CONCEPT DEVELOPMENT OF EJECTOR JIG AND FIXTURE AT DIPPING PROCESS FOR PIN MANUFACTURING

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CHAPTER 1

INTRODUCTION

1.1 Project Overview

Manufacturing industries have responded to the demand for goods manufacturing growths in today's worlds. There are various new and sometimes drastic ways of producing parts. Starting from Computer Aided Manufacturing and Computer Numerical Control to current advanced manufacturing concepts like Flexible Manufacturing System (FMS), Statistical Process Control (SPC) and Just-in-Time (JIT), the manufacturing phase has undergone many revolutionary and advanced changes.

These revolutions desire for more cost-effective and efficient work holding devices and method like jig and fixture. There are two most fundamental jig and fixture design principle that commonly stressed out which is simplicity and economy.

This project is collaboration between a textile manufacturing company in Malaysia and Universiti Teknikal Malaysia Melaka. In conjunction of this Company-University Collaboration (CUC), student will be assigned to a task to improve the operation cycle time in their dedicated process called dipping process which requires operator to eject a batch of pins that attached to a base mold and eject it at the fastest time possible.

1.2 Problem Statement

From observation and In-Line Manufacturing visit, current ejection process at dipping process currently practiced in this company is a manual process by hand which gave the non-competitive cycle time with average of 15.83 seconds to eject and using the non-ergonomic process that required a lot of energy with 2.30 kg of equipment to eject the pin from the base.

Ejection of a work piece or parts from its mold is one of the major problems faced by the manufacturing company, especially for a company that produce special product. The ejection jig or equipment was not in the normal market and sometimes need to be customized. The cost of customization is definitely expensive.

Jigs are important equipment using in any industry. Before this, jigs always have limited function like just one part can be support for one process. This makes the production slow and cannot fulfilled customers demand. Nowadays, there are several methods that are available to improve design to increase the productivity.

As a matter of fact, manufacturing for global competitive clearly require the success of current engineering which is the process that allows the design team to involve in a comprehensive plan for product design and manufacturing processes result in lower production cost and shorter lead time.

As a result, this project will study and give some concept by producing the best jig and fixture at dipping process to achieve the best cycle time.

1.3 Objectives

The objectives of this project are as below:

1. To investigate the current practice of pin ejection.

2. To design and fabricate the prototype of the jig and fixture to eject the pins from its mold/base.
3. To choose the best design for implementation suggestions

1.4 Scope of project

The scopes of this project are:

1. Design and evaluation jig which will eject a batch of 3 types of pins 34 x 0.65mm to 45 x 0.65mm sized with depth of attachment on base is 3mm.
2. Design an ejector jig for the dipping process to perform the ejection operation of parts from the holding base.
3. Design of jig using Auto CAD 2008 and choose the best design using Pugh's matrix selection method and based on prototype cycle time trial result.

1.5 Report Arrangement

This project report consists of five chapters. The first chapter will discuss about the introduction of the project, which briefly explained the project background and problem statements. Here also will state the project objectives and scope of the study.

The second chapter will discuss about some literature review based on jigs and fixtures application and importance, design fundamental and concept selection method.

Third chapter discusses the methodology to be used in this project. The steps and flow chart will be shown in this chapter.

Fourth chapter will explained the project result and outcome with some relevant analysis.

Lastly, the fifth chapter will conclude the project outcome.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Jigs and Fixtures

One of the economical ways to produce a component in mass is by using jigs and fixtures. Jig and fixtures have become one of the most important facilities in the mass production system. In order to manufacture desired parts accurately, jigs and fixtures are used as a production-work holding devices. It was built to support, locate, and hold every part in order to ensure that correct relationship and alignment between other tools and work piece is maintained within the specified limit (Hoffman, 2004).

The jig is a special device that supports, locate, and hold on a part to be machined or produce. Usually jigs are shaped with hardened steel bushing to guide the tools in the manufacturing process (AYC Nee et al, 1987). The primary purpose of jig is to provide accuracy, interchangeability, and repeatability in the manufacturing of products. For example, when a key is duplicated, the original key is used as a base so the new key can have the same path as the old one. It is called a template. In manufacturing system, template and jig are both the same part (Hoffman, 2004).

The fixture is a device that supports,locates and holds the part or work pieces for a particular operation. However it does not guide the cutting tool. It provides references surface only. Fixture is a unique device that each one is made to fit a specific part or shape.

2.1.1 Types and Functions of Jig and Fixture

The jigs and fixtures are mainly used when huge quantities of parts are to be produces, or for higher specifications and medium quantity parts. The main variation between temporary and permanent jig and fixture is the relationship of cost and benefit between the work holder and the process. Several applications involve jigs and fixtures only for speed while several applications require low speed but higher precision. The criteria of the application give direct influences on the type of jig or fixture making and nevertheless, the price (Charr Lane, 1965).

The names used to describe the various types of fixtures are determined mostly by how the tool is made. Jigs and fixtures are made basically the same way as far as locators and positioners are concerned. The main structure difference is mass. Because of the increased tool forces, fixtures are built stronger and heavier than a jig would be for the same part. Plate fixtures are the simplest form of fixture. The basic fixture is made from a flat plate that has a variety of clamps and locators to hold and locate the part. The simplicity of this fixture makes it useful for most machining operations. Its adaptability makes it popular. The angle-plate fixture is a variation of the plate fixture. With this tool, the part is normally machined at a right angle to its locator. (Hoffman, 2004).

2.1.1.1 Permanent Jigs and Fixtures

Permanent jigs and fixtures are usually used for a single operation on one specific part. It can trim down the operator decision-making and improved productivity since the complexity of the work holder or jigs is increased (Fazlina Mansor, 2010). So that the tool will have a lower cost per unit or per operation. Due to that, more money and time are needed for these work holders or jigs. Permanent jigs and fixtures are normally built up from regular tooling components and custom-made parts (Charr Lane, 1965).

Most fixtures are designed for a particular work piece, thus being called 'dedicated fixtures'. With typical costs of dedicated fixtures amounting to 10-20% of the total manufacturing costs, the economic impact of flexible fixturing could be dramatic. The traditional method has been to design and create a 'dedicated' fixture with the sole objective of producing a high quantity of the same part.(N. P. Maniar, D. P. Vakharia, 2013).

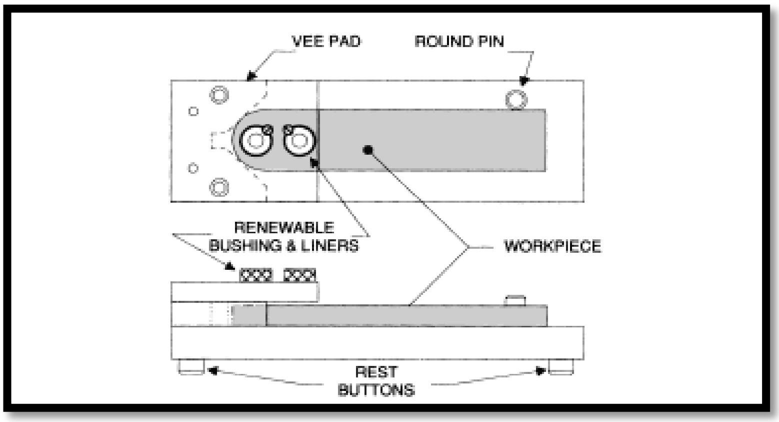


Figure2.1: Permanent work holder for drilling operation

2.1.1.2 Modular Fixtures

Modular fixture is the combination of ideas and elements from permanent and temporary work holding to make durable-yet-low costwork holders. The main advantage of this type of fixtures is that it can be made from the standard components (Charr Lane, 1965). The fixture designed to be disassembled-free when the operation is complete in order to allow the reprocess of the components in a different fixture (Campbell, 1994).

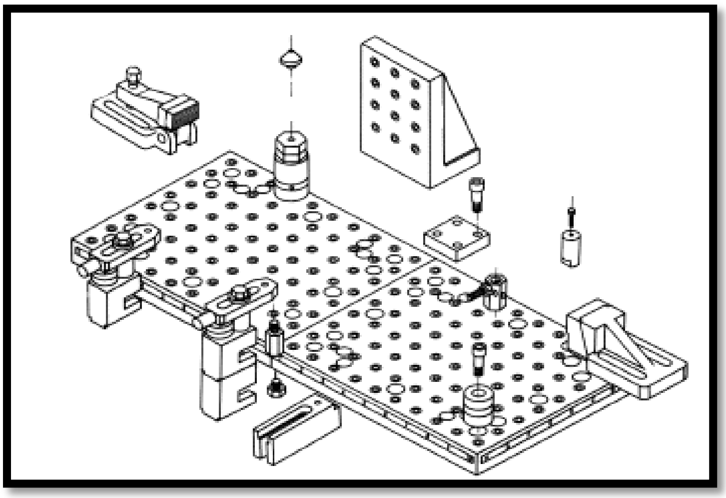


Figure 2.2: Modular Work holder

2.1.1.3 General-Purpose Fixtures

General-purpose fixtures is not suitable for long production runs because its require high level of operator care and awareness to sustain it accuracy and consistency. The cost to construct this work holder is not so expensive compared to permanent work holder. This work holder also is not specific so that its versatility permit for repetitive use of a variety of different or limited production runs. It also adapted to many types of machine for many different parts.

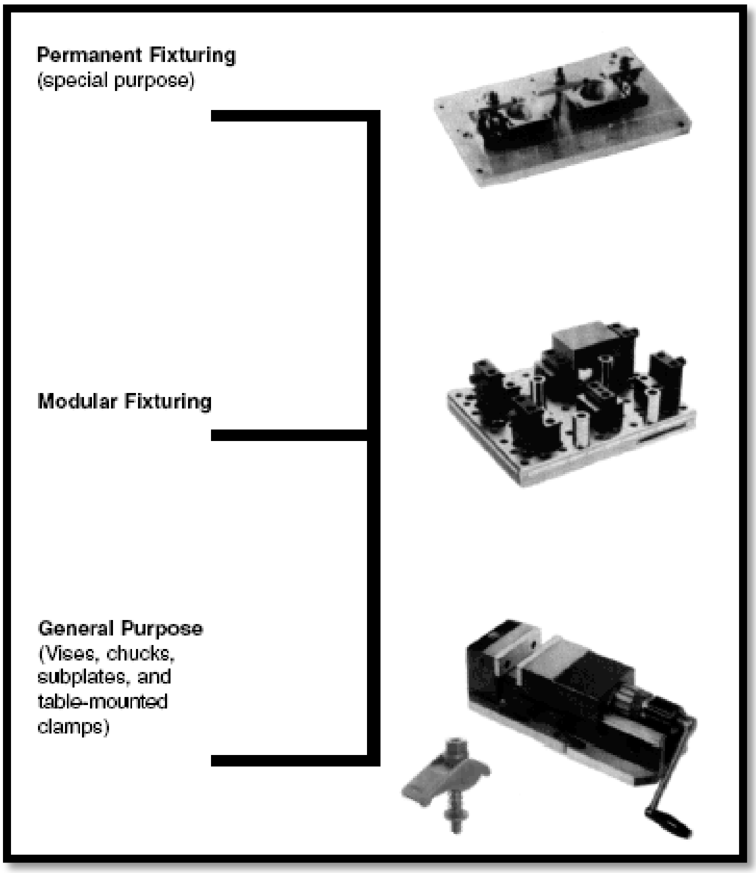


Figure 2.3: Hierarchy of work holders

2.1.2 Importance of Jig and Fixture

The use of a jig and fixture can improve the productivity. It can reduce operation and working time. The operator can eliminate the marking process, manual positioning and repetitive checking for the functions of the fixture is to locate the work quickly, accurately, and securely support and hold the work during operation (Joshi, 2001).

Jigs and fixtures were also important in term of interchangeability. Selective assembly is no more needed. Any kind of part of the machine would be able to fit properly (Joshi, 2001). It assists consistent quality in manufacture (Henriksen, 1973).

Furthermore, there is no longer needed for skillful setting of the work pieces or tool since the part can easily and quickly located onto the tools. It can allow any average person to use the jigs and fixtures (Joshi, 2001). Therefore, the requirement for hiring high skilled labor is reduced.

By reducing working time, improve interchangeability and reduce skilled worker labor cost, the use of a jig and fixture contribute to cost reduction to the production. It reduces cost of maintenance, assembly and the subsequent supply of spare parts (Henriksen, 1973).

2.2 Jig and Fixture Design Fundamental

There are several requirements that need to be considered for a designer before designing the jigs and fixtures. The initial steps are information organizing related to the process and product to be manufactured. Designers must identify the overall size and shape of the part. For example, a part having the same holes pattern need a feature such as end cap and housing (Hoffman, 2004). The type and condition of jig material need to be identified because it has significant impact to the tool fabrication and usage. The right material also influences on how the part is located and held (Fazlina Mansor, 2010). There are several categories of material available in market such as steel, tool steel, cast iron, aluminum, magnesium, sintered tungsten carbide, plastics, wood and other nonmetallic materials (Henriksen, 1973). The operation to be performed also needs to be clear because some operation can use multipurpose jigs and single-purpose or dedicated operation is preferred for high-speed operation. Other design fundamental such as degree of accuracy, number of pieces to be made, and locating and clamping surfaces has to be identified in order to initiate the design of a jig and fixture.

Furthermore, the design requirement criteria in term of human element also need to be considered. This human element requirement needs to be considered because there is always a need for people in manufacturing industries. Human factors related to the operation of the tools. The operators and inspectors are the person who involved in the proposed of jig and fixture. Human element such as ergonomics and safety are the major requirement need to consider by the designers (Hoffman, 2004).

2.3 Computer- Aided Design Software

Computer- aided design (CAD) software has been used for many years and widely in our world. By using CAD, the product or part design can be more accurate than hand-drawn designs and it can reduce human error. Users are able to save and edit ideas which make it easier and cheaper to modify a design of parts or a jig and fixture.

Many industrial researchers and practitioners have viewed the complex task to design a fixture because it acts as an important relationship between manufacturing and designing activities in industries (J.Cecil, 2002). As we discussed previously, the use and application of jigs and fixture is very important in the industry. Therefore, it is in order to design a jig and fixture, it require an increased level of knowledge because, it involve geometric accuracy and elements (F.Mervyn et.al, 2003). Computer-aided design is commonly used for these designing purposes. In this section, some of methods using computer-aided-design will be presented.

A method called FIXES is a computer-aided planning consists of two parts; setups selection and design of a fixturefor every setup. The Laboratory of Production Engineering was involved in the development of computer-aided fixturing (CAF) since January 1983. Started in early 1985, the FIXES project has been improved for a more complex setup and fixtures positioning faces has been developed (Burma and Klas, 1988).

AutoFix, a fully automated jig and fixture design system is the integration of knowledge-based reasoning with a whole range traditional computer-aided design (CAD) techniques including solid modeling, parametric design and finite-element analysis (Pham and Lazaro, 1989).

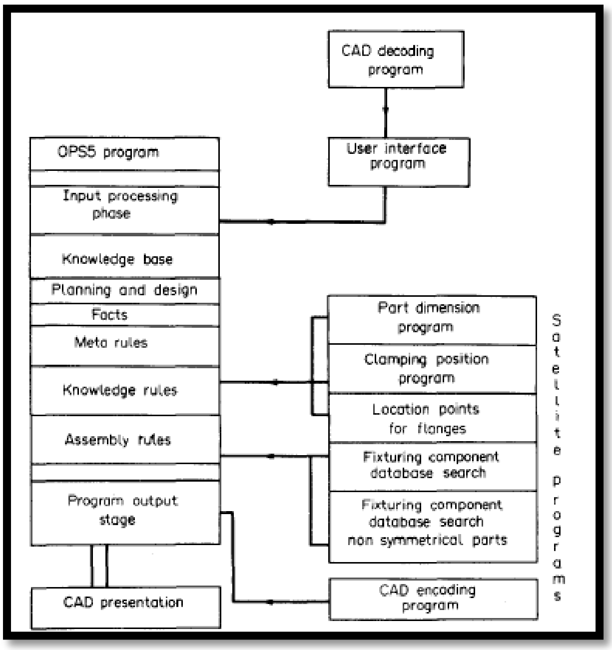


Figure 2.4: AutoFix Block Diagram

Other than that, the Modular Element Fixture Design Expert System (MEFDES) has been developed to give a 3D CAD representation of a finished part, part characteristic, raw material, and design an appropriate fixture using modular and manufacturing database. It is an automated rule/ object based expert fixture-design system intended to couple design and manufacturing activities in real time (Senthil et al).

Currently, in many manufacturing industries, CATIA is the most commonly used software for computer-aided design purpose. CATIA stands for Computer Aided Three-dimensional Interactive Application. CATIA has been created by Dassault Systems of France and is marketed & technically supported worldwide by IBM. Using CATIA as design software is easy but some difficulty in term of editing some parameters will be occur because designers have to re-edit each individual parts. So, it is time consuming.

Solid works is a tool that provides feature-based 3D modeling capability for mechanical design. It comprises basic part modeling, assembly composition and from that drawing creation. Advantages using Solid works such as auto checks and auto correct before sending for fabrication, allows designers to compare their design components and drawing with other design works, able to work with multiple data, drawing format and converting the drawing format such as from DWG to DXF and lastly one of the important advantages of using Solid work is it uses Microsoft structured storage format in which make it more user friendly since students and computer user widely used Windows.

Autodesk Auto CAD is also one of the regular used computer-aided design (CAD) programs that especially used among students. It creates accurate and professional drawings. Even though it is a leading CAD programs, the number of file formats it can import or export is limited. This limitation creates problems when using other CAD programs with more advanced tools and exporting the program to an Auto CAD format (Ryan, 1999).

For this project study, Auto CAD is the simplest software that can be used and it also machine-friendly since the current machine in Fakulti Kejuruteraan Pembuatan (FKP) is still using Auto CAD format to install design into the machine.

2.4 Concept Selection

Many researchers have used a variety of methods for the decision-making process when selecting the most potential design of tools and fixtures.Some practical approach to design based on the concept of selection was identified. First, the generation of alternative concepts using ideation techniques, second, the selection of the 'most-likely-to-succeed' concepts for further development into feasible alternatives; third, the formulation and solution of selection-decision (Nagesh et al, 1985).

For example, Arslan, Catay, and Budak (2004) presented a decision support system (DSS) involving nine criteria (flexibility, productivity, adaptability, cost, reliability, precision, space, safety and environment, service and maintenance) for tool selection using the weighted average approach and a Cost/Benefit analysis. Ayagˇ and Özdemir (2006) presented the MADM process for machine selection based on the fuzzy AHP and Cost/Benefit analysis. The fuzzy AHP is also used by Durán and Aguilo (2008) to evaluate and justify the advanced manufacturing system (Nguyen, et al, 2014).

Some other method such as Quality Function Deployment (QFD) was also used by researchers for decision making, such as material selection (Afshar et, al, 2013). Boothroyd and Dewhurst also developed the design for manufacture and assembly (DFMA) methodology, which focuses on simplifying the structure, eliminating inefficiency in design, cutting costs and quantifying improvements (Albinana and Vila, 2011). On the other hand, a methodology based on costs, by means of models of manufacturing processes called PRIMA (Process Information Maps) has been introduced (Swift and Booker, 1997).

A decision-matrix based method called Pugh's method concept selection has been introduced by Pugh (Pugh, 1990). It matrix based selection was derived from market analysis which suggested to facilitate new product design so that it is advantageous for lean technology for greater efficiency (Thakker et al, 2008).The Pugh Matrix is not proposed to be a mathematical matrix; it is simply an arrangement for expressing ideas and the criteria for the evaluation of these ideas in a visible, user-friendly fashion (Linda and Gerrit, 2014).

CHAPTER 3

METHODOLOGY

3.1 Introduction

The purpose of this chapter is to present the methodology used for this project. It will focus on the jig and fixture designing phases as presented in the flow chart below.

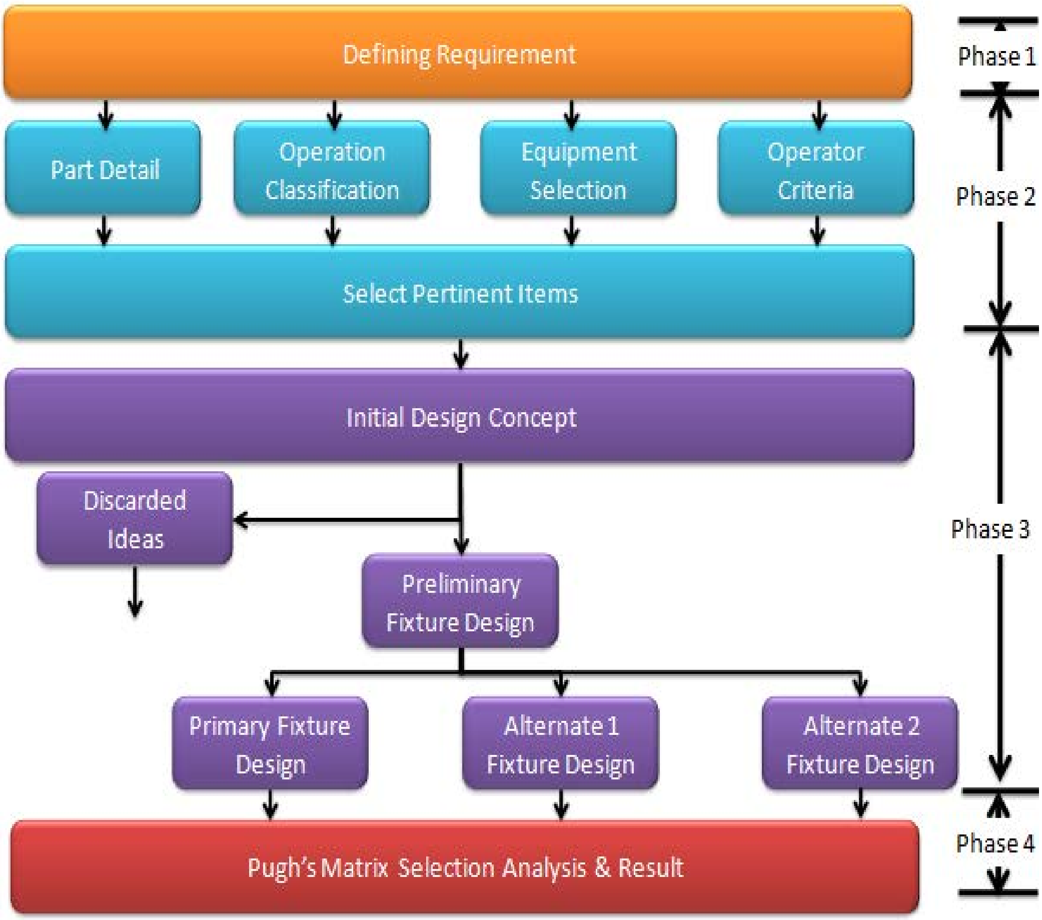


Figure 3.1: Design Methodology Flow

3.2 Phase 1: Defining Requirement

As discussed previously the initial steps in tool-designing is data collection or information organization such as identifying what problem to be solved, and what needs to be achieved. In this project, we are improving the existing operation work method. The main objectives are focus on improvement of quality, cost, delivery, management and safety (Q, C, D, M, and S) as shown in Table 3.1 below.

Table 3.1: Target Check Item

Check Item	Target
Quality	1. Maintain the current quality 2. Reduce number of reject part
Cost	Reduce current process cost (15.83 seconds)
Delivery	Increase number of pins ejected at one single operation
Management	Easy to use and easy to storage
Safety	Reduce edges or shape that can bring injuries to operator during operation

The design might be design only for dedicated parts or for the whole part family. Problem identification and needs requirement data can be collected by factory visit and observation. Conducting a factory visit can help to get close to the operation and process itself. All above target and requirement for this project will be share with details analysis in the Result Analysis and Discussion in Chapter 4.

3.3 Phase 2: Gathering and Analyzing Information

In the second design phase, all data is collected and assembled. The data such as part details, operation classification, equipment selection and operator criteria are collected. Notes from interviews of operators, supervisors and engineers related to the operation are taken and video recording can be done for further references. There are four categories of design considerations has been divided that need to be collected which are;the work piece, manufacturing operations (refer Figure 3.2), equipment, and personnel. A checklist is shown in Table 3.2.

Table 3.2 : Design Consideration Checklist

Workpiece	
1	Size
2	Shape
3	Material Type
4	Locating point
5	Production Quantity
Operation	
1	Type of operation
2	Number of seperated operation
3	Inspection requirement
Equipment	
1	Machine tool
2	Ejection equipment and tools
3	Equipment availability and Scheduling
Personnel	
1	Safety equipment
2	Safety regulation and work rules
3	Operator fatigue
4	Possible Automation

The process flow chart shown in Figure 3.2 is the process flow that operates in the dipping process department. The project will focus on the process of ejection of pins from base plate because it is the request from the company management since the process is currently done manually by the operator and consume a lot of time to be finish.

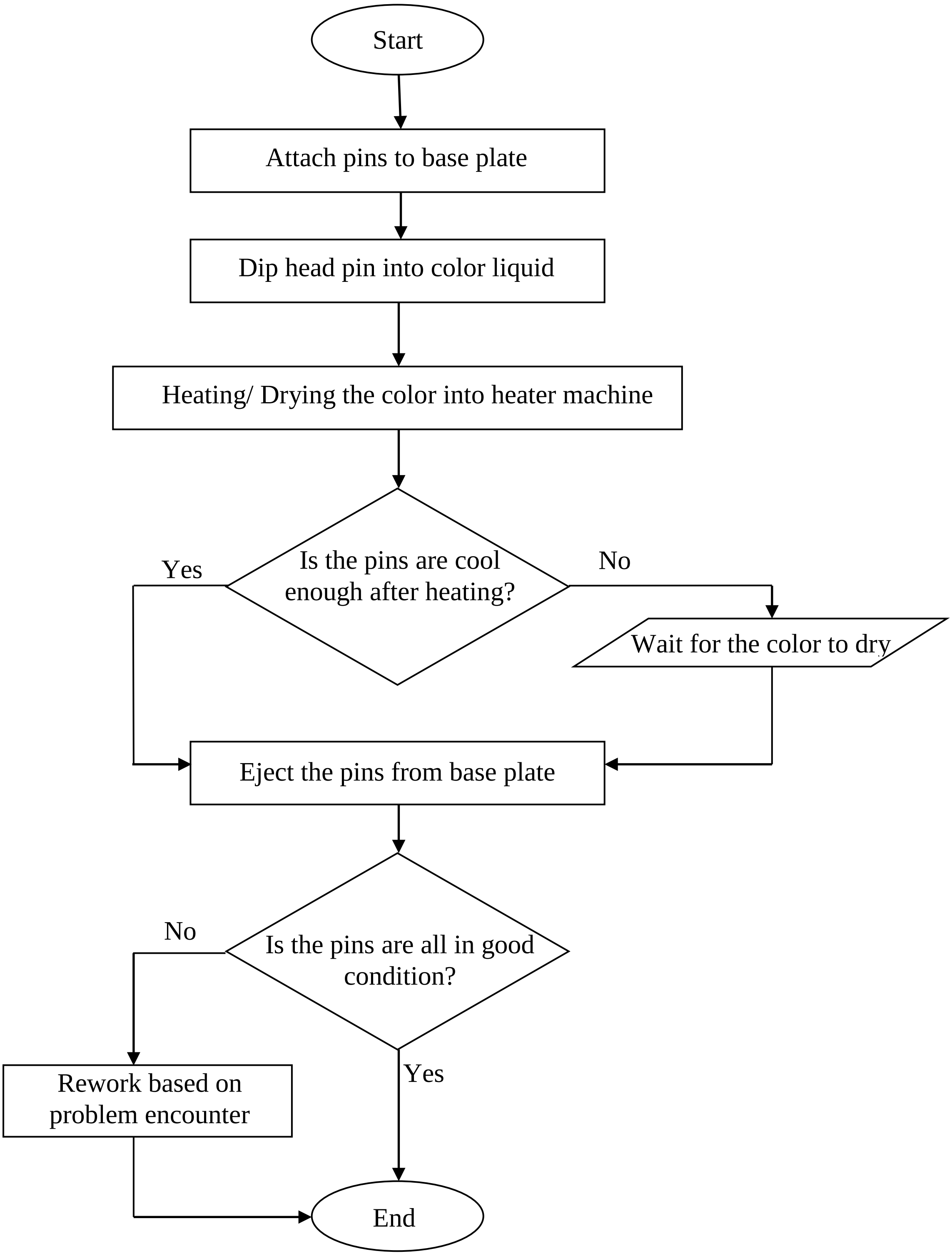
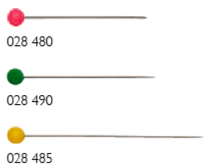


Figure 3.2: Overall Process Flow Chart

3.3.1 Work piece Considerations

The most important factors and the major references on jig and fixture design is the work pieces specification. It includes the part shape and size, required accuracy, material properties of part, the number of pieces and also locating and clamping surfaces. As for this project, the work piece will focus only for the three types of pinswith depth of base attachment is 3mm. Each work piece base will have approximately 32x23 pins, which means the total of 736 pins per base will be attached. Table 3.3 and Figure 3.3 show the work piece image.

Table 3.3 : Workpiece Descriptions

Plastic- headed pins				
Description	Size	Color	Weight	Code No
Hardened & tempered steel, rust protected 	32 x 0.65mm	neon	15g	028 480
	34 x 0.65mm	assorted		028 490
	45 x 0.65mm	yellow		028 485

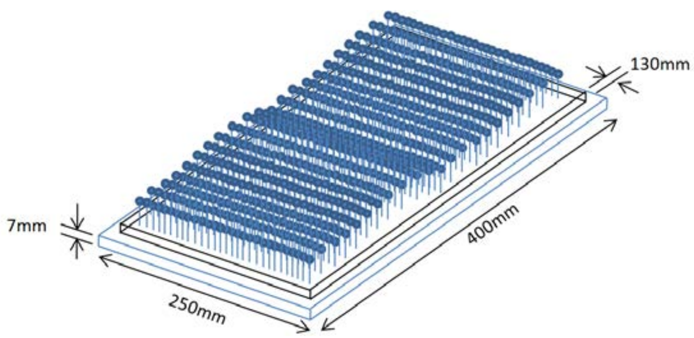


Figure 3.3: Dimension of pin base plate

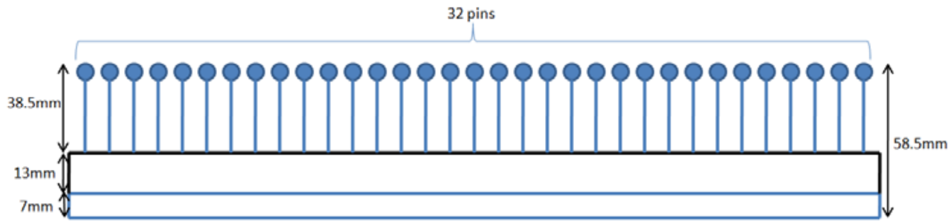


Figure 3.4: Side dimension of pins line

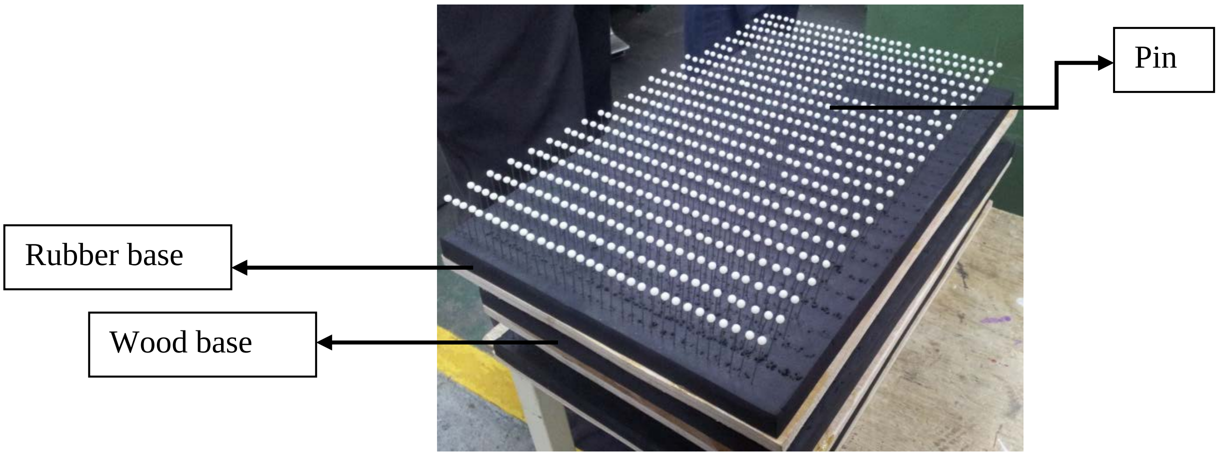


Figure 3.5:Work piece top view

3.3.3 Equipment Considerations

The equipment considerations determine whether the work holder is designed for single or multiple parts. Usually, process engineer selects the required function of the equipment before the tool designer starts the design process. Nevertheless, the tool designer must confirm the equipment choices for the operation. Figure 3.6 shows the current equipment that has been used by the operator to eject the pins from the rubber base.

Figure 3.6: Equipment to eject pins

Using this current equipment, the process to eject the pins from base plate is taking about 15.83 seconds. This cycle time is according to observation and time taken by three different operator who done the process of ejection frequently. The total of 10 base plates was observed.

3.3.4 Personnel considerations

The main important consideration in this phase is ergonomics and safety. The ergonomics and safety elements should comply with the Occupational Safety and Health Administration (OSHA).

3.4 Phase 3: Developing several option

Many options are taken and no discarded options are done while alternatives designs are developed to ensure the design are feasible. Brainstorming for ideas are done by the participation from the designer, project supervisor, factory engineers, operators and some friends. Gathering their ideas without eliminates any small ideas are important to get some thought and suggestion for the design. The brainstorming session then followed by the design sketches. It is important to sketch the idea to illustrate the design clearly. After some sketches, the design can be interpret into CAD system for 2D illustration.

3.5 Phase 4: Choosing the best option and implementation

Pugh concept selection will be the method for choosing the best design options.Table 3.4 shows the example of matrix to evaluate and select the design based on multiple designs and criteria (Stuart Burge, 2009).

Table 3.4: Pugh Matrix Example

Pugh Concept Selection	Design A	Design B	Design C	Design D
Criteria 1	0	+1	0	+1
Criteria 2	0	-1	0	+1
Criteria 3	0	0	0	+1
Criteria 4	0	-1	+1	+1
Criteria 5	0	-1	+1	5
Criteria 6	0	-1	0	-1
Criteria 7	0	+1	0	-1
Criteria 8	0	+1	0	-1
Criteria 9	0	-1	0	0
Criteria 10	0	0	-1	0
TOTAL +	0	3	2	5
TOTAL -	0	5	1	4
TOTAL SCORE	0	-2	1	1

From Table 3.4, select a baseline design concept for example “Design Concept A”. This baseline is score as “0” against all of the criteria. The other candidate design concepts are then compared in a pair wise fashion against Design Concept A for each of the criteria. If a candidate design concept is:

- better than the baseline a “+1” is entered in the appropriate cell
- worse than the baseline a “-1” is entered in the appropriate cell
- the same than the baseline a “0” is entered in the appropriate cell

The overall evaluation is made by adding the “+1” and “-1“ for each design concept. The highest total score will be selected as the best design.

As for the implementation, the selected design will be fabricate for prototype. This prototype will be send to the factory and a testing session will be conducted to evaluate the result of cycle time reduction.

CHAPTER 4

RESULT ANALYSIS AND DISCUSSION

4.1 Current situation analysis (Current Equipment)

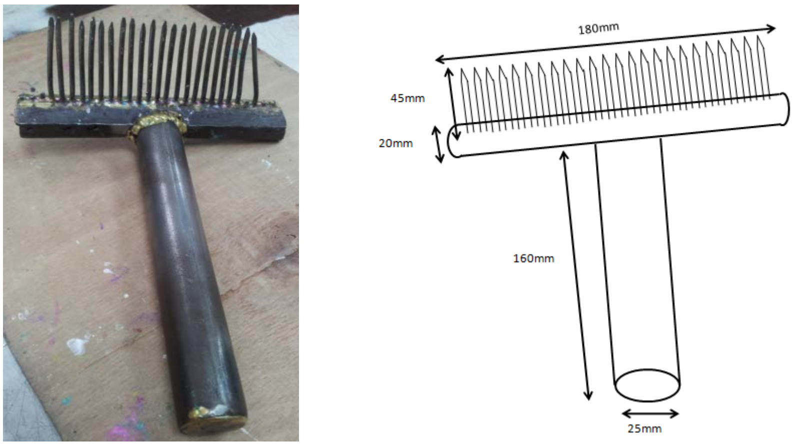


Figure 1.1: Current equipment used

The current equipment is made from metal material which the weight is 2.30 kg per equipment. The specification of this equipment is 160mm handle length, 20mm diameter of nail holder, 45mm length of nail height and 180mm length of total equipment. There are 22 slots of nails on this equipment (refer Figure 4.1).

Using this equipment, cycle time data was collected for 10 base plate ejection processes. The purpose of 10 timescycle time collected is to get more accuracy for the optimum cycle time should be for this ejecting pin process. The results are shown in Table 4.1.

Table 4.1: Current cycle time data

No	Cycle time (second)		
	Operator 1(25months experience)	Operator 2(8 months experience)	Operator 3(29 months experience)
1	14.5	15.6	14.2
2	15.3	15.3	14.5
3	14.8	16.1	14.7
4	14.4	17.4	15.6
5	17.6	15.4	14.8
6	16.9	16.8	15.7
7	14.2	17.3	15.5
8	18.4	18.1	15.3
9	15.4	15.4	16.3
10	16.7	16.3	16.4
Average	**15.82**	**16.37**	**15.3**
Total Average	**15.83**		

All data collected during trial at process line for 3 operators with different experienced had been shared with responsibility engineer as in Appendix A for verification and confirmation. Table 4.1 is the summary for the cycle time for current equipment which shows the unconsistency of cycle time taken by the 3 operators. The unconsistency occur due to different experience and skill by each operator. Operator 1 who takes 15.82 seconds average cycle time has work at this operation line for about 25 months, operator 2 who takes averagely 16.37 seconds has worked for about 8 months while operator 3 who takes 15.30 secondshas worked for about 29 months in this operation line. From these 3 operators, the grand total average of ejection process is 15.83 seconds.

Based on quality, cost, delivery, management, and safety (QCDMS) criteria, the current situation result was identified. The result is shown in Table 4.2.

Table 4.2: QCDMS analysis result (current situation)

Check Item	Target	Result
Quality	1. Maintain the current quality 2. Reduce number of reject part	2% reject pin from ejection process. 13,586 ppm (part per million)
Cost	Reduce current process cost (15.83 seconds)	RM36.95 per operation (1 base= 736pins)
Delivery	Increase number of pins ejected at one single operation	13 times ejection process per base
Management	Easy to use and easy to storage	Not ergonomic due to equipment weight = 2.30 kg
Safety	Reduce edges or shape that can bring injuries to operator during operation	High possibilities to get injured due to open sharped edges of nails

Based on the QCDMS result table, for the quality criteria, the result shown 2% rejected pin from each ejection process as there is at least 10 pins were rejected out of 736 pins per base due to pin bending occur because of high force of ejection by the operator since the process were done manually. For the record, 13,586 pins will be rejected per million of pins (Raziq, 2014).

For cost criteria, total cost for raw material, components, process, tooling and administration are RM66.24. 10% is for raw material, 5% for component, 56% for process, 20% for tooling and 9% for administration cost. The 56% for process cost consist of RM36.95. The details of each cost breakdown had been shared and discussed with the responsibility from the person in charge and engineer as shown in Appendix B.

For delivery criteria, from the observation, each operator needs to do at least 13 times ejection process to eject all the pins from the base plate.

For management criteria, the current equipment were not ergonomics for the operator due to the weight of the equipment is 2.30 kg which means each ejection process, the operator need to lift the equipment several times in 15.83 seconds. This repetitive operation may contribute to arm injuries to the operator.

Lastly, for the safety criteria, from the observation, the current equipment not has its own storage place when not in used. The equipment will just left on the table or pins bins. It will increase possibility for operator to get injured since the equipment has open sharp edges of nails.

4.2 Creation of the Jig & Fixture

Based on the current situation analysis, we can see that current practice of pin ejection need some improvement. Therefore, several ideas were created to design the jig. From the brainstorming three designs were discussed.

4.2.1 Design Jig 1

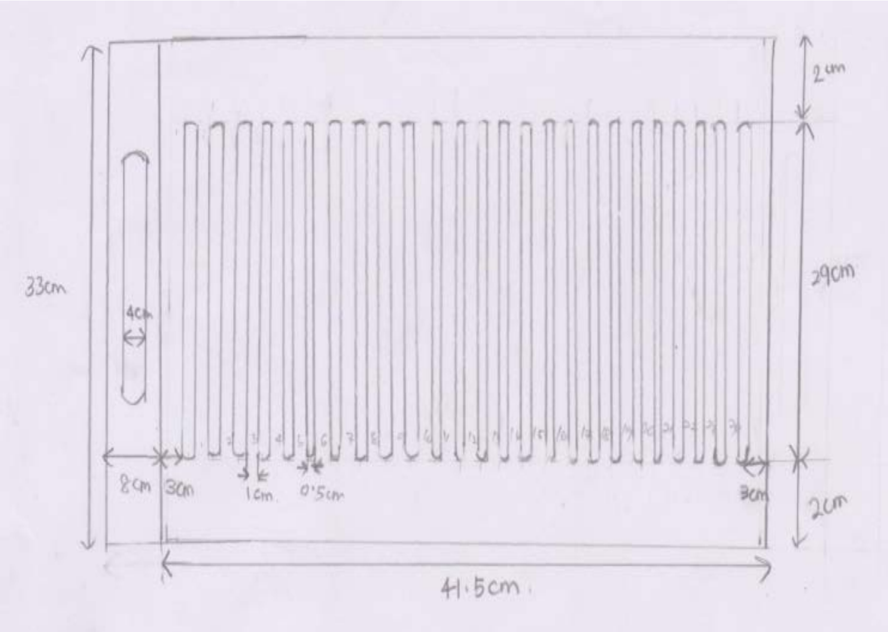


Figure 4.2:Sketch Design Jig 1

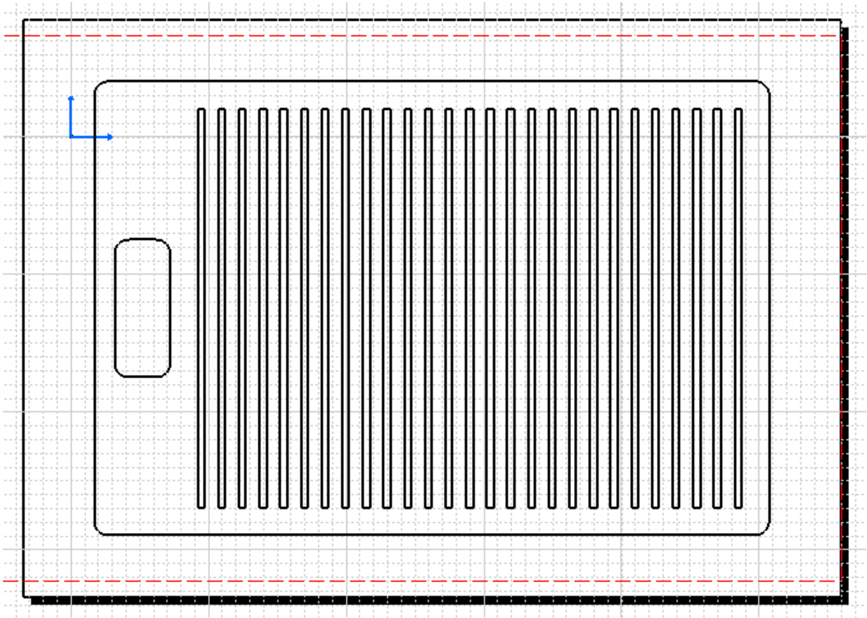


Figure 4.3: 2D AutoCAD Jig 1

Figure 4.4: Prototype Jig 1

For Jig 1, the idea was based on the concept of comb but ‘close comb’. It was called ‘close comb’ because at every end of comb teeth are close. Only the gap between teeth that have a slot gap will hold the pins when it was aligned according to the pin lines.

This design dimension is 415x330mm which is bigger than the size of base plate. The design was designed bigger for the purpose of easy slotting the pins into the comb teethes. The prototype was made from acrylic material and cuts using laser cutting machine. The size of teeth gap is 5mm. The teethes length is 10mm and the height is 290mm.

The prototype was brought to the operation line on 23rd July 2014. Unfortunately, after the prototype was tested at the operation line, the pins cannot be eject from the base plate. This is due to small size of teethes gaps makes the pin cannot properly slotting into the teethes. Other than that, the teeth lines are inconsistent and not standardize for each row. Therefore, the jig cannot be insert into the pin lines.

The QCDMS criteria cannot be evaluated since the operation was unsuccessful and it shows that the jig is fail to perform the ejection process.

4.2.2 Design Jig 2

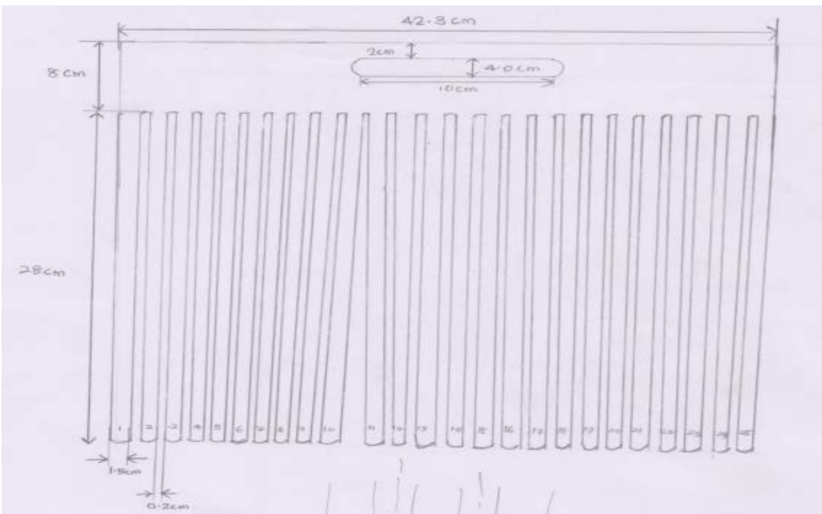


Figure 2: Sketch Design Jig 2

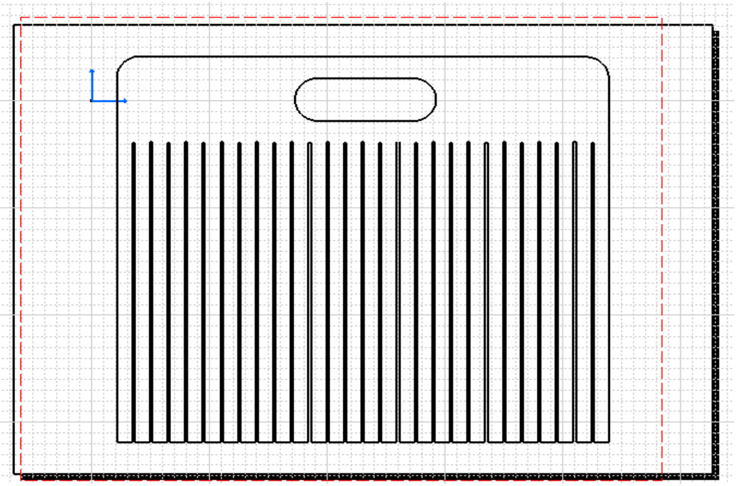


Figure 3: AutoCAD Design Jig 2

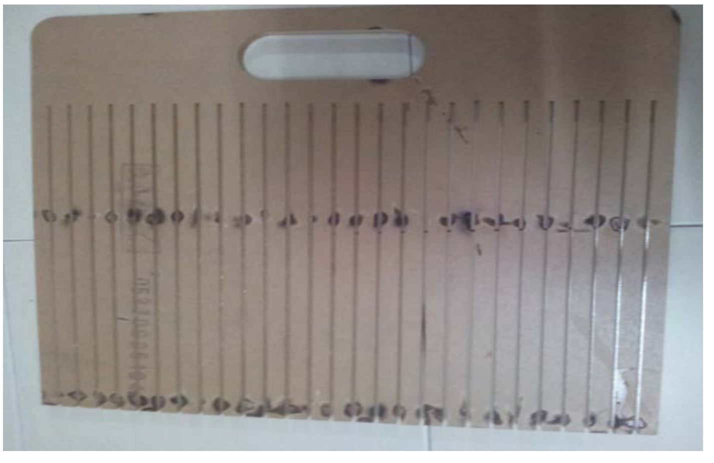


Figure 4: Prototype Jig 2

Design Jig 2 was also based on the concept of comb. The comb teeth will be used to hold the pins and the pull force will eject the pins from the base plate. The dimension of this jig is 423x360mm. It consist of 25 teethes which have 24 slots that gap 2mm each. The teeth length is 15x280mm. The remaining height of 80mm on the top of the jig is for the comb holder.

For this prototype, it was made from 100mm thickness of acrylic material and cuts using laser cutting machine at Bengkel Fakulti Kejuruteraan Pembuatan. The AutoCAD design was installed into the machine and by the help of machine's technician, the machine operate the cutting operation accordingly.

After fabrication of prototype was done, a trial session was conducted for 10 base plates and by using same operator as the previous session. The result of trial session is shown in Table 4.3.

Table 4.3: Jig 2 Trial Cycle Time Data

No	Cycle time (second)		
	Operator 1 (25 months experience)	Operator 2 (8 months experience)	Operator 3 (29 months experience)
1	49.4	50.2	46.9
2	42.6	51.3	43.8
3	43.1	43.5	49.4
4	40.2	45.7	45.6
5	38.2	51.7	39.6
6	44.2	49.4	44.6
7	43.5	48.7	46.2
8	39.6	50.2	45.1
9	38.3	45.6	43.5
10	39.9	47,8	47.2
Average	**41.9**	**43.63**	**45.19**
Total Average	**43.57**		

All data collected during trial at process line for 3 operators with different experienced had been shared with responsibility engineer as in Appendix A for verification and confirmation. From the trial result, the total average cycle time collected by the 3 operators and 30 base plates is 43.57 seconds. This means, the used of this jig consumes larger cycle time than the used of current equipment. This result arises due to more time required to align and insert the comb teethes into the pins line which have 23 lines per base. Furthermore, each base plate does not have same line from each other. The pins lines are not consistent from each other due to unstandardize movement of base plate during the pin attach process. The QCDMS criteria were evaluated for this Jig 2 and the result are as Table 4.4.

Table 4.4: QCDMS Jig 2

Check Item	Target	Result
Quality	1. Maintain the part quality 2. Reduce number of reject part	1% reject pin from ejection process.
Cost	Reduce current process cost (15.83 seconds)	Process cost increase due to cycle time increase (43.57 seconds =RM45.27)
Delivery	Increase number of pins ejected at one single operation	4~5 times pulling process required to finish the whole pins
Management	Easy to use and easy to storage	Easy to storage but size is larger than previous equipment
Safety	Reduce edges or shape that can bring injuries to operator during operation	No sharp edges that can bring injuries to operator

The quality criteria result shown 1% rejected pin form each ejection process as there is only 5 to 6 pins was bending due to high pulling force of the jig. It shows that 1% improvement was achieved compared to previous equipment rejection result.

For cost criteria, the cycle time influence the process cost. The cycle time for Jig 2 was increased for about 27.74 seconds. It means that the process cost will also increase to RM45.27 (refer Appendix B).

From observation during using the Jig 2, at least 4 to 5 puling process required to finish eject the whole pin from the base plate. It shows the result was improved from the previous result that required at least 13 pulling process to finish one base plate ejection.

For management criteria, even though the size is larger than the current equipment and Jig 2, but it is easy to storage since the shape is flat.

Lastly, for the safety criteria, from the observation, the Jig 2 have no sharp edges since each edge are chamfered. There is minor possible of injuries for the operator to use this kind of jig design.

4.2.3 Design Jig 3

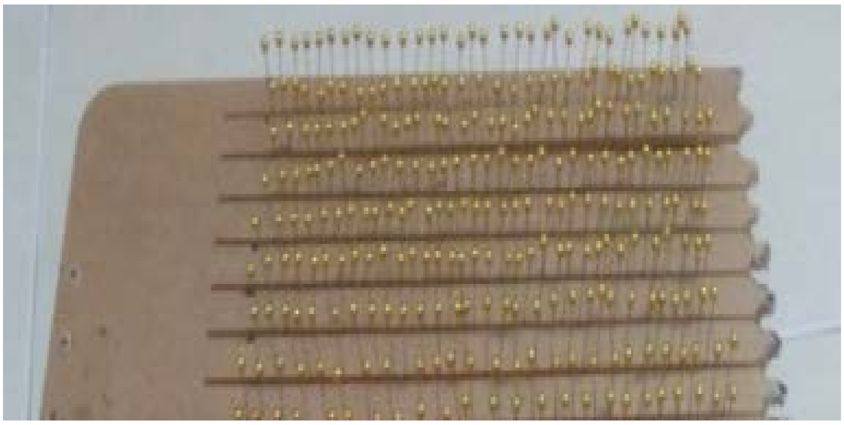


Figure 5: Prototype Jig 3

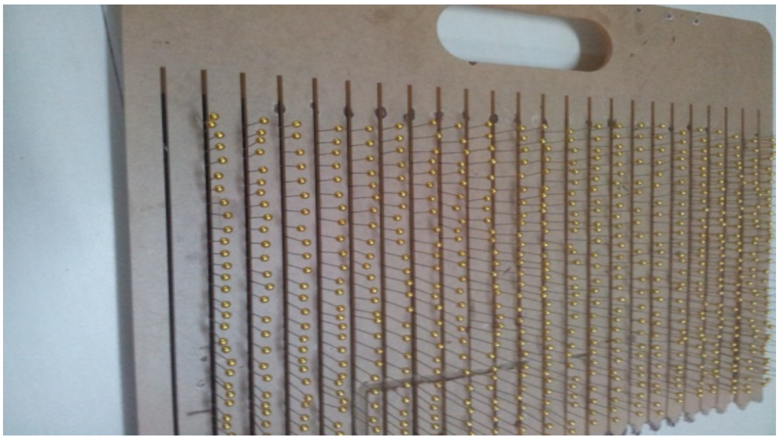


Figure 6: Step 1 - Insert the pin line by line into the jig slots

Figure 7: Step 2-Pull the jig and the pin will eject from the base into the polybin

Jig 3 was design based on the modification of problem occur in Jig 2. The modification was made by discussion with operators and supervisor. Based on the result of the Jig 1 and Jig 2, the difficulty to insert the jig through the pin lines is the main issue to get the best cycle time. Therefore, Jig 3 was designed by the shape of chamfered teethes for easy slotting in every line at pin bases by investigate and do an accurate calculation for the gap between the pin line which need to be adjusted. In addition, the dimension of the jig is same as Jig 2 but the thickness was reduce using 40mm acrylic plate so that the weight was reduced.

Same as Jig 2, a trial session was conducted to test the function of Jig 3 and cycle time data was collected as in Table 4.5.

Table 4.5: Jig 3 trial cycle time data

No	Cycle time (second)		
	Operator 1 (25 months experience)	Operator 2 (8 months experience)	Operator 3 (29 months experience)
1	4.6	4.3	4.5
2	3.8	4.2	4.3
3	4.4	4.8	4.6
4	4.8	4.9	4.3
5	5.2	5.2	4.5
6	4.3	4.3	4.2
7	4.1	5.4	4.4
8	4.5	5.4	4.3
9	4.3	4.3	4.6
10	4.1	4.2	4.5
Average	**4.41**	**4.7**	**4.42**
Total Average	**4.51**		

From the result collected, it shows the cycle time was decrease from 15.83 seconds to 4.51 seconds which contributes 72% reduction of cycle time from the current practice. The cycle time average taken by 3 operators are similar for each other due to the flexibility of the jig. The design of the jig is very easy to use and can be used by any level of operator skills no matter how many months or years of experience they have. The QCDMS criteria were evaluated for this Jig 3 and the result are as Table 4.6.

Table 4.6: QCDMS for Jig 3

Check Item	Target	Result
Quality	1. Maintain the part quality 2. Reduce number of reject part	0% rejection of pins
Cost	Reduce current process cost (15.83 seconds)	Process cost decrease by cycle time reduction (4.51 seconds = RM33.55)
Delivery	Increase number of pins ejected at one single operation	1~2 times pulling process required to finish the whole pins
Management	Easy to use and easy to storage	Easy to storage but size is larger than previous equipment
Safety	Reduce edges or shape that can bring injuries to operator during operation	No sharp edges that can bring injuries to operator

The quality criteria result shown 0% rejection of pin from each ejection process because the jig used the thinner material than before that is more flexible so that the pins does not bending even the force to pull the pins is high.

For cost criteria, since the 72% reduction of cycle time for Jig 3 was achieved, it means that the process cost will also decrease to RM33.55 (refer Appendix B). The cost reduced about RM3.40 per base.

From observation during using the Jig 3, at least 1 to 2 puling process required to finish eject the whole pin from the base plate. The first pulling ejection will eject most of the pins and the second pulling ejection will eject the balance.

Same as Jig 2 result, for management criteria, even though the size is larger than the current equipment and Jig 3, but it is easy to storage since the shape is flat.

Lastly, for the safety criteria, there is minor possible of injuries for the operator to use this kind of jig design because there is no sharp edges and no sharp nails is used like the current equipment.

4.3 Pugh Matrix Selection

After the data and evaluation was gathered for the 3 jigs, the final selection of jig will be deciding using Pugh Matrix selection method. The Pugh Matrix selection result shown as in Table 4.7.

Table 4.7: Pugh Matrix Selection

No	Criteria	Baseline	Jig 1	Jig 2	Jig 3
1	Quality	0	-1	-1	+1
2	Cost	0	0	+1	+1
3	Delivery	0	-1	0	+1
4	Management	0	0	+1	+1
5	Safety	0	+1	+1	+1
TOTAL +1			**1**	**3**	**5**
TOTAL -1			**2**	**1**	**0**
TOTAL SCORE			**-1**	**2**	**5**

The evaluation performed in Table 4.7 indicates that with a total score of 5, Jig 3 is chosen as the best design among the other two jigs. The Jig 2 is at second place by scoring 2 score and the Jig 3 at third place by -1 score. For more detail score, assigning scores and re-calculating the total score as shown in Table 4.8.

Table 4.8: Pugh Concept Selection Matrix

Pugh Concept Selection Matrix		Baseline	Jig 1	Jig 2	Jig 3
Quality	Good Quality (No bending pin)	0	-1	+1	+1
	No reject pin	0	-1	+1	+1
	Quick	0	-1	-1	+1
Cost	Affordable	0	+1	+1	+1
	Reduce process cost	0	-1	-1	+1
Delivery	Reliable	0	-1	+1	+1
	Durable	0	-1	+1	+1
	Easy to storage	0	-1	+1	+1
Management	Low Maintenance	0	-1	+1	+1
	Easy to use	0	+1	+1	+1
	Good Size	0	-1	+1	+1
Safety	No sharp edges	0	+1	+1	+1
	Low weight	0	-1	-1	+1

Total +1	0	3	10	13
Total -1	0	10	3	0
Total Score	0	-7	7	13

Table 4.8 shows the inclusion of the additional criterion has not changed the ranking of the options. The Jig 3 still ranked at number one best choice to use. Therefore, Jig 3 is proposed to be implement in the operation line.

4.4 Jig Standardization

For the jig standardization, the company need to consider three proposal which is; 1- allocate budget to fabricate real jig, 2- periodical maintenance for the jig calibration and 3- share the same idea or method with other departments if necessary. Budget allocation is necessary for the company to invest for real jig fabrication using the proper material. The budget cost is depends on the material they want to use. Periodical maintenance for jig calibration is needed to ensure that the jig is long lasting. The idea of jig concept also can be share to other department if suitable for their parts.

4.5 Future Work

Since there is only the jig concept is proposed, for future work, the company need to consider if any additional equipment or component need to be include into the jig to make the jig more easy to use and faster time can be achieved. The jig proposal concept is still manually operates by human and automated jig or machine may be necessary for future work.

CHAPTER 5

CONCLUSION

The paper presents the concept development of ejector jig and fixture for dipping process. The use of prototype trial and Pugh Concept Selection Matrix determine the most appropriate decision on design concept was discussed. The most important criteria that need to be considered are the cycle time as well as the quality, cost, delivery, management and safety of the concept selection. As a conclusion, finally the objectives of this project are achieved as below:

1. To investigate the current practice of pin ejection.

   Every area in dipping process had been identified by data collected in manufacturing line visit and complete discussion and analysis with responsible engineer. During the visit, the current practice of pin ejection applied in the factory is using an equipment which has 2.30 kg weight and required longer process time which is 15.83 seconds. The cycle time was taken from three operators for 10 bases of pins and average cycle time is calculated.

2. To design and fabricate the prototype of the jig and fixture to eject the pins from its mold/base.

   Sketching for jig design and Auto CAD drawing was develop to fabricate the prototype of the jig so that the prototype can be tested in the real process at the factory. Three designs was drawn and fabricated which every data collected had been analysis for the best cycle time and countermeasure.

3. To choose the best design for implementation suggestions.

    Based on the three design of jigs, every trial had been completed and followed by the result from Pugh Concept Selection Matrix. As a result, Jig 3 concept was chosen as the best design due to achieve in every quality, cost, delivery, management, and safety requirement for this project.

The result of QCDMS as shown earlier in Table 4.6 shows that the jig is satisfying all the requirement and criteria needed for the company. The cost of production decrease can ensure that the implementation of new jig may increase their company profit which improves the process productivity.

The selected jig also user-friendly for the operator which is easy to use, quick and ergonomic. It is beneficial for the operator since they also need to perform other process such as color dipping and cooling the liquid after heating. It makes the operator work faster and easy. They can improve their work efficiency and also health. New jig is more light weight and no sharp edges that can reduce injuries possibility during performing the ejection process.

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APPENDIX A

Cycle time data collected for current practice and each prototype.

After Eg 1 : Trial, cannot fit in.

No	Cycle time		
	Operator 1	Operator 2	Operator 3
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
Average			
Total Average			

Fail

15 sec

Before Current

No	Cycle time		
	Operator 1	Operator 2	Operator 3
1	14.5	15.6	14.2
2	15.3	15.3	14.5
3	14.8	16.1	14.7
4	14.4	17.4	15.3
5	17.6	15.4	14.9
6	16.9	16.8	15.7
7	14.2	17.3	15.5
8	18.7	18.1	15.2
9	15.4	15.4	16.3
10	16.7	16.3	16.4
Average	15.82	16.37	15.3
Total Average	15.83		

25 sec

Variance (s)
10 sec / sheet

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21/8/14

① Kak Ida :
② Adila :
③ Latipah Kasim :

Jg 2

No	Cycle time		
	Operator 1	Operator 2	Operator 3
1	49.4	50.2	46.9
2	42.6	51.3	43.8
3	43.1	43.5	49.4
4	40.2	45.7	45.6
5	38.2	51.7	39.6
6	44.7	49.4	44.6
7	43.5	48.7	46.2
8	39.5	50.2	45.1
9	38.3	45.6	43.5
10	39.9	47.8	47.2
Average	41.9	43.63	45.19
Total Average	43.57		

Jg 3

No	Cycle time		
	Operator 1	Operator 2	Operator 3
1	4.6	4.3	4.5
2	3.8	4.2	4.3
3	4.4	4.8	4.6
4	4.8	4.9	4.3
5	5.2	5.2	4.5
6	4.3	4.3	4.2
7	4.1	5.7	4.4
8	4.5	5.4	4.5
9	4.3	4.3	4.6
10	4.1	4.2	4.5
Average	4.41	4.7	4.42
Total Average	4.51		

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21/8/14

APPENDIX B

Table for Cost Justification

Cost Breakdown for Finish Good Pin(736 Pins for 1 Base)

NO	ITEMS	COST (RM)	%
1	RAW MATERIAL	6.62	10
2	COMPONENT	3.31	5
3	PROCESS	36.95	56
4	TOOLING	13.25	20
5	ADMINISTRATION	6.11	9
	TOTAL COST	**66.24**	

Process Cost Breakdown (current situation)

PROCESS NAME	MACHINERY	CYCLE TIME (SEC)	COST PER MINUTE (RM)	PROCESS COST (RM)
		(A)	(B)	(A X B)
PIN STICKING	CARREONE MACHINE	31.00	1.00	31.00
DIPPING		4.00	0.30	1.20
PULLING		15.83	0.30	4.75
PROCESS COST TOTAL				**36.95**

Process Cost Breakdown (Jig 2)

PROCESS NAME	MACHINERY	CYCLE TIME (SEC)	COST PER MINUTE (RM)	PROCESS COST (RM)
		(A)	(B)	(A X B)
PIN STICKING	CARREONE MACHINE	31.00	1.00	31.00
DIPPING		4.00	0.30	1.20
PULLING		43.57	0.30	13.07
PROCESS COST TOTAL				**45.27**

Process Cost Breakdown (Jig 3)

PROCESS NAME	MACHINERY	CYCLE TIME (SEC)	COST PER MINUTE (RM)	PROCESS COST (RM)
		(A)	(B)	(A X B)
PIN STICKING	CARREONE MACHINE	31.00	1.00	31.00
DIPPING		4.00	0.30	1.20
PULLING		4.51	0.30	1.35
PROCESS COST TOTAL				**33.55**