
- Lower direct labor cost, due to the reduction in number of workers
- Reduced inventory, due to the planning and programming precision
- Consistent and better quality, due to the automated control
- Lower cost/unit of output, due to the greater productivity using the same number of workers
- Savings from the indirect labor, from reduced errors, rework, repairs and rejects.

➢ **Disadvantages**

- Limited ability to adapt to changes in product or product mix (ex. machines are of limited capacity and the tooling necessary for products, even of the same family, is not always feasible in a given FMS)
- Substantial pre-planning activity
- Expensive, costing millions of dollars
- Technological problems of exact component positioning and precise timing necessary to process a component
- Sophisticated manufacturing systems.

2.2 Concept of modular assembly line

An assembly line is a manufacturing process in which interchangeable parts are added to a product in a sequential manner to create an end product. The assembly line was first introduced by Eli Whitney to create muskets for the U.S. Government. The assembly line was first introduced by Eli Whitney to create muskets for the U.S. Government. Henry Ford later introduced the moving assembly line for his automobile factory to cut manufacturing costs and deliver a cheaper product. [3]

By December 1913, the plant people had set up the experiment with winches and ropes pulling the chassis down a line where the assemblers stood in one place with their parts piles. In January 1914 the Ford production engineers installed the continuous chain to keep the chassis line moving. Working out the 'bugs' dropped the time very rapidly from the 6 hours using the winches a dramatic drop from the 17 hours labor input in the old moving team system [4-5].

There are many variables to consider when choosing the best method to move products through an assembly line. And generally, as the product becomes more complex, so too does the equipment for transporting that product from one assembly station to the next. Short product life cycles complicate the situation. As products change or volume increases, traditional material handling methods may prove inadequate or counter productive. The conveyor technology can help increase productivity and reduce assembly costs. An assembly system has to be designed to fit the special characteristic of modular products. Given a family of modular products, designing an assembly system at a low cost is an important problem.

(a) Modular assembly line simulator.

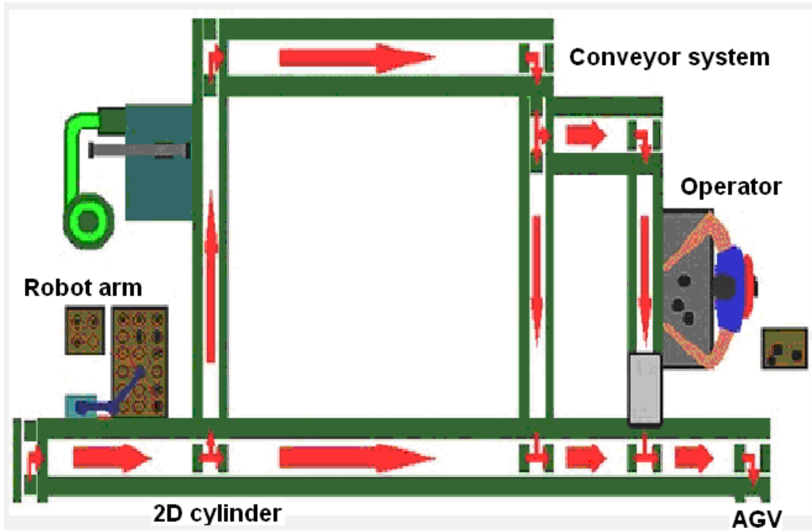


Figure 2.3: Modular assembly line simulator [5]

Figure 2.3 shows the modular assembly line simulator. This simulation is designed for the optimization of the assembly layout and process. Each working phase is represented by a different module; the modules communicate each other over. Various parameters can be monitored such as production rate and delay time. From this simulation, the product will move along the conveyor. Then, it will be sense by a sensor. From that simulation, 2D cylinder will push forward and will move through the other conveyor. Then, the robot arm will make its work. After that station, it will move along the conveyor until its sense by a sensor. This process will repeat until arrived at the end stage. At this stage, the operator will check the product whether it will be rejected or approved. After that, it will ready for packaging. The code is written using the object oriented Modsim III [6].

2.3 Modular fixtures

In order to get the qualified components, the workpieces must be positioned in this correct position. So, we need a device to hold the workpiece in this correct position and orientation in the machining tool. This device having this function is a fixture. Fixture is a device used in machining, inspection, assembly, welding, and other manufacturing operations to locate and hold a workpiece firmly in position so that the required manufacturing processes can be carried out corresponding to design specifications.

The design of a modular fixture needs to be conveyed to the NC programmer to ensure "wreck-free" machining. Fixtures can be built in a central area using the actual part as a model. Once completed, the programmer can extract the data needed to write a successful program. In some cases, the programmer assumes the duties of a tool designer by selecting components and creating fixtures on a CAD terminal. Since components are selected based on the fixturing need, tool designers can concentrate on handling a company's dedicated fixturing needs.

Success in implementing modular fixturing requires coordination and cooperation. Using modular fixturing is a different way of doing business. From the machine operator's point of view, nothing changes. Modular fixtures will hold parts as firmly and accurately as dedicated fixtures.

Three main types of workholding fixtures are used for metalworking operations. General Purpose Fixtures incorporate standard and reusable components. These fixtures are suitable for short run production and prototypes. Modular Fixtures incorporate standard components, but they also have the flexibility to be used for production of varied batches of parts, such as those that are typical of the aerospace industry. Dedicated Fixtures are more complex devices that are designed to hold specific workpieces in mass production applications such as automotive parts manufacturing. In general, dedicated fixtures are more costly to design and fabricate than modular fixtures, and they also are more difficult to assemble and disassemble [6]. (Refer to Figure 2.4).

Workholding fixtures typically incorporate various components such as adjustable angle plates, parallels and blocks to restrain various sizes and shapes of workpieces. These components typically attach to sub-plates, base-plates or tombstones via a grid alignment of mounting holes that allows restraint of various parts. In addition, fixtures may incorporate components such as locating pins, V-type locators, round locators, edge locators and rest pads.

Clamps are used to hold parts against the various locating features of the fixture. These clamps may be mechanical, strap or side-type, lever-type, toggle-type, pneumatic or hydraulic. The proper clamping configuration and sequence for a given work piece depends on many factors including workpiece stiffness and inherent stresses, number and position of locators and the applied clamping forces. In general, however, clamps and locators should be placed as far apart as practical. Clamps should also be positioned directly over locators or other supports to avoid part distortion under clamping force [7]

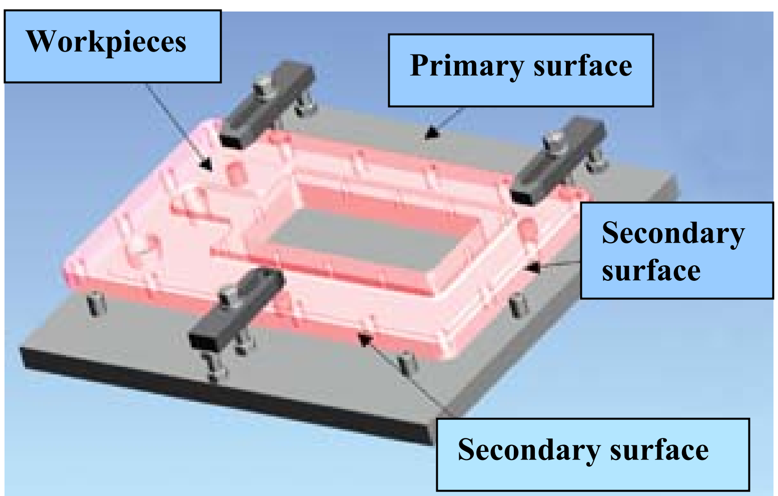


Figure 2.4: A workholding with six contact points arranged as shown is the most efficient method for flat, rigid workpieces

Standardisation of components, sizes and materials of fixtures is conducive to the arrangement of database of components. The main advantages of using modular fixtures are their flexibility and the reduction of time and cost required for the intended manufacturing operations.

(a) Function of the fixtures.

From the definition of fixture, it can be further decomposed into 3 basic functions [8]:

1. Ensuring stable machining accuracy.

   This is the most important task of fixture design to ensure the positional accuracy and relative dimensional accuracy of machining surfaces in each setup. Fixture is installed on the worktable of the machine tool by locating and clamping. The fixture is located on the machine table by the bottom plane of fixture body and fixed by screws. And workpiece is correctly located and clamped in the fixture. Due to the fixture position in the machine tool and the workpiece position in the fixture have been determined, the relative positions between the workpiece and the cutting tool and between the workpiece and cutting movements are determined either. Therefore, the accuracy can be ensured.

2. Ensuring high productivity.

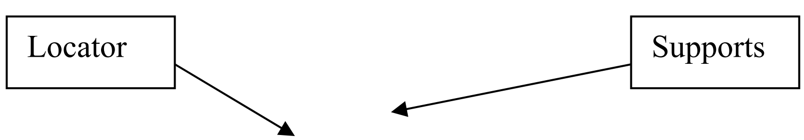
   Fixture is designed for easy load and unloads of workpieces, utilization of automated or semi automated clamping devices, easy chip disposal. Of course, the selections of these fixture functions are greatly determined by the lot size of the product. In job production, fixturing flexibility is desired, usually modular fixtures and other general-purpose fixtures are used. In mass production, productivity is important, it is reasonable to design and fabricate dedicated fixtures with good performance. Modular fixtures and adjustable fixtures are often used for certain flexibility and other fixturing performances.

3. Ensuring Operation Convenience and Safety.

   Fixture is designed to be convenient for loading and unloading workpieces, convenient for machining chip disposal, convenient for measurement (workpiece dimensions) and adjustment operations (relative position between cutting tool and the workpiece).

(b) Basic components a typical fixture.

Commonly, a fixture is composed of the following components: locators, clamps, supports, connectors, tool-guiding components, fixture body and other components or devices as shown in Figure 2.5. Modular fixture components can be assembled on various plates such as sine plates and angle plates depending on the part orientation required in a setup.



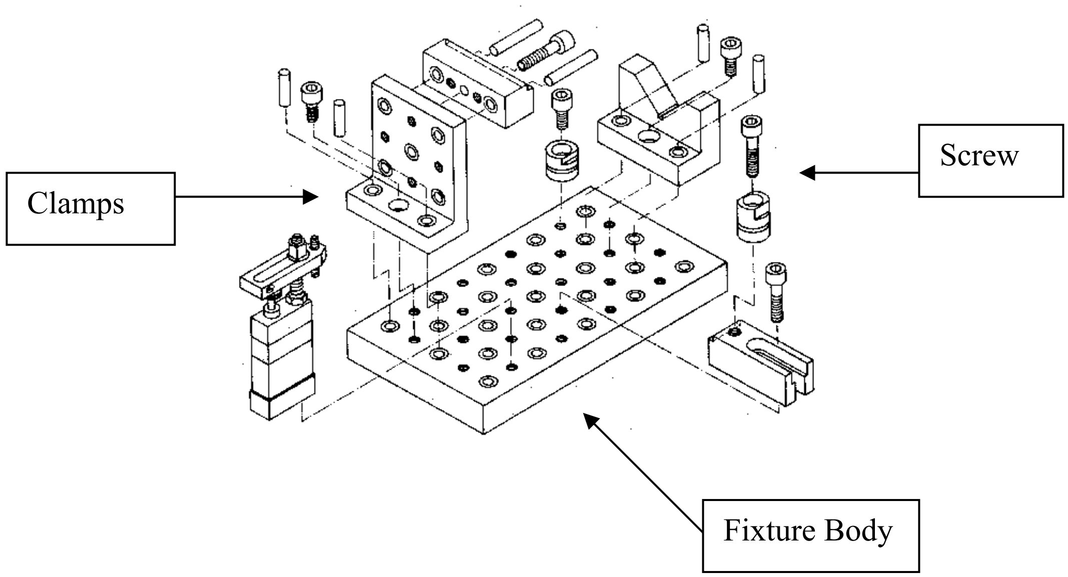


Figure 2.5: Layout of modular fixture

- Locators = Locators are directly in contact with the workpiece, and used to determine the workpiece position and orientation in the fixture.

- Clamps = Clamps are used for securing the workpiece in the located position under machining and other external forces. In this fixture, a cam clamp is applied.
- Supports = Supports are used to minimize deflection and distortion of the workpiece caused by the machining and clamping forces and sometimes its own weight. Because it is not used to constrain the degree of freedom of the workpiece, support must be positioned at the point on the workpiece, where the support can effectively minimize the deflection and distortion of the workpiece, or the

contact deformation of the workpiece surface without interference with accuracy of location.

- Fixture body = fixture

  Fixture body is a fixture base upon which all other components are assembled. In the same time, it is placed on the machine table to locate and secure the whole fixture on the machine table.

- Connecting units= Connecting units are structural components in the fixture design, and used to support other functional components (including locators, supports and clamps) and connect them to the fixture body.

- Others = components

  Other fixture components such as handles, fastening (such as bolts, nuts, and washers), and the fixture devices or components designed according to the special requirements of the fixture, such as index devices, and so on.

(c) The basic principle of fixture design

The figure below shows the steps involve in making the product design. The fixture design process has 4 steps like fixture planning, fixture configuration, and fixture construction and fixture assembly.

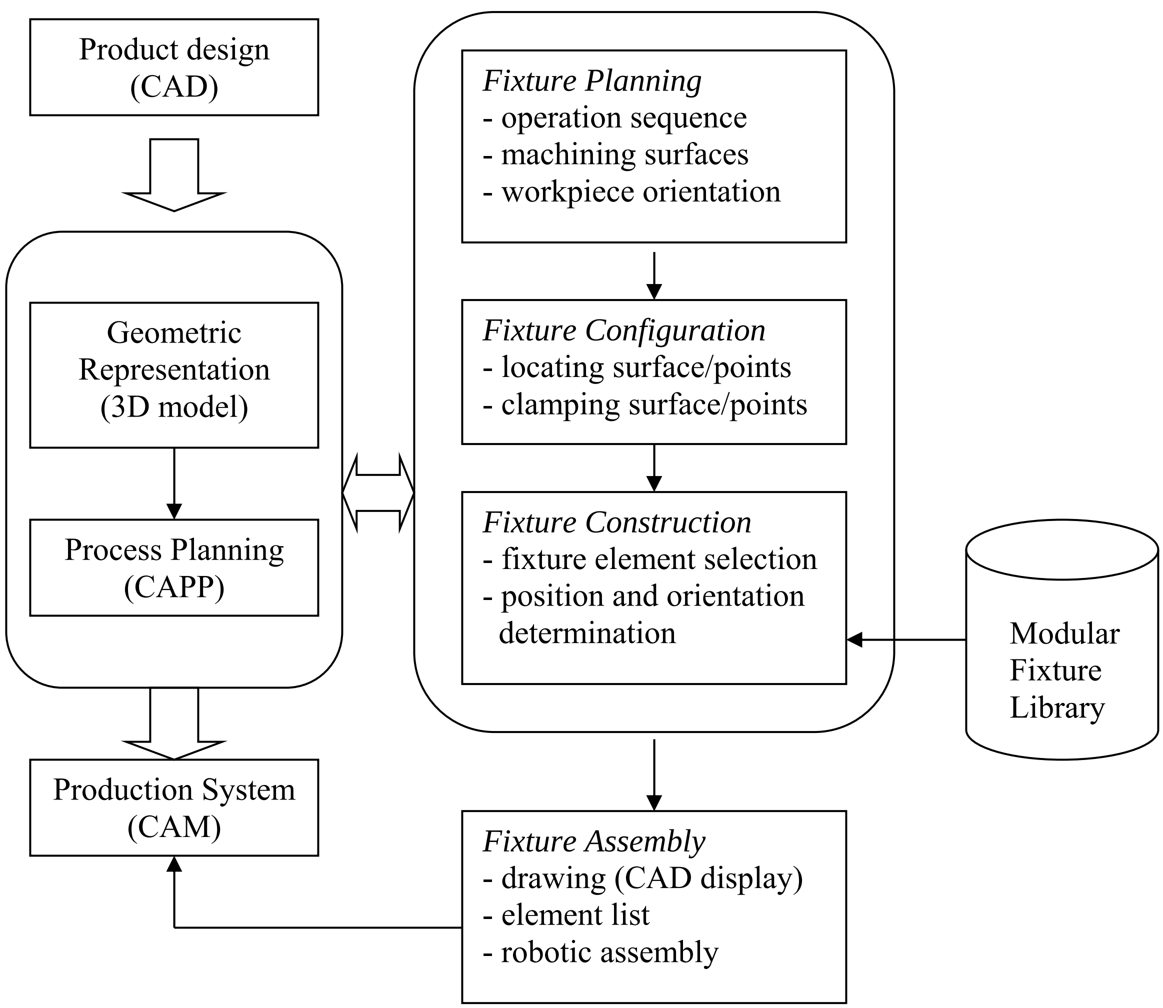


Figure 2.6: A framework for fixture design in manufacturing system.

The fixture design process can be divided into:

- *Fixture planning* is to determine the number of setups, the orientation of workpiece in each setup, and the machining surface in each setup.
- *Fixture configuration* is to determine a set of locating and clamping points on workpiece surfaces such that 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 the fixture components in strict accordance with the previous stage.

The most basic principles of fixture design are locating principle and clamping principle.

(i) Locating principle

For a rigid workpiece in space, there are six degrees of freedom describing the position and orientation of the workpiece, as shown in Figure 2.7. They are three linear motions (along x axis, y axis, and z axis) X, Y, and Z, and three rotational motions (around x axis, y axis, and z axis) α_x, α_y, α_z. [9].

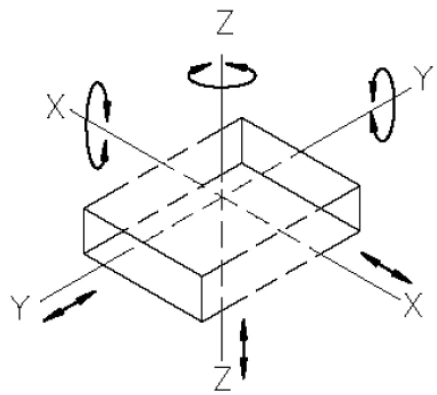


Figure 2.7: Six degrees of freedom of a workpiece.

Fixture design is to constrain all or part of the six DOFs so that the workpiece position and orientation can be uniquely determined in the fixture. How can we constrain the six DOFs of the workpiece in a fixture? The most typical method is to set six locating pins in a fixture, which are in contact with the workpiece, as shown in Figure 2.8.

The six contact points between the workpiece and the locators are configured in three mutually perpendicular planes A, B, and C on the workpiece, where three points in contact with the bottom surface A of the workpiece constrain 3 DOFs (Z, α_x, α_y,), which is called the primary locating datum, two points in contact with the left-side plane B constrain 2 DOFs (X, and α_z), which is called the secondary locating datum, and one point in contact with the back C constrain the last DOF (Y), which is called the tertiary locating datum. This is the 3-2-1 locating principle.

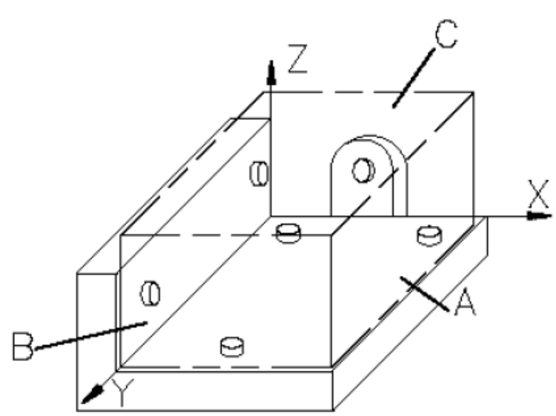


Figure 2.8: The six-point locating principle

(ii) Clamping principle

As we described above, the main purpose of the clamping is to securely hold the workpiece against the locators throughout the machining cycle. The basic requirements of clamping devices include the followings [9]:

1) After clamping the workpiece should keep in contact with the locators so that the location is ensured.
2) The clamping force should be sufficient for resisting the machining force and other forces so that the workpiece will not change its position and vibration will not appear, but the clamping force should not be so great that the workpiece surfaces are damaged or workpiece deformation is significant.
3) The clamping operation should be simple, time saving, safe, and easy for workpiece loading and unloading, especially no impact to the workpiece, machine tool components, and cutting tools.
4) The complexity of the clamping device should be suitable to the production type and batch size. For example, in mass production and automated production, power-activated clamps are widely used. In job or small-batch production, manually operated clamping devices are normally used.

When designing a clamping device for a fixture, there are four aspects to be determined:

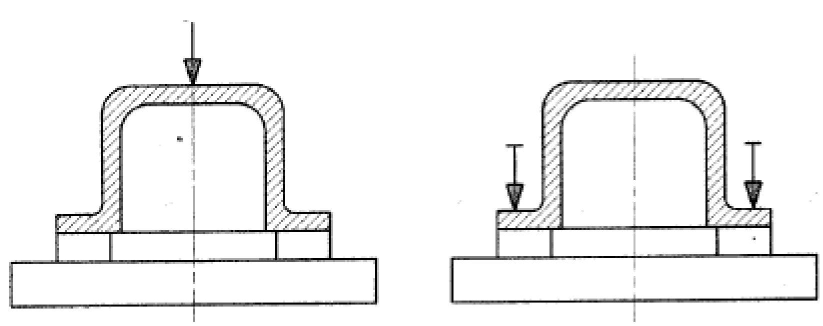
- clamping direction,

- clamping position,
- amplitude of the clamping force,
- the type of clamping mechanisms.

(iii)Selection of clamping position

Once the clamping direction is selected, the clamping position on the workpiece can be chosen according to the following rules.

1) The clamping position should be against the locator or in the locating triangle region.
2) The clamps should always contact the workpiece at its most rigid point so that without distorting the workpiece. Such as shown in Figure 2.9.
3) The clamping position should be as close as possible to the cutting position in order to increase the clamping reliability and reduce the vibration.



(a) (b)

Figure 2.9: Clamping position

(d) Modular fixture

The Figure 2.10 shows the layout of modular fixture. A Fixture is a device that holds a part for machining, assembly, inspection, etc. Modular fixturing uses a number of simple locators (pegs) and clamps to that plug into a lattice of holes to hold the part. Modular fixture elements such as baseplates, locators, supports and clamps are stored in a database and the user can pick and place them at any place as desired

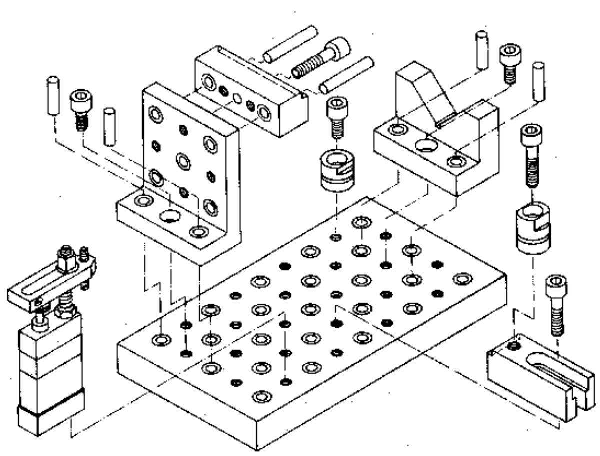


Figure 2.10: A layout of modular fixture

Modular Fixture Design [10]

i. Automated fixture design based on your customized settings:

- Create the support system with base plates and/or beams. Refer to Figure 2.11.

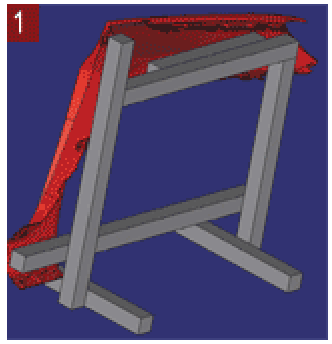


Figure 2.11: Support

- Indicate the contact points where fixture elements are needed and define the type of contact (for example, orientation of fixture base and contact; shape of fixture base). Refer to Figure 2.12.

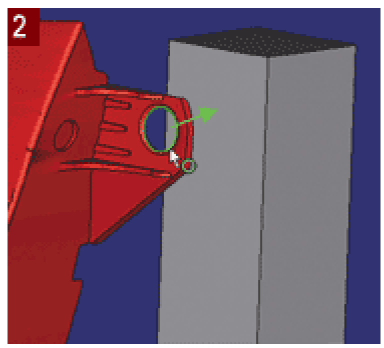


Figure 2.12: Contact point

ii. Individual fixture element geometry:

The fixtures have a unique and well-defined geometry. They will fit to the part only on the specific spots you've indicated.

iii. Labelling for easy identification and positioning:

Fixtures are automatically labelled with the assembly position and the parts' name(s). This not only allows speedy set-up of the system, but also enables easy identification, storage and reuse if required.

iv. Easy and quick fit with the part:

Thanks to a straightforward assembly method, the system is quickly ready for use. Fixture elements can be mounted quickly on a RapidFit base plate or on beams of common, modular fixturing systems.

v. Time- and cost-effective production:

Once created, you can easily produce fixtures with various production techniques. Because RP technologies are time-efficient and cost-effective, these provide the ideal solution for manufacturing fixture elements. The elements can be built simultaneously with the part, which further increases your time savings.

(e) Example:

The EasyFix Modular Fixture System is one of the example it's provides CMM users with a flexible toolbox of clamping and support components that can easily be combined to hold just about any type of part. The system has no boundaries, with a vast array of standard components that can easily cope with parts of any size. As the system is truly modular, the user has the freedom to purchase individual items as and when they are required.

The standard kits consist of various selections of clamps and supports, with some also including the patented EasyFix base plate and a "quick-lock" vice. Additional components can be purchased individually, although the standard kits provide the benefit of large overall cost savings.

The modularity of the system enables fixtures to be built in a matter of minutes. Having built a fixture, the user can easily modify or adapt the solution to suit CMM probing requirements. *EasyFix* does not require the use of a specialised tool room, saving enormous amounts of time and money. Once a fixture is no longer required, it can quickly be broken down, and all components can be re-used on a totally new fixture. If the fixture is to be re-used in the future, there is absolutely no need to store the fixture - the user simply documents the fixture with the easy to use Windows software. In this way, financial investment is kept to a minimum.

As an added benefit, the optional EasyProject software provides users with a computer aided design and documentation tool.

CHAPTER 3

METHODOLOGY

3.0 DESIGN PROCESS FLOW

Methodologies for this project are as shown in Figure 3.1.

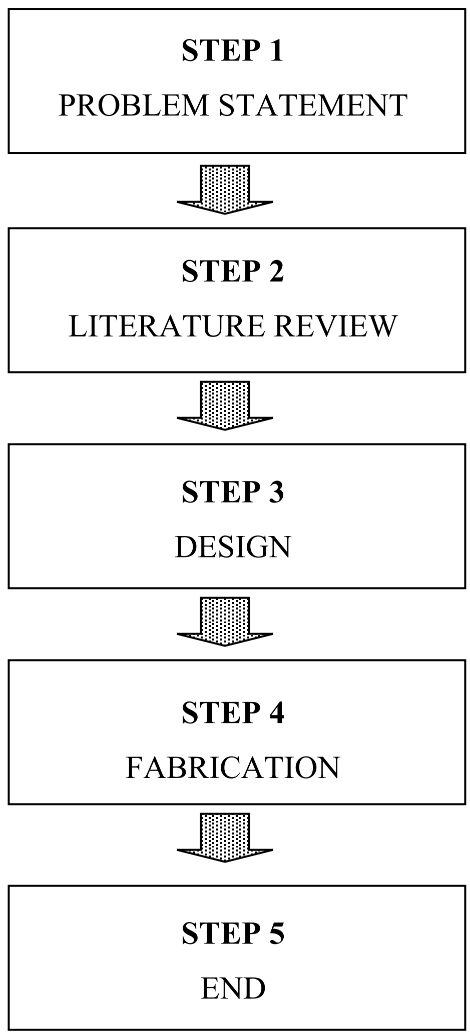


Figure 3.1: Step of the design process used in the research.

Step 1 – Problem Statement

This step includes the understanding the design problem and conceptual design. Other than that, it also has to design the assembly line and develop the system based on modular approach. 3 pin plug head assembly will be used in assembly simulation. In designing the optimum assembly line and conveyor, it depends on how it handling and arrangement automatically or manually.

An assembly line is a manufacturing process in which interchangeable parts are added to a product in a sequential manner to create an end product. A conveyor is a term generally applied to mechanical devices designed for the purpose of moving material in a horizontal or slightly in dined direction. The conveyor technology can help increase productivity and reduce assembly costs.

For this step, there are 3 factors that must be considered in designing the assembly line. Factors 1 is selected the materials that want to be used in fabrication. Factor 2 is estimate the length of the conveyor system. This length must be suitable with the number of part in base plate of the 3 pin plug. In order to reduce time and the part of the 3 pin plug only 4 processes, the arrangement length of the conveyor must be suitable.

Step 2 – Literature Review

In this step, its need to identify the basic layout of the modular assembly line in order to assembly the 3 pin plug. From chapter 2 that have been discussed before, an assembly line is a manufacturing process in which interchangeable parts are added to a product in a sequential manner to create an end product.

This is important because it can reduce time to assembly, increased the productivity and reduce assembly costs. Generally, as the product becomes more complex, so too does the equipment for transporting that product from one assembly station to the next.

Beside that, the fixture is designed to hold specific work pieces. Clamps are used to hold parts against the various locating features of the fixture.

The main advantages of using modular fixtures are their flexibility and the reduction of time and cost required for the intended manufacturing operations. This fixture design is suitable for short run production and prototypes.

Step 3 – Design

In this step, the material based on the function of the components was selected. This selection will consider many aspects. Not so light, not so heavy. This is because to make sure the times of making the products is not so long. The selection of the material is important in order to make the process or activities completed without any problem. Basically, these selections also incriminate cost by doing this product.

After that, the next activity is fabricating the component based on the drawing that has been done in AutoCAD and Solid Work 2003. In this step, two activities will be done such as developing the conveyor and fabricating the base plat 3 pin plugs. This step may take a few times for completing the projects. In fabrication, error will exists like the measurement of the components is not exactly perfect. Sometimes, it will need to fabricate it again.

In this step, the design time is reduced. By reducing the time and the amount of resource consumed in responding to these change, flexibility and productivity of the system enhanced. An assembly system has to be designed to fit the special characteristic of modular products. The material so handled may be conveyed in a practically uninterrupted stream from one point to another.

More over, change can be implemented in a systematic and incremental manner. In this step, morphology chart is used in this project. This morphology chart is use to select the best design concept among the design-design due to modular approach. It figures the characteristics that consist in each design concept. If any problem happens during the test, the product needs to be designed again to make sure that it suits to the specification required.

Step 4 – Fabrication

In this step, a design that has been created in AutoCAD and Solid Work 2003 drawing will be fabricate. The product that has been fabricated is called a prototype. From the prototype, it gives a real look whether the design is acceptable in dimension and parameter. For sure from this step there are some dimension or shape not fitted just like been shows by AutoCAD and Solid Work 2003 drawing. So, there need some improvement that should be done for making the complete product. It also needs ideas on functionality of the product. This step also will figure how the product will be manufacture when it successfully done.