Modeling of Manufacturing Assembly Line for 3 Pin Power Plug

by

Nor Azida Bt Abdull Aziz

Dissertation submitted
in partial fulfillment of the requirement for the
Bachelor of Engineering (Hons)
(MECHANICAL ENGINEERING)

JUNE 2004

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
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CERTIFICATION OF APPROVAL

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Approved by,

....

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and the original work contained herein have not been undertaken or done by unspecified sources or persons.

....

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ABSTRACT

The design of assembly lines for production operation is deemed crucial to ensure optimal productivity and minimal work in progress. A case study involving investigation of manufacturing assembly line is to be considered for computer based modeling using WITNESS. The objective of this project is to model a manufacturing assembly line for 3 pin power plug using WITNESS and to conduct a sensitivity analysis that would improve the production capability and output rate. The scope of the project is to conduct the corresponding time study for manufacturing assembly line of 3 pin power plug assembly including setup time and operation time. To conduct a simulation project using WITNESS, there are several phases that to be concerned. The phases are established objectives, scope and level of model details, data collection, structuring the model, building the model, testing the model, experimentation, documentation, presentation of result and implementation. The simulation result for manual assembly shows that the number of finished product is 1332 pieces of 3 pin power plug in per day. The total time taken for manual assembly for a 3 pin power plug is 43.2 sec (including handling time and insertion time). The throughput time is 0.72 per minute. The time taken to insert the part by using single station with one arm is 22 second while using two arms it's just required 9 seconds. The throughput time for single station with one arm robot is 0.46 minute per pieces and for two arms is 0.25 minute per pieces. The result from simulation shows great increased on the number of part produces when we introduce automated assembly. In single station with one arm robot, 2085 pieces produces in daily. The production of the plug increased double if compared with manual assembly. While the double arm robot can produces 3839 pieces of power plug daily. From the result, it shows that the single station system with two robot arm yield the best results. It can be concluded that WITNESS is among one of the powerful tools to do a simulation for assembly lines. Therefore further exploration on how to use the software should be enhanced in order to fully utilize the benefit and capability of the simulation

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CHAPTER ONE

INTRODUCTION

1.1 Background of study

When considering the manufacturing of a product, a company must take into account the factors that affect the choice of assembly method. For a new product, the following considerations are generally important:

- Suitability of the product design
- Production rate required
- Availability of the labor
- Market life of the product

To optimize the assembly processes, the goal is normally to minimize workers' idle time by allocating to each workstation an equal amount of work while observing the precedence restrictions of the elementary work steps. Finally, automating the manufacturing machines by replacing manual labor and human operator control with automated operations and control, so thereby make the manufacturing process faster, more reliable, more accurate, more flexible and less expensive.

1.2 Objectives

- To model the manufacturing assembly line for a 3 pin power plug using WITNESS
- To conduct a sensitivity analysis to improve the production capability and output rate.

1.3 Problem Statement

The design of assembly lines for production operation is deemed crucial to ensure optimal productivity and minimal work in progress. A case study involving investigation of manufacturing assembly line is to be considered for computer based modeling using WITNESS.

This project will include (but not limited to) the following activities:

- Investigation and analytical study of related manufacturing assembly line.
- Production of corresponding simulation model using WITNESS.
- Conduct the appropriate sensitivity analysis on the actual simulated model.
- Propose alternative assembly line design and/or operation.
- Evaluation.

1.4 Scope of the project

The scope of the project will include:

1.4.1 Conduct the corresponding time study for manufacturing assembly line of a 3 pin power plug assembly including:

- Setup time
- Operation time

1.4.2 Analysis and Sensitivity analysis:

- Production rate and capacity
- Throughput time
- Work in progress

CHAPTER TWO

LITERATURE REVIEW

2.1 Production system facilities

A production system is a collection of people, equipment and producers organized to accomplish the manufacturing operations of a company (or other organization). Production system can be divided into two categories or levels as indicated in figure below, [6]:

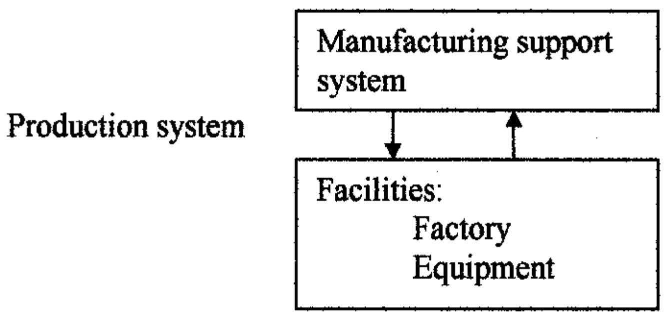


Figure 2.1: The production system consist of facilities and manufacturing support system

- *Facilities*:

  The facilities of the production system consist of the factory, the equipment in the factory and the way the equipment is organized.

- *Manufacturing support system*:

  This is a set of procedures used by the company to manage production and to solve the technical and logistics problems encountered in ordering materials, moving work through the factory, and ensuring that products meet quality standards. Product design and certain business functions are included among the manufacturing support systems.

In modern manufacturing operations, a portion of the production system is automated and or computerized. However, production systems include people. People make these systems work. In general, direct labor people (*blue collar worker*) are responsible for operating the facilities, and professional staffs (white collar worker) are responsible for manufacturing support system.

In creating the layouts, there are several data, which could assist the process. One of the essential data is the frequency of trips or flow of material or some other measure of interaction between facilities. If the data is not available, the facilities designer must at least have subjective information about the flow intensities between facilities. The other data is shape and size of facilities. Besides, it is also important to know the available floor space and the adjacency requirements between pairs of facilities.

There are three types of basic layouts; (1) Process layout, (2) Product layout (assembly line) and (3) Cellular manufacturing.

In general, the production resources of *process layout* are arranged by common processes. This layout is often used to produce or process a large variety of non-standardized products in relatively small batches. As for the *product layout*, the production resources are arranged by the production sequence of products. This layout is common to produce or process a limited number of standardized products with direct material flow. *The Cellular Manufacturing* or *Group Technology* layout is to allocate dissimilar machines into cells to work on products having similar processing requirement. *The Cellular Manufacturing* layout is designed to gain the benefits of product layout in job-shop kind of production.

2.2 Manufacturing system.

Manufacturing can be defined as the application of physical and chemical processes to alter the geometry, properties and appearance of a given starting material to make parts or products; manufacturing also includes the joining of multiple parts to make assembled products. The processes that accomplish manufacturing involve a combination of machinery, tools, power and labor. Manufacturing is almost always carried out as a sequence of operations. Each successive operation brings the material closer to the desired final steps.

A manufacturing system consists of several components. In a given system, these components usually include:

- Production machines plus tools, fixture and other related hardware
- Material handling system
- Computer system to co-ordinate and/ or control the above component
- Human worker

The eight types of manufacturing system are depicted in figure 2.2 below, [6]:

a) **Type I M**: *Single station manned cell.* The cell basic case is one machine and one worker ($n = 1$, $w = 1$). The machine is manually operated or semi-automated, and the worker must be in continuous attendance at the machines.
b) **Type I A**: *Single station automated cell.* This is fully automated machine capable of unattended operation ($M<1$) for extended period of time (longer than one machine cycle). A worker must periodically service it.
c) **Type II M**: *Multi-station manual system with variable routing.* This has multiple stations that are manually operated or semi-automated. The layout and work transport system allow for various routes to be followed by the parts or products made by the system. Work transport between station either manual or mechanized.

d) **Type II A**: *Multi-station automated system with variable routing.* This is the same as the previous system, except the stations are fully automated (n>1, w_i =0, M< 1). Work transport is also fully automated.

e) **Type II H**: *Multi-station hybrid system with variable routing.* This manufacturing system contains both manned and automated stations. Work transport is manual, automated or a mixture (hybrid).

f) **Type III M**: *Multi-station system with fixed routing.* This manufacturing system consists of two or more stations (n>1), with one or more workers at each station (w_i >1). The operations are sequentially, thus necessitating a fixed routing, usually laid out as a production line. Work transport between stations is either manual or mechanized.

g) **Type III A**: *Multi-station automated system with fixed routing.* This system consists of two or more automated stations (n>1, w_i =0, M<1) arranged as a production line or similar configuration. Work transport is fully automated.

h) **Type III H**: *Multi-station hybrid system with fixed routing.* This system includes both manned and automated station.

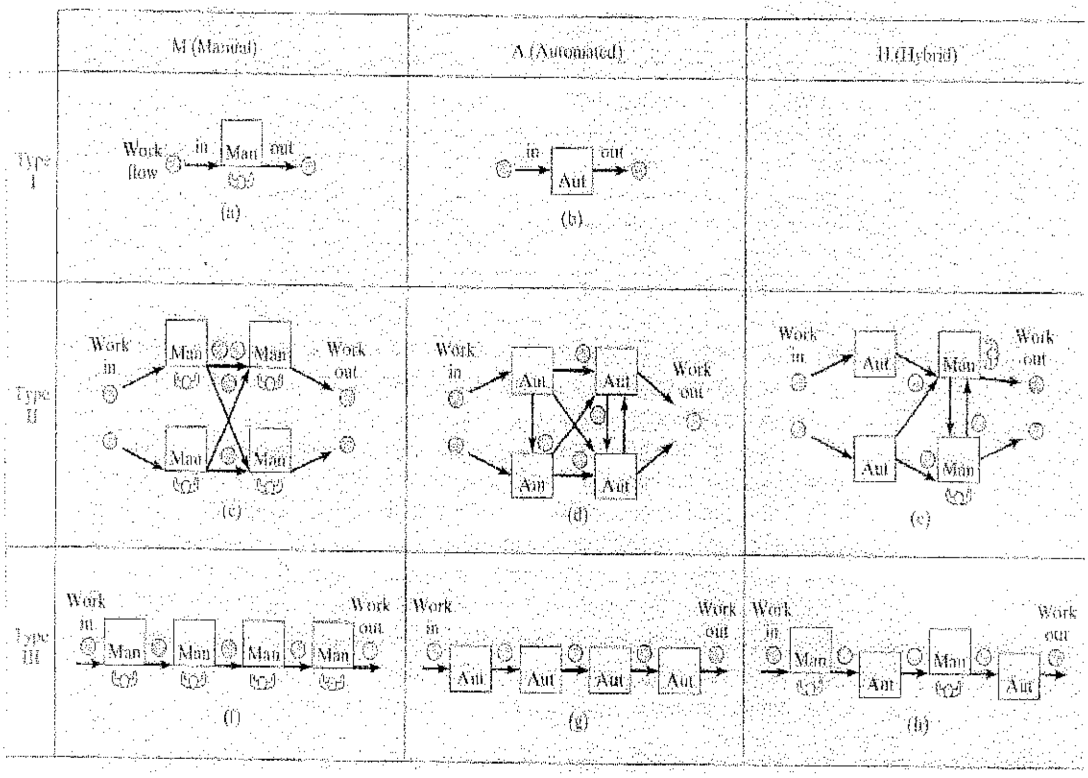


Figure 2.2: Classification of manufacturing system [6]

2.3 Simulation (WITNESS)

Developed in the 1950's, simulation is a process of building a model that mimics reality. Discrete- Event simulation, modeling a system over time, is the ability to model random events based on standard or non-standard distributions and to predict the complex interactions between these events, [7].

A traditional definition of simulation is: the act or process of simulating, feigning; the imitative representation of the functioning of one system or process by means of the functioning of another; examining of a problem often not subject to direct experimentation by means of a simulating device.

Simulation software designers generally define simulation as imitating the operations of various kinds of real world facilities or processes, the process of designing a mathematical-logical model of a real system and experimenting with this model on a computer.

Simulation has much to offer any organization. The role of simulation is to evaluate alternatives that either support strategic initiatives, or support better performance at operational and tactical levels. Simulation provides the information needed to make this type of decisions. The simulation approach supports multiple analyses by allowing rapid changes to a model's logic and data and is capable of handling large, complex system such as manufacturing facilities.

Using simulation to visualize the system under investigation increases the credibility of a project. There are many benefits to be gained through simulation modeling. These include:

- A greater understanding of the system being studied
- Improved communication of ideas
- Lower cost
- Ability to try many options quickly and easily

Simulation provides its users with an understanding of the system being modeled while avoiding the consequences of working with live system. For example:

- The cost of building the proposed system
- Disturbing an existing system
- Destroying a system during stress testing

Simulation allows the user to monitor the dynamics of a system under various conditions. Simulation does not guarantee an optimal solution to any problem; it is the only appropriate analysis technique when formal mathematical methods cannot reflect the natural behavior of a system. Simulation provides:

- Risk reduction
- Greater understanding
- Operating cost reduction
- Capital cost reduction
- Ability to perform 'what if' analysis
- Implementation of the best option

WITNESS is an interactive simulation program. It supports incremental development of the models. It also allows a graphical display of model behavior. The models can also be altered during running.

Witness application includes:

- The evaluation of capital project
- Running models regularly for testing production schedules
- The evaluation of alternative proposals
- The improvement of existing facilities
- The management of changes.

Figures 2.3, 2.4 and 2.5 show an example of a WITNESS simulation model, designer elements and the interactive box in WITNESS

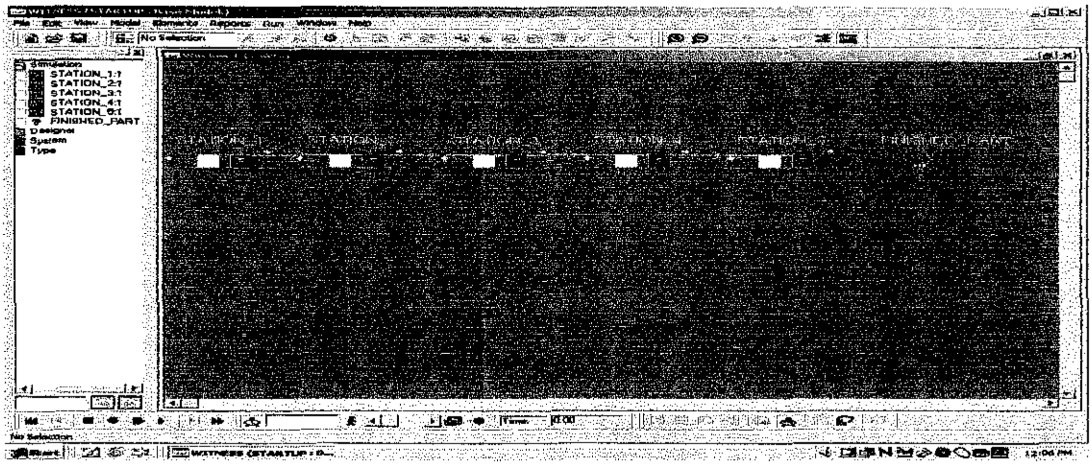


Figure 2.3: WITNESS simulation

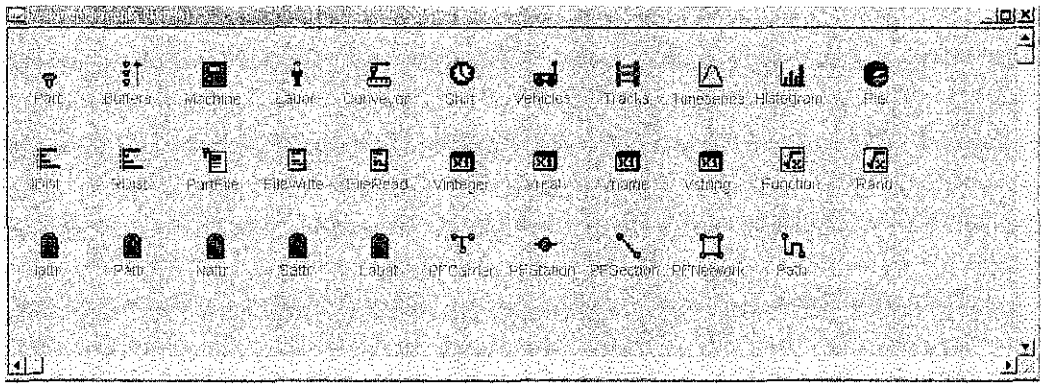


Figure 2.4: Designer element in WITNEES simulation interface

Figure 2.5: Interactive box in WITNEES simulation interface

2.4 Assembly Process

Assembly involves the configuring and attachment of parts to create a product. This activity generally concerns discrete product manufacturing more than continuous process industries such as chemicals and food processing. The current state of assembly technology covers a wide spectrum of capability and practice across many industries, and includes a mix of manual and automated techniques..

The product assembly activities of a manufacturing enterprise can be functionally divided into two sub-elements for assessment and planning purposes:

- Includes all assembly or subassembly processes and equipment required to bring together, configure, align, orient, and adjust components and materials to form the end product.
- Includes all assembly or subassembly processes and equipment required to physically attach parts, materials, and components, such as screwing, riveting, stapling, nailing, gluing, wrapping, interlocking, tying, fusing, sewing, welding, soldering, bonding, pegging, coupling, laminating, insertion, sealing, and similar activities.

If the product has not been design with automated assembly in mind, manual assembly is probably the only possibility. Similarly, automation will not be practical unless the anticipated production rate is high. If labor is plentiful, the degree of automation desirable will depend on the anticipated reduction in cost of assembly ad the increase in production rate assuming the increase can be absorbed by the market.

A shortage of assembly worker will often lead a manufacturer to consider automatic assembly when manual assembly would be cheaper. This situation frequently arises when a rapid increase in demand for a product occurs. Another reason for considering automation in a situation in which manual assembly would be more economical for research and development purposes, where experience in the applications of assembly robots were conducted on this basis.

2.5 Designs for Assembly (DFA)

Once parts are manufactured, they need to be assembled into subassemblies and products. The assembly process consists of two operations, handling followed by insertion.

Design for assembly should be considered at all stages of the design process. As the design team conceptualizes alternative solutions and begin to realize their thought on paper, it should give serious consideration to the ease of assembly of the product or subassembly during production and during field service, [4].

Design engineers need DFA tool to analyze effectively the ease of assembly of the product or subassembly that they design. It should also eliminate subjective judgment from design assessment, allow free association of ideas, enable easy comparison of alternate design, ensure that solutions are evaluated logically, identify assembly problem areas and suggest alternate approach for improving the manufacturing and assembly.

Below is a list of DFA guidelines, [5}:

- *Minimize the total number of parts:* Go through the list of parts in the assembly and identify those parts that are essential for the proper functioning of the product.
- *Minimize the assembly surface*: Simplify the design so that fewer surface need to be prepared in processing.
- *Avoid separate fasteners*: The use of screw in assembly is expensive. Snap fits should be used whenever possible.
- *Minimize assembly direction*: All parts should be design so that they can be assembled from one direction. The need to rotate in assembly requires extra time and motion and may require additional transfer stations and fixtures.
- *Maximized compliance in assembly*: Excessive assembly force may be required when part are not identical or perfectly made.
- *Minimize handling in assembly*: Parts should be designed to make required position easy to achieve.

CHAPTER THREE

METHODOLOGY

3.1 General

In order to perform the project successfully, there are several steps taken. Among the steps are:

- Identify preliminary research work,
- Planning, information or data gathering,
- Structure the design layout,
- Check the parameter for the design layout,
- Simulation,
- Result and discussion.

3.2 Tool

The tool required to conduct this project is WITNESS software. WITNESS has helped to achieve significant benefits, including:

- Validation of new processes prior to launch.
- Improved customer service levels.
- Optimization methods and techniques.
- 3D visualization.
- Data mining analysis.
- Resource forecasting, planning and scheduling links with enabling technologies such as spreadsheet, drawing, CAD, costing packages forecasting.
- Integrated decision support technologies suite.

3.3 Modeling and Simulation

The role of simulation is to evaluate practical alternatives that are available to be analyzed. By modeling, the complexity of a large system, even a big factory is able to handle. In addition, the simulation approach supports sensitivity analysis by allowing rapid changes to a model's logic data. WITNESS is the software that will be used to analyze the operations. WITNESS evolves a visual, interactive and interpretative approach to simulation without the need for compilation. [2]

In order to conduct a simulation project using WITNESS, there are several phases that need to be considered. The phases are listed as following:

3.3.1 *Establish objectives.*

- This is the most important phase of any simulation project. The aim of any simulation project should be to make a better manufacturing decision. As a simulation modeler, the manufacturing decision must be well understand as it is likely to have important implication for the content of the simulation model.

3.3.2 Scope and level of model details.

- The scope of simulation model refers to where it begins and where it ends.
- It is important to limit the scope of the project as far as possible.
- With regard to the levels of detail contain within a model, the golden rule is to model the layout in order to achieve the model's objectives.
- It is possible to use WITNESS elements to represent combination of real world processes and therefore to model a process at the higher levels.

3.3.3 Data collection

- All the data must be collected prior the modeling and simulation
- Whenever the estimation is being used, it should be declared as assumption upon which the model is based. If the model later proves in adequate as the real world situation, then it is possible to scrutinize the assumption upon which it was based.

3.3.4 *Structuring the model*

- An important final step before building a simulation model is to structure it. This will identify the most difficult area for the model building and highlight any additional data requirements that may have been overlooked up to now, such as transfer time between processes.
- This plan typically takes the form of the sketches of the facility to be model. The plan should identify which WITNESS element is to be used to model each real life process.

3.3.5 Building the model

- It is recommended to built the model incrementally, and test the stages thoroughly before built the next stages. It is easier to find the possible problems for a model than we have to search through an entire model.

3.3.6 Testing the model

- Testing a model consist of verification and validation.
- Verification ensures that the content of the model is consistent with our expectation.
- Validation investigates accuracy of the model compared to real world.

3.3.7 *Experimentation*

- Successful experimentation typically involves using a warming up period or starting condition, deciding on the suitable run length, and running the model with more than one random number stream.

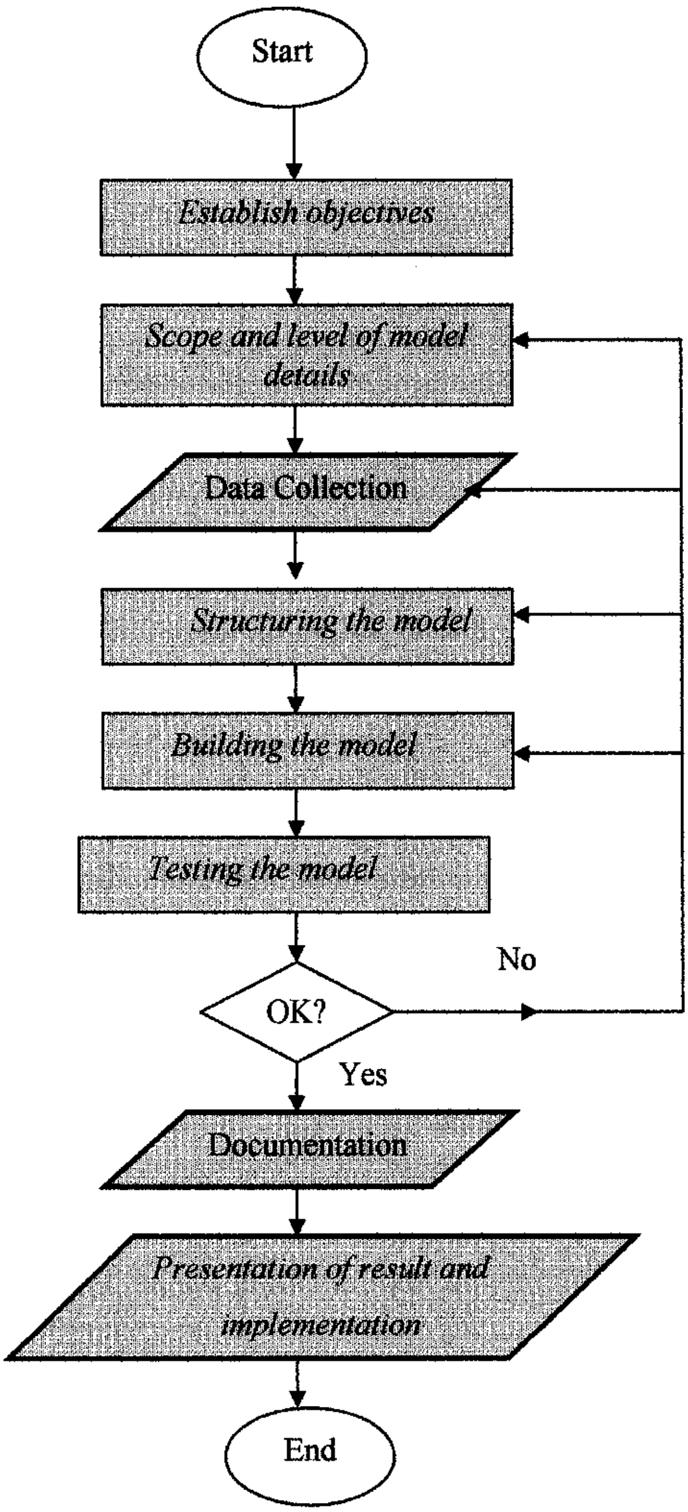
3.3.8 *Documentation*

- It is the good idea to document the way in which we built the building of a model, as it make it easier to understand it if we examine it at the later stages.
- Most element details dialog and display notes in the simulation window can be attached notes to.

3.3.9 Presentation of result and implementation

- The method of presentation of result depends on the size of the simulation project and the culture of the organization.
- An animated model provides an effective communication tools to support business decision particularly if we have enhanced its graphical display.
- The model will evolves to support better decision making in the future.

** Please refer to Figure 3.1 for the flow chart of modeling using WITNESS*



Figures 3.1: Modeling flow chart using WITNESS simulation [2]

CHAPTER 4

CASE STUDY: ASSEMBLY OF THREE-PIN POWER PLUG

4.1 Feasibility Study

The decision to build or purchase an automatic assembly system is generally based on the results of a feasibility study. The objective of this study is to predict the performance and economics of the proposed system. In automated assembly, these predictions are likely to be subjected to greater error than with most other type of production equipment, mainly because the system is probably one of a kind and its performance depends heavily on the qualities of the parts to be assembled.

Certain information is clearly required before a study can be made. For example, minimum and maximum production rates during the probable life of the machines must be known.

For this case study, an assembly process of a three pin power plug has been chosen. This case study is a benchmark of assembly processes. The three pin power plug consist of 10 different parts that will be assembled together to produces a finished product. In the assembly of the power plug, there are 15 operations involved. Among the operations are load base onto work carrier, insertion of fuse clip sub assembly, insertion of neutral pin and etc. The CAD drawing in Figure 4.1 shows clearly the components in three pin power plug.

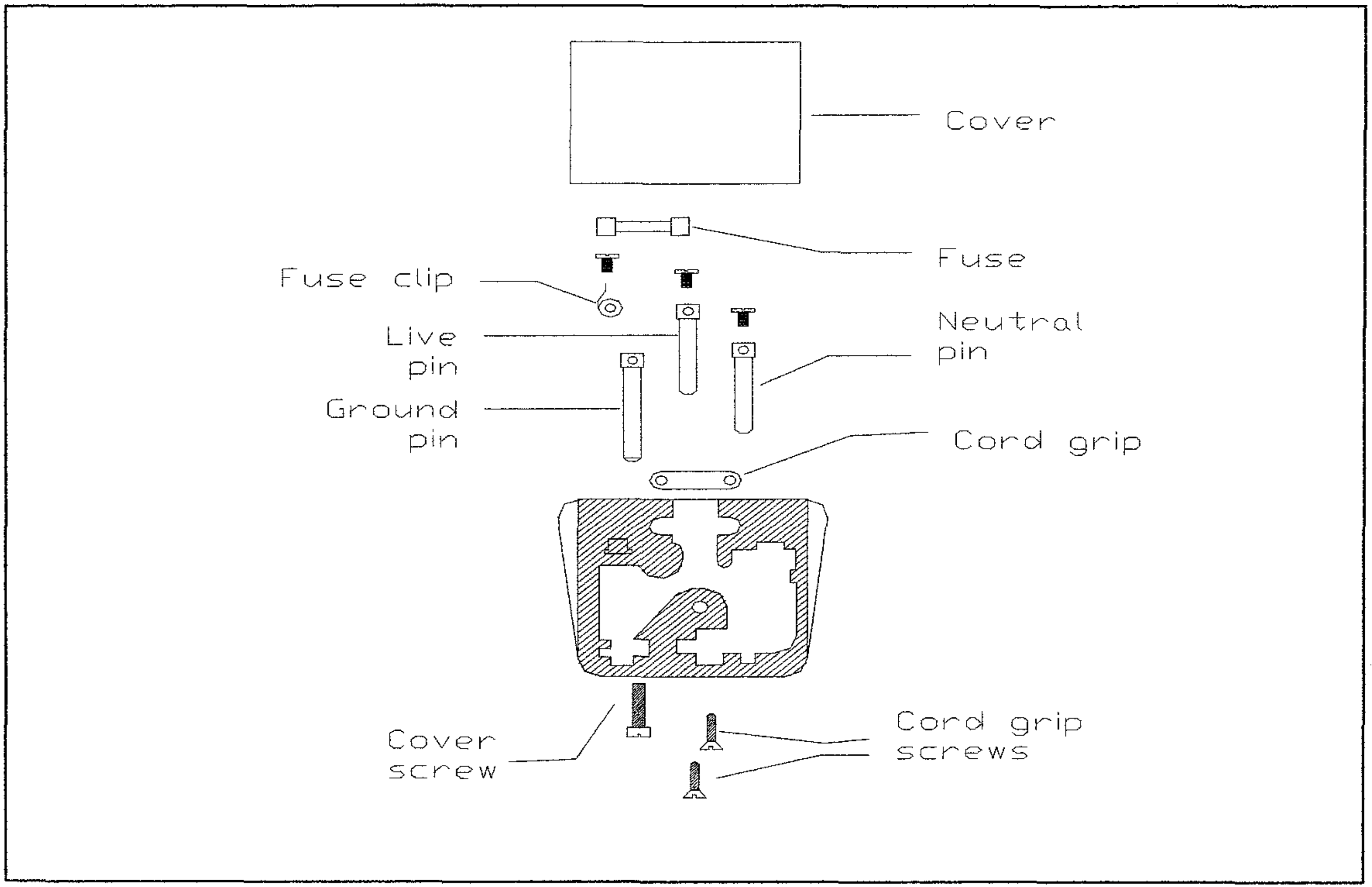


Figure 4.1: CAD drawing for three pin power plug subassembly

4.2 Precedence Diagram

It is always useful when studying the assembly of the product to draw a diagram that shows clearly and simply the various ways in which the assembly operation may be carried out. In most assemblies, there are alternatives in the order in which some of the part may be assembled. There are also likely to be some parts for which no flexibility in order is allowed.

In the precedence diagram, all the operations that can be carried out first are placed in column 1. Usually, only one operation appears in this column; placing the base part on the work carrier. Operations that can be performed only when at least one of the operations in column 1 has been performed are placed in column 2. Lines are drawn from each operation in column 2 to the preceding operations in column 1. Third stage operations are then placed in column 3, with appropriate connecting lines from a given operation to the left indicates all the operations that must be completed before the operation under consideration can be performed.

It can be seen that no flexibility exist in the ordering of operations 1, 7, 8 and 9. Operations 2, 3, 4, 5 and 6, however can be carried out in any order between operations 1 and 7 except cannot be performed until both 4 and 5 are completed. Considering the group of operations 4-6 first, there are two ways in which these can be performed; either 4, 5, 6 or 5, 4, 6. Operation 3 could be performed at any stage in this order, giving 4 x 2 = 8 possibilities. Thus the precedence diagram below represents 40 possible orderings of the various assembly operations and will be useful when we consider the layout of proposed assembly machine.

Figures 4.2, 4.3 and 4.4 show clearly the precedence diagram to assemble the 3 pin power plugs.

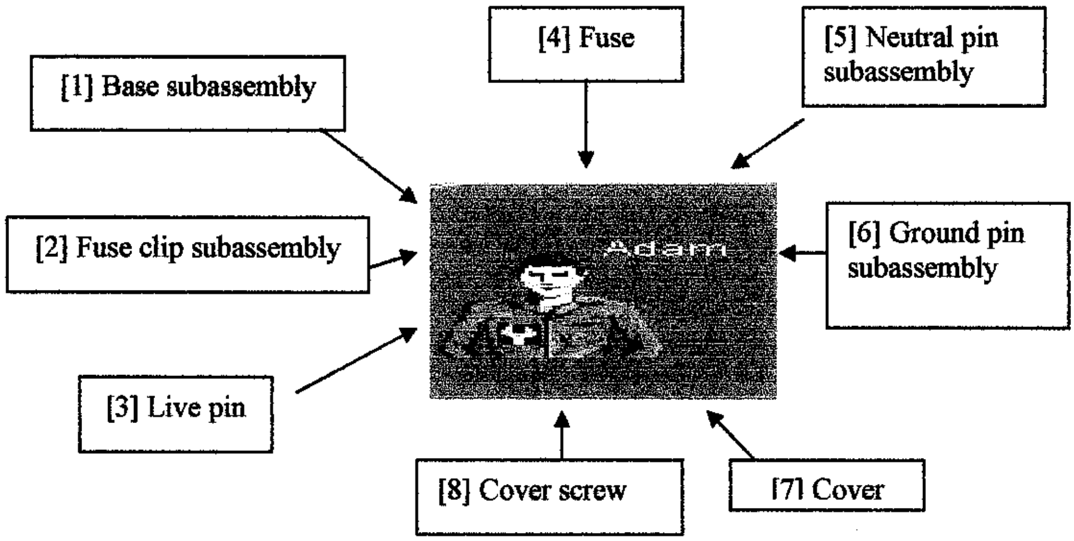


Figure 4.2: Single station Manual assembly for 3 pin power plug

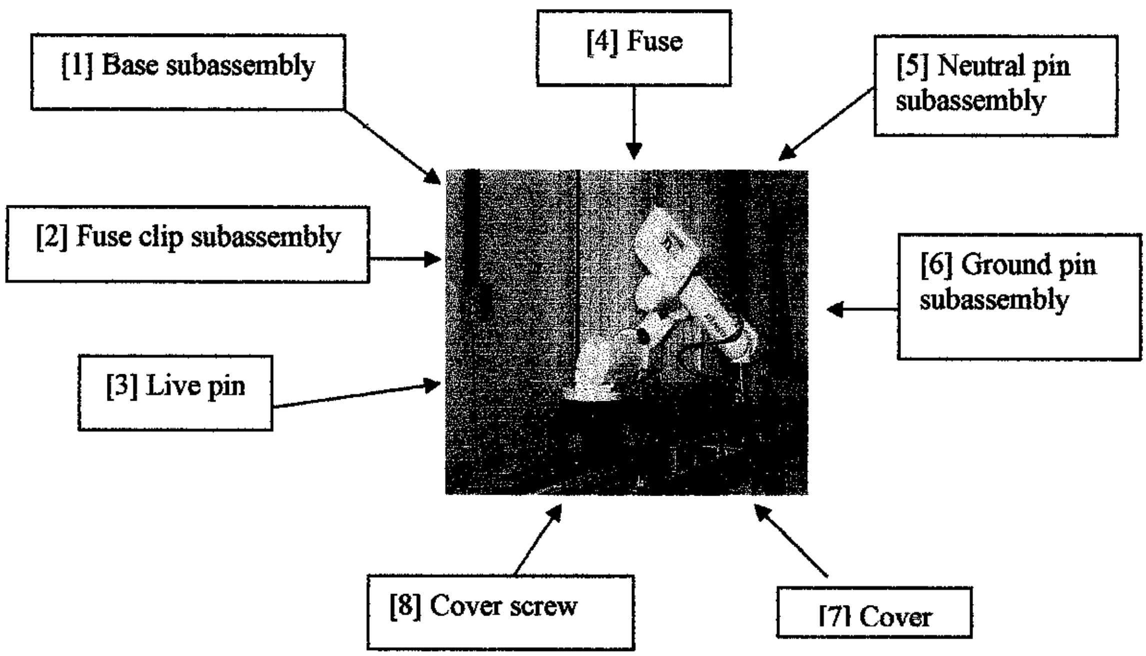


Figure 4.3: Single station One-arm robot assembly for 3 pin power plugs

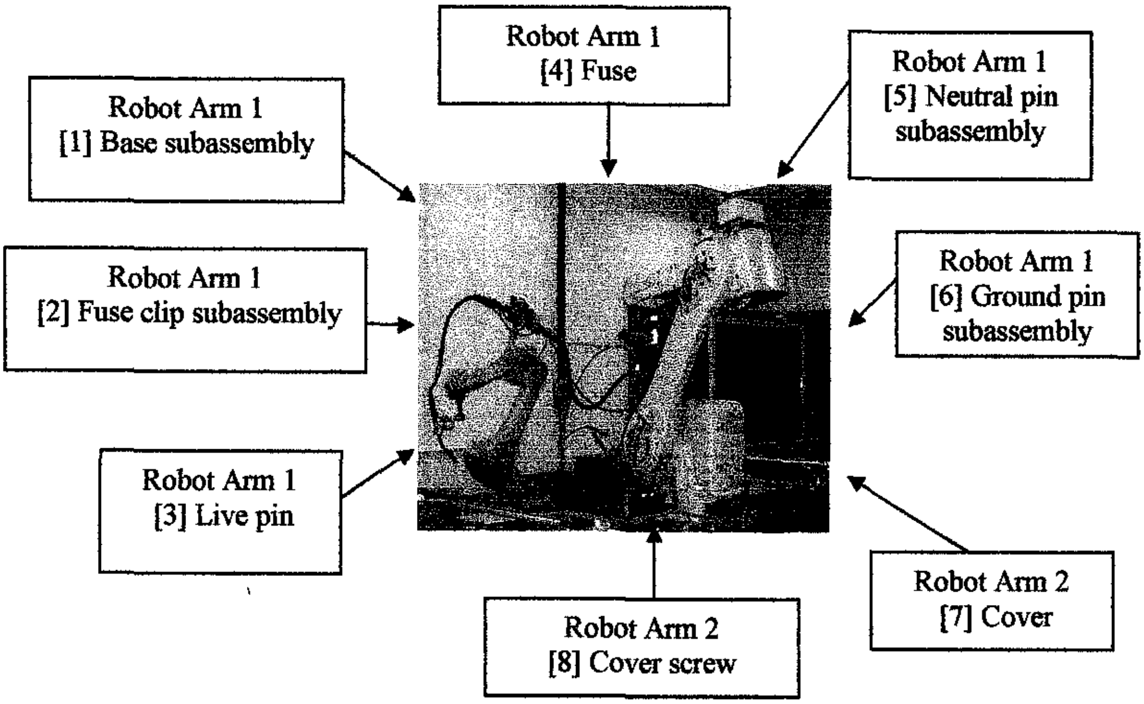


Figure 4.4: Single station Two-arm robot assembly for 3 pin power plugs

PART	TYPES OF ASSEMBLY			
	Handling Time (sec) for all three type of assemblies	Single station Manual assembly	Single station One-Arm Robot Assembly	Single station Two-Arm Robot Assembly
		Insertion Time (sec)		
1. Base subassembly	1.95	1.5	3.0	1.1
2. Fuse clip sub	1.80	1.5	3.0	1.1
3. Live pin	1.13	5.0	3.0	1.1
4. Fuse	1.80	1.5	3.0	1.1
5. Ground pin subassembly	2.73	1.5	3.0	1.1
6. Neutral pin subassembly	1.80	1.5	3.0	1.1
7. Cover	1.95	5.5	3.0	1.4
8. Cover screw	1.5	6	1.0	1.0

Table 4.1: Analysis of 3 Pin Power Plug for various type of assembly

** Please refer to Appendix 1A for manual insertion estimated times*

4.3 Types of design layout

The design layout is important to be analyzed during the modeling of assembly operations. In order to perform the assembly operations for 3 pin power plug, there are three different layouts that are take into consideration. The layouts are namely single station manual assembly, single station one-arm robot and single station two-arm robot. The indexing machines also will be analyzed but the simulation cannot be performed due to the unknown of insertion time for each part in the 3 pin power plug assemblies.

The single station manned cell, is the standard model which consist of one worker tending one machine, is probably the most widely used production method today. It dominates job shop production and batch production, and it is not uncommon even in high production, and it is not uncommon even in high production. Figure 4.3 below shows clearly the layout that has been done in the WITNESS window interface.

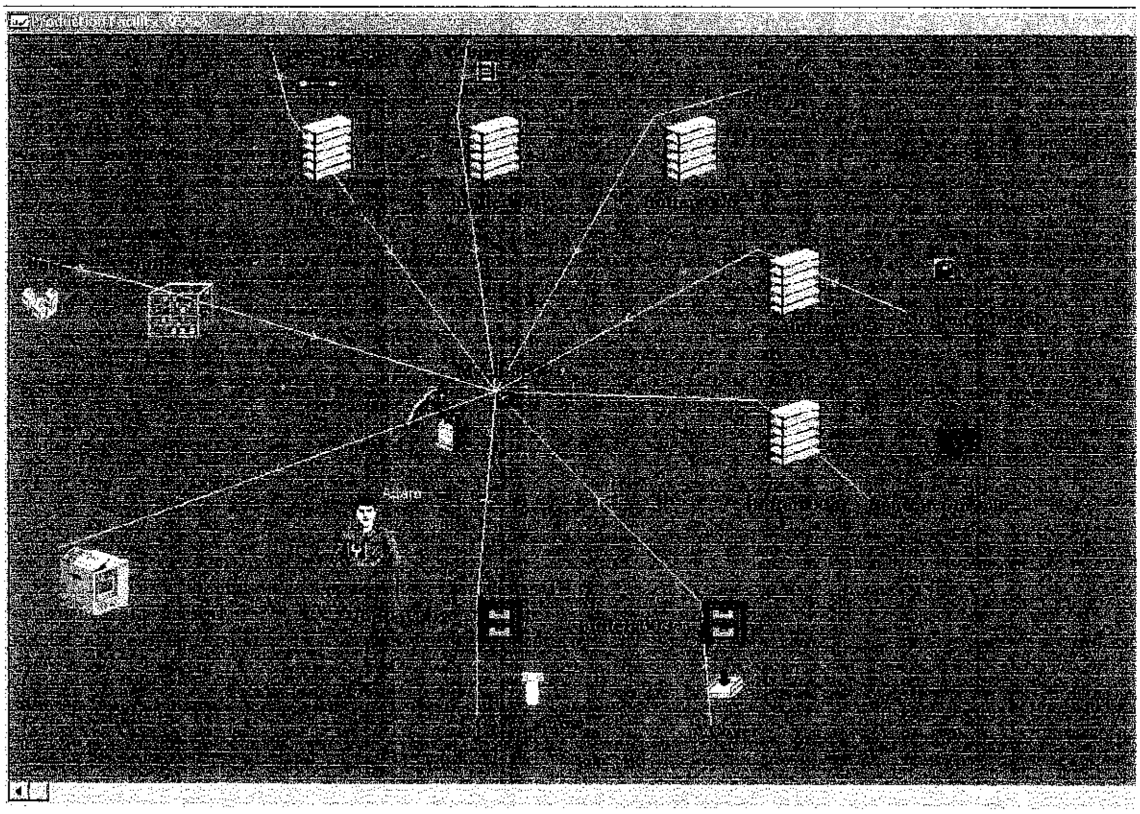
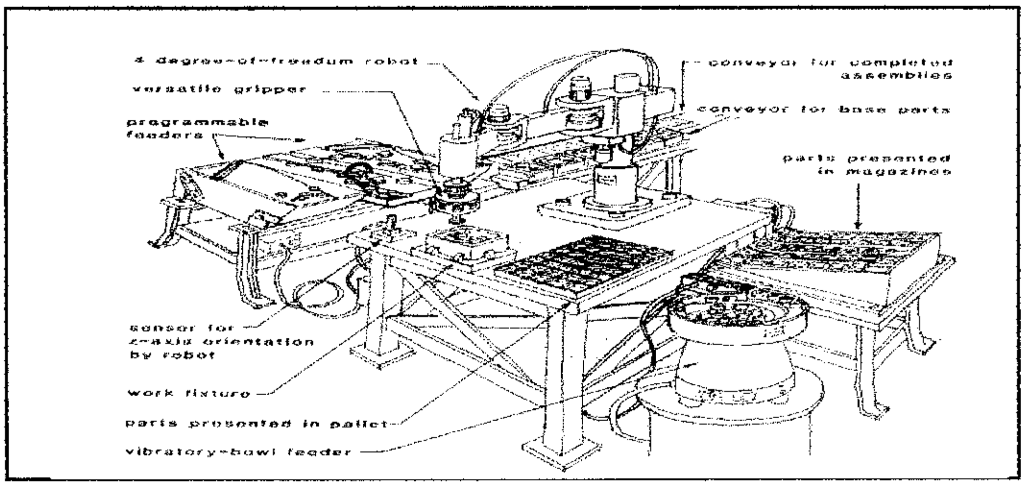
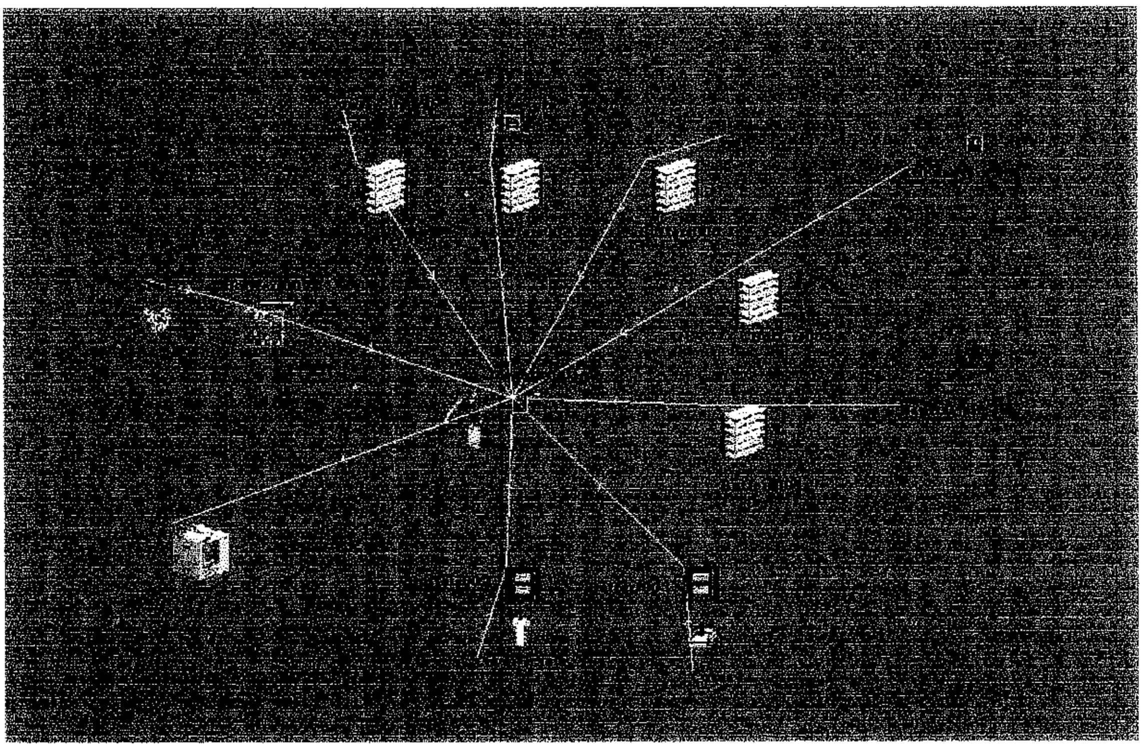


Figure 4.5: WITNESS layout of single station manual assembly for 3 pin power plug

The single station automated cell consists of fully automated machine capable of unattended operation for a time period longer than one machines cycle. A worker is not required to be at the machine except periodically to load and unload parts or otherwise tend it. There are 2 type of single station automated system to be analyzed, that are single station with one arm robot and single station with 2 arm robots.

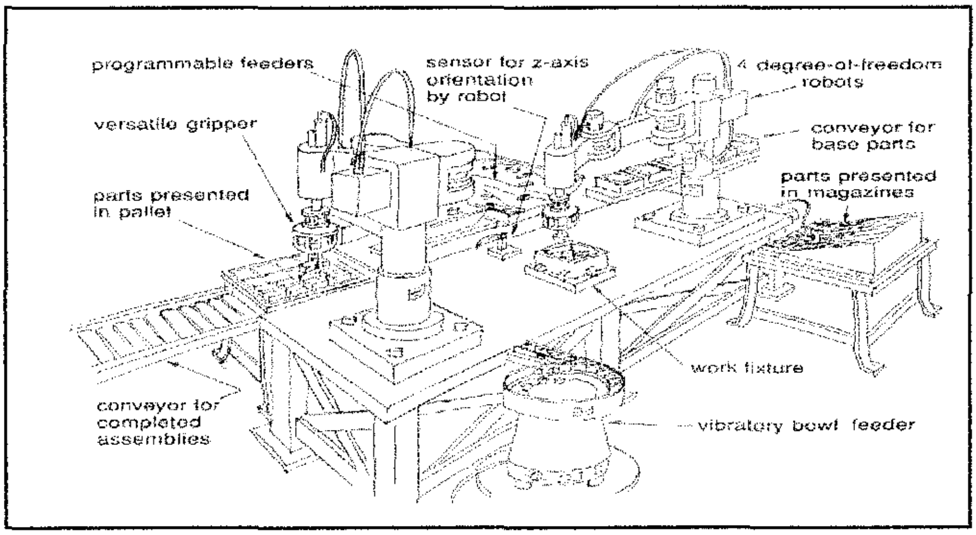


(a)

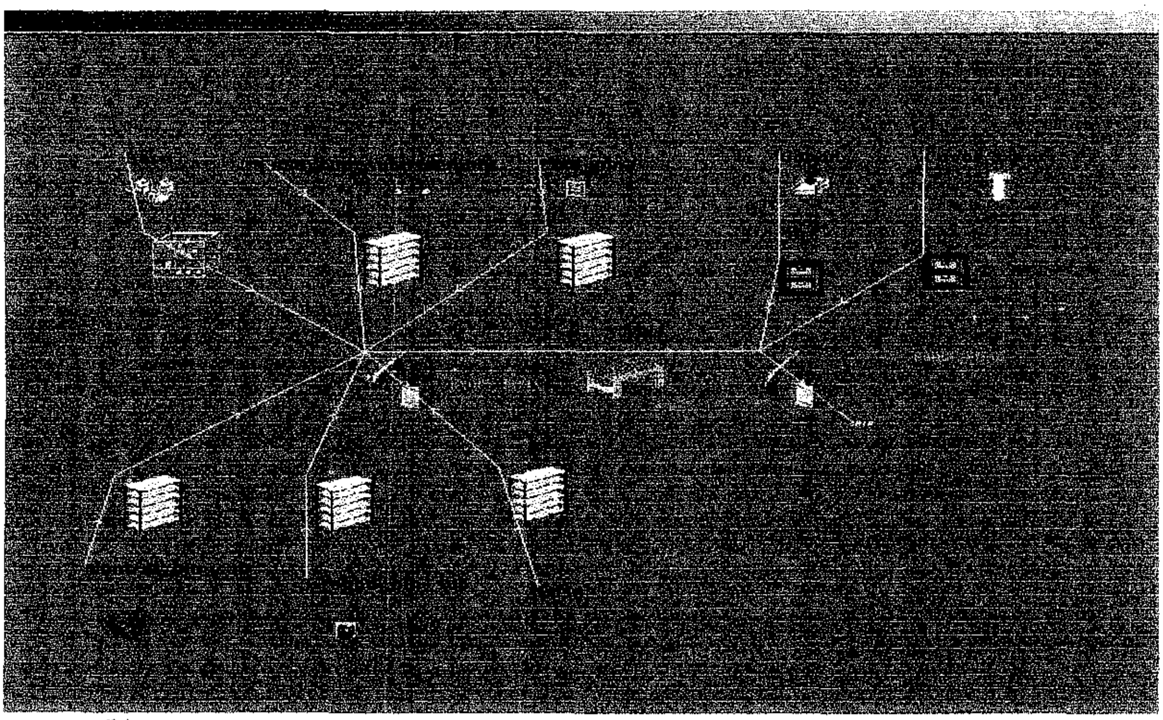


(b)

Figure 4.6: (a) Single Station assembly system with one robot (b) WITNESS layout of single station with one robot assembly for 3 pin power plug



(a)



(b)

Figure 4.7: (a) Single Station assembly system with two robot (b)WITNESS layout of single station with two robot assembly for 3 pin power plug

4.4 Automatic assembly fixture.

In automatic assembly, the various individual operations are generally carried out at single workstations. For this purpose, the assembly is usually built up on a base or work carrier, and the machines is designed to fix the base to the fixture. This step is carried out by the robot pick the base from tray or pallet and put it to the fixture. For this method of assembly, the fixture must be provided to ensure that no relative motion exists between the assembly and the work head or robot while the operations are being carried out.

An example of typical fixture for single station robot assembly is shown below:

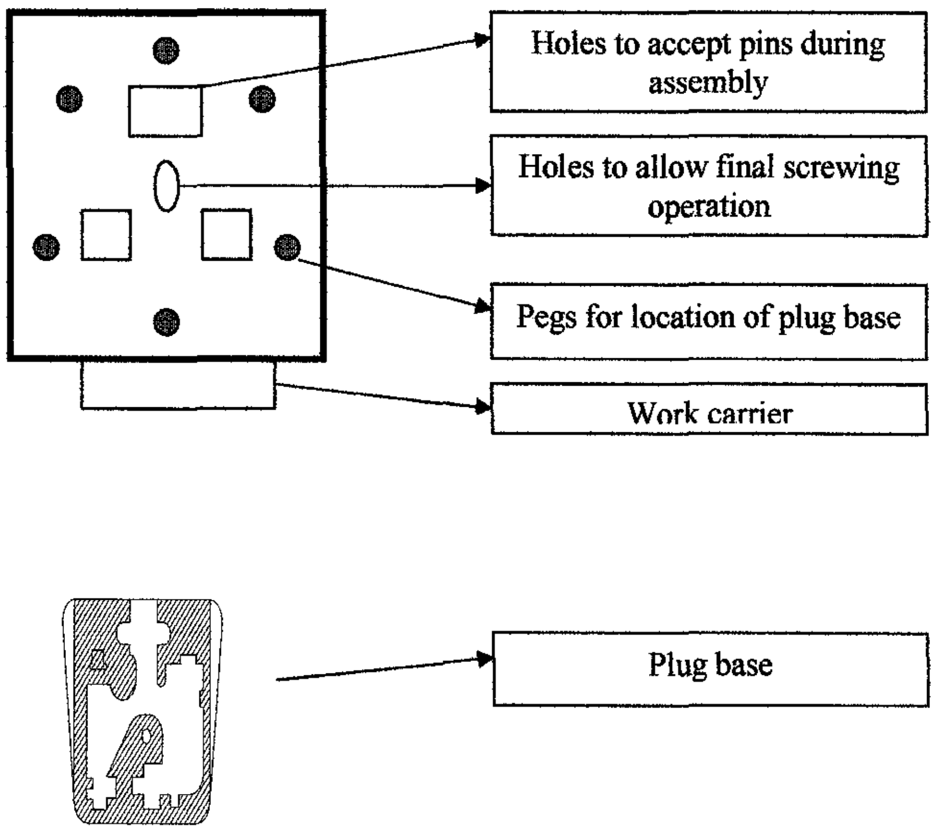


Figure 4.8: Work carriers suitable for holding and transferring three pin power plugs

4.5 Indexing machines

If it is assumed that the base, top and fuse clip are to be assembled manually on the in-line indexing machine, at least two assembly workers will be required. The first positioned at the beginning of the line, could place the base subassembly on the work carrier and place the fuse clip assembly in the base (operations 1 and 5, respectively). The second assembly worker could assemble the cover and remove the complete plug assembly from end of the line (operation 7 and 9).

It is generally necessary for an assembly machine to include some inspection stations. It is clear that after plug cover has been assembled, there will be no simple means of inspecting for the presence of the fuse clip, the fuse, and the three small screw in the neutral and earth pins and fuse clip. Thus it will be necessary to include an inspection head on the machine immediately before operation 7 (the assembly of cover), which will check for the presence of these parts.

It is also necessary to decide whether the inspection head should be designed to stop the machine in the event of a fault or to prevent further operations being performed on the assembly. In this case, it will be assumed that the memory system is incorporated where the inspection head will be designed to activate the memory system rather than to stop the machines.

The general layout of a suitable in-line indexing machine is shown below. Note that operations 4 and 6 have been arranged immediately after first (manual) station to minimize the possibility of the fuse clip becoming displaced during the machine index. When the fuse is in position, the fuse clip is then positively retained. These desirable features provide further restriction in the order or assembly, and the precedence diagram is modified as shown in Figure 4.9 [1]

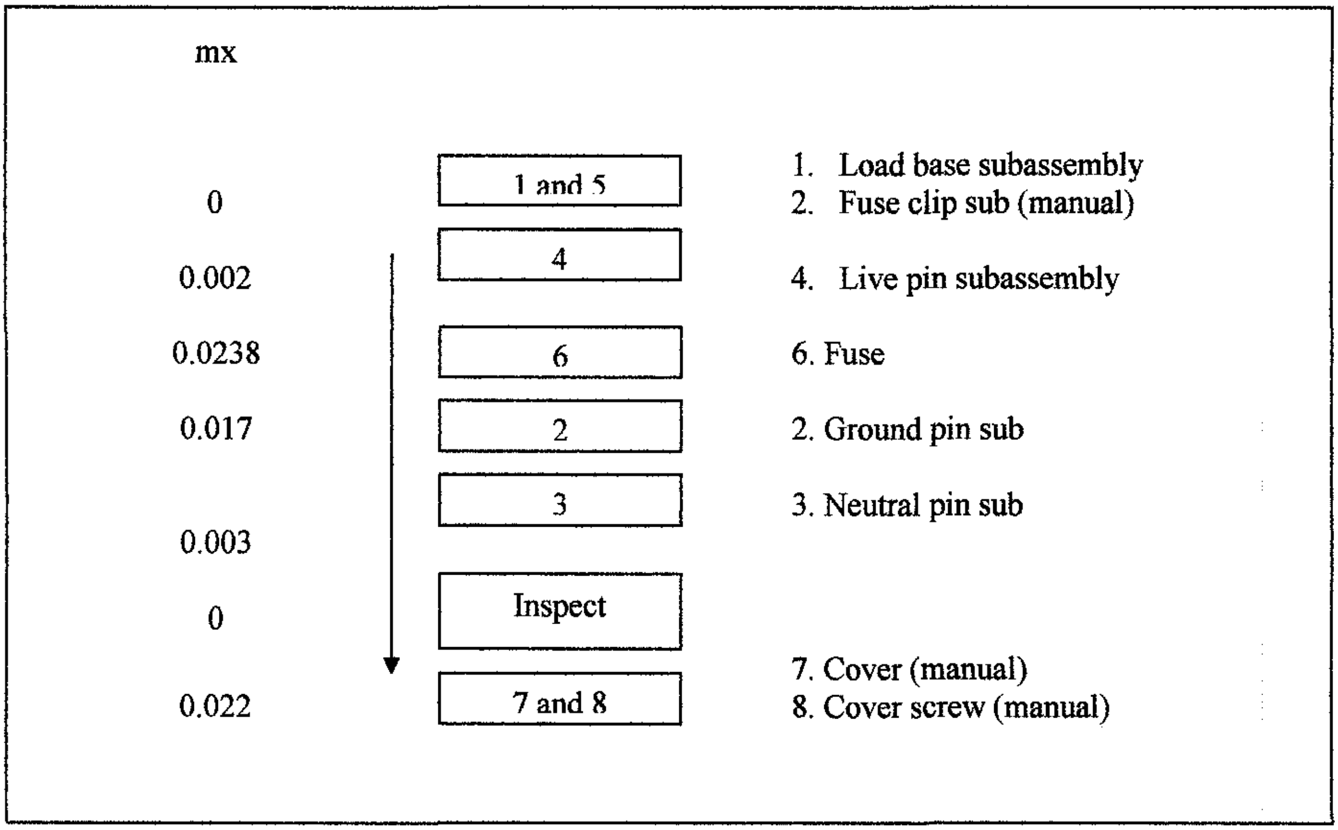


Figure 4.9: Station layout of in-line indexing machine [1]

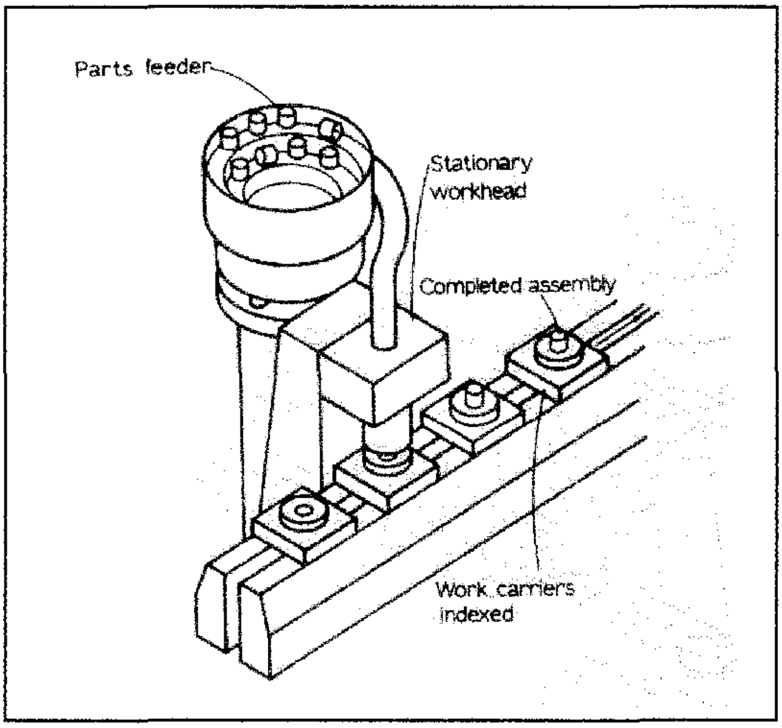


Figure 4.10: In-line indexing machine [1]

The downtime on an indexing machine is given by the sum of the downtime on the individual heads due to the feeding of defective parts plus the effective downtime due to the production of unacceptable assemblies.

If for each machines station, x is the effective proportion of defective to acceptable parts, then *mx* is the average proportion of defective that will cause a machine stoppage, and *(1-m)x* is the effective average proportion of defectives that will spoil the assembly but not stop the machine. The downtime due to the machine stoppages and the final production rate are found as follows.

In the production of N assemblies, the number of machine stoppages is $N\sum mx$, where $\sum mx$ is the sum of the individual values of *mx* for the automatic work heads.

If T is the average time to correct a fault and restart the machine, the downtime due to machine stoppages is $NT\sum mx$; if t is the machine cycle time, the proportion of downtime D will be given by

$$D = \frac{\sum mx}{t/T + \sum mx}$$

The figure then are rearrange in the table below to give the effective quality levels for various operations. From the figures, it can be seen that the value of $\sum mx$ is 0.0678 and assuming that t = 7.7 (the time taken to place the base subassembly on the work fixture and assemble the fuse clip) and that T(the average time to correct a fault and restart the machine) = 40 sec, yield:

$$D = \frac{0.0678}{7.7/40 + 0.0678} = 0.26\ (26\%)$$

Operation	Automatic station on free transfer machine	Effective quality level, x	Ratio of defectives causing machine stoppages , m	mx	(1-m)x
1. Assemble base subassembly to work carrier	-	0.001	0	0	0.001
2. Assemble earth pin subassembly into base	4	0.017	1.0	0.017	0
3. Assemble neutral pin subassembly into base	3	0.003	1.0	0.003	0
4. Assemble live pin into base	1	0.002	1.0	0.002	0
5. Assemble fuse clip subassembly into base	-	0	0	0	0
6. Assemble fuse into live pin and fuse clip	2	0.0294	0.813	0.0238	0.0056
7. Assemble cover	5	0.001	0	0	0.001
8. Assemble cover screw	5	0.022	1.0	0.022	0
9. Remove complete assembly	-	0	-	-	-
10. Inspection	-	0.01	0	0	0.01
Totals				0.0678	0.0176

Table 4.2: Effective quality levels in assembly of power plug [1]

During the time the machines is operating, some of the assemblies produced will contain defective parts that did not stop the machine and, assuming that no assembly contains more than one such defective part, the production rate of acceptable assemblies P_a will be given by:

$$P_a = \frac{[\,1 - \sum (1-m)x\,]\,(1-D)}{t}$$

From the table $\sum(1\text{-m})x = 0.0176$ and therefore from equation and t = 7.7 (the time taken to place the base subassembly on the work fixture and assemble the fuse clip)

$$P_a = \frac{(0.9812)\,0.74}{7.7} = 0.094 \text{ assemblies / sec (5.7 assemblies / min)}$$

CHAPTER FIVE

RESULTS

5.1 Result and finding

WITNESS simulation was used to investigate weather the theory is correlates with the layout of the system or not. By doing the simulation, the sensitivity analysis can be conducted to test how sensitive or critical this data due to the change that will be introduces to the system.

For the simulation, the systems are evaluated in daily basis.

1 day = 2 shift /day * 8hrs/ shift * 60min / 1hr

= 960 minutes / day

= 16 hrs / day

The results are then were tabulated in the given table and graph.

From the result, the throughput time and production rate can be calculated based on the formula given below:

Production Rate = No of parts produced / 16 hours

Throughput Time = (16 hours / No of parts produced) * (60 minutes / 1 hr)

5.1.1 Analysis of manual assembly for 3 pin power plug

From the simulation that has been done using WITNESS software, the results for manual assembly in daily operation (16 hrs) are tabulated below:

Manual labor	
% of busy	99.93
% of idle	0.07
No of parts produced	1332

Table 5.1: Statistic from WITNESS simulation for the condition of labor

Name	Base	Fuse clip sub	Live pin	Fuse	Ground pin sub	Neutral pin sub	Cover	Cover screw
No. Entered	1334	1334	1334	1334	1333	1333	1333	1333
No. Assembled	0	1332	1332	1332	1332	1332	1332	1332
No. Rejected	0	0	0	0	0	0	0	0
W.I.P.	2	2	2	2	1	1	1	1

Table 5.2: Statistic from WITNESS simulation for the part to be assembled by the labor

Name	B2	B3	B4	B5	B6	B7	B8	B9
Total In	1333	1333	1333	1333	1334	1334	1334	1334
Total Out	1333	1333	1333	1333	1333	1333	1333	1333
Now In	0	0	0	0	1	1	1	1
Max	1	1	1	1	1	1	1	1
Min	0	0	0	0	0	0	0	0

Table 5.3: Statistic from WITNESS simulation for the condition at the buffer

Production Rate = No of parts produced / 16 hours

= 83.25 units / hrs

Throughput Time = (16 hours / No of parts produced) * (60 minutes / 1 hr)

= 0.72 min / piece

The table and graph in the next page will demonstrate the condition for every hour the manual assembly of 3 pin power plug.

Time (minutes)	%of Busy	% of Idle	No of parts produced
15	95.71	4.29	19
30	97.86	2.14	40
60	98.93	1.07	82
120	99.46	0.54	165
180	99.64	0.36	249
300	99.79	0.21	415
360	99.82	0.18	499
480	99.87	0.13	665
540	99.88	0.12	749
600	99.89	0.11	832
780	99.92	0.08	1082
870	99.93	0.07	1207
960	99.93	0.07	1332

Table 5.4: % of busy, % of idle and no of parts produced *at various times (minutes) of manual assembly for 3 pin power plug.*

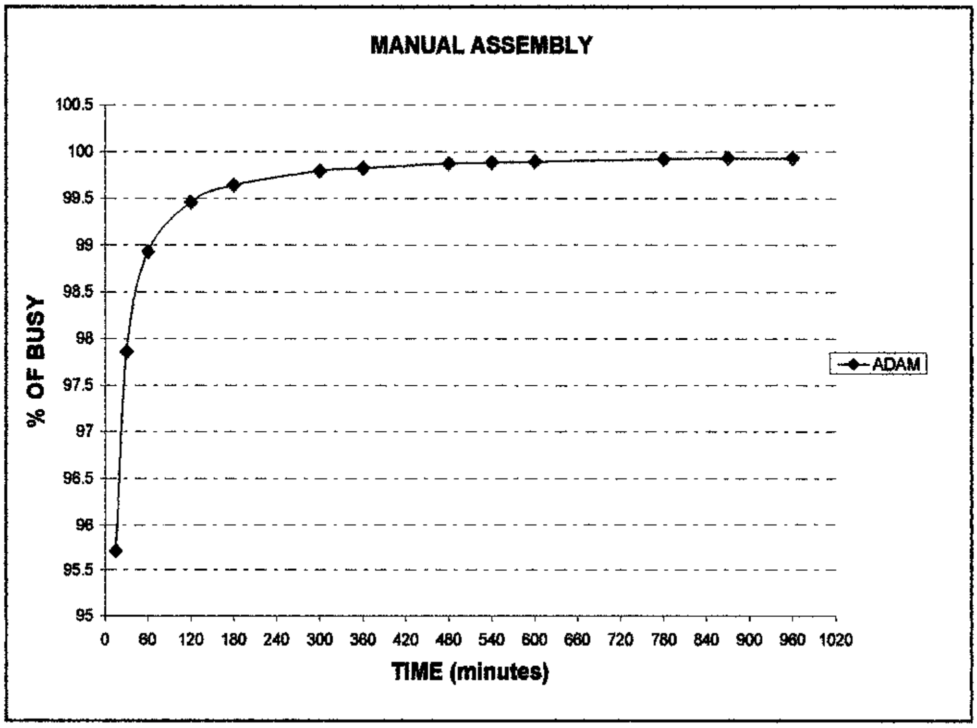


Figure 5.1:% of busy (labor condition) for every hour in manual assembly

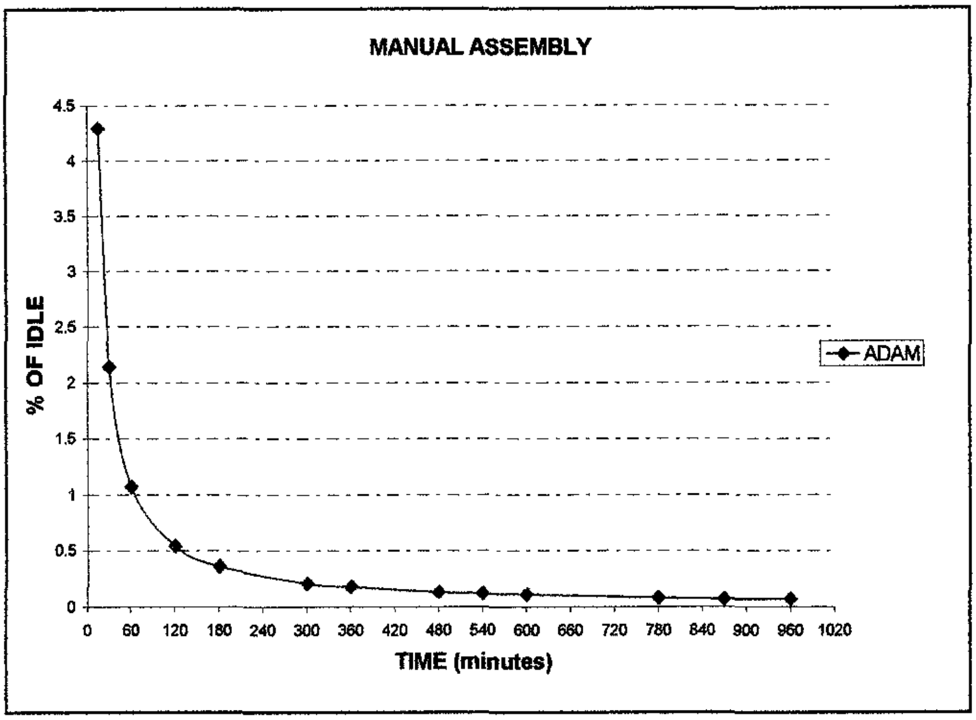


Figure 5.2: % of idle (labor condition) for every hour in manual assembly

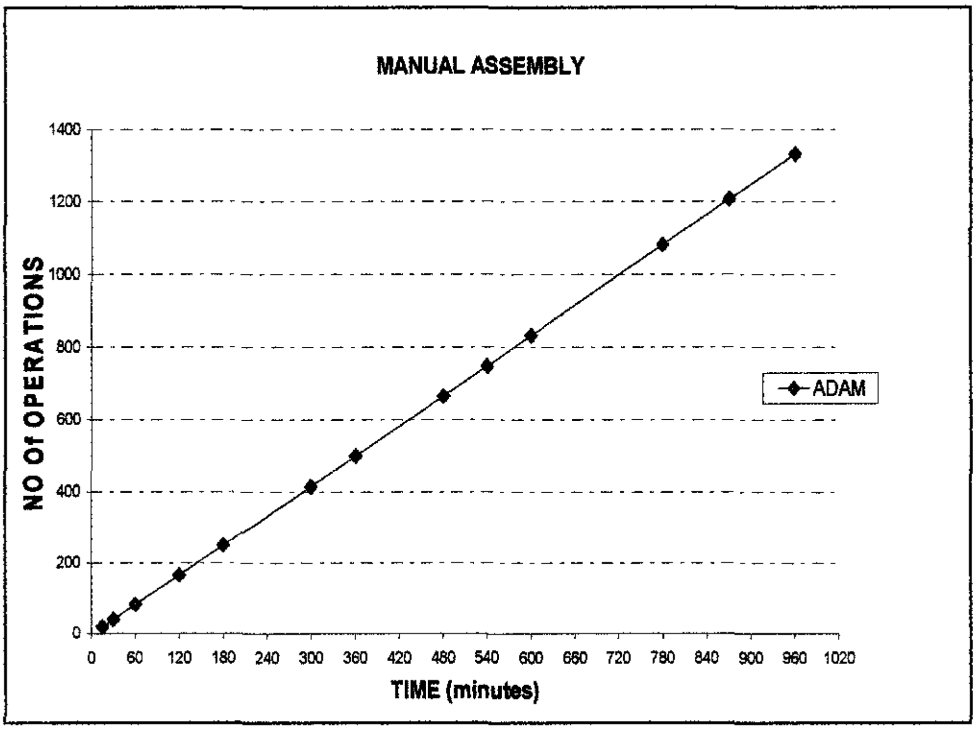


Figure 5.3: No of parts produced *for every hour in manual assembly*

5.1.2 Analysis for Single station One-Arm Robot Assembly

From the simulation that has been done using WITNESS software, the results for single station one-arm robot assembly in daily operation (16 hrs) are tabulated below:

Single station One-Arm Robot Assembly	
% of busy	99.96
% of idle	0.04
No of parts produced	2085

Table 5.5: Statistic from WITNESS simulation for the condition of robot in single station one arm robot assembly

Name	Base	Fuse clip sub	Live pin	Fuse	Ground pin sub	Neutral pin sub	Cover	Cover screw
No. Entered	2086	2086	2086	2086	2086	2086	2086	2086
No. Assembled	2085	2085	2085	2085	2085	2085	2085	2085
No. Rejected	0	0	0	0	0	0	0	0
W.I.P.	1	1	1	1	1	1	1	1

Table 5.6: Statistic from WITNESS simulation for the part to be assembled by the robots

Name	B2	B3	B4	B5	B6	B7	B8	B9
Total In	2086	2086	2086	2086	2086	2086	2086	2086
Total Out	2086	2086	2086	2086	2086	2086	2086	2086
Now In	0	0	0	0	0	0	0	0
Max	1	1	1	1	1	1	1	1
Min	0	0	0	0	0	0	0	0

Table 5.7: Statistic from WITNESS simulation for the condition at the buffer

Production Rate = No of parts produced / 16 hours

= 130.3125units / hrs

Throughput Time = (16 hours / No of parts produced) * (60 minutes / 1 hr)

= 0.46 min / piece

The table and the graph in the next page will demonstrate the condition for every hour of single station one arm robot assembly for 3 pin power plug.

Time (minutes)	%of Busy	% of Idle	No of parts produced
15	97.53	2.47	36
30	98.77	1.23	80
60	99.38	0.62	150
120	99.69	0.31	315
180	99.79	0.21	625
240	99.85	0.15	975
360	99.9	0.1	1105
420	99.91	0.09	1200
480	99.92	0.08	1315
540	99.93	0.07	1400
600	99.94	0.06	1555
690	99.95	0.05	1735
780	99.95	0.05	1885
870	99.96	0.04	1975
960	99.96	0.04	2085

Table 5.8: % of busy, % of idle and no of parts produced *at various times (minutes) of single station one arm robot assembly for 3 pin power plugs*

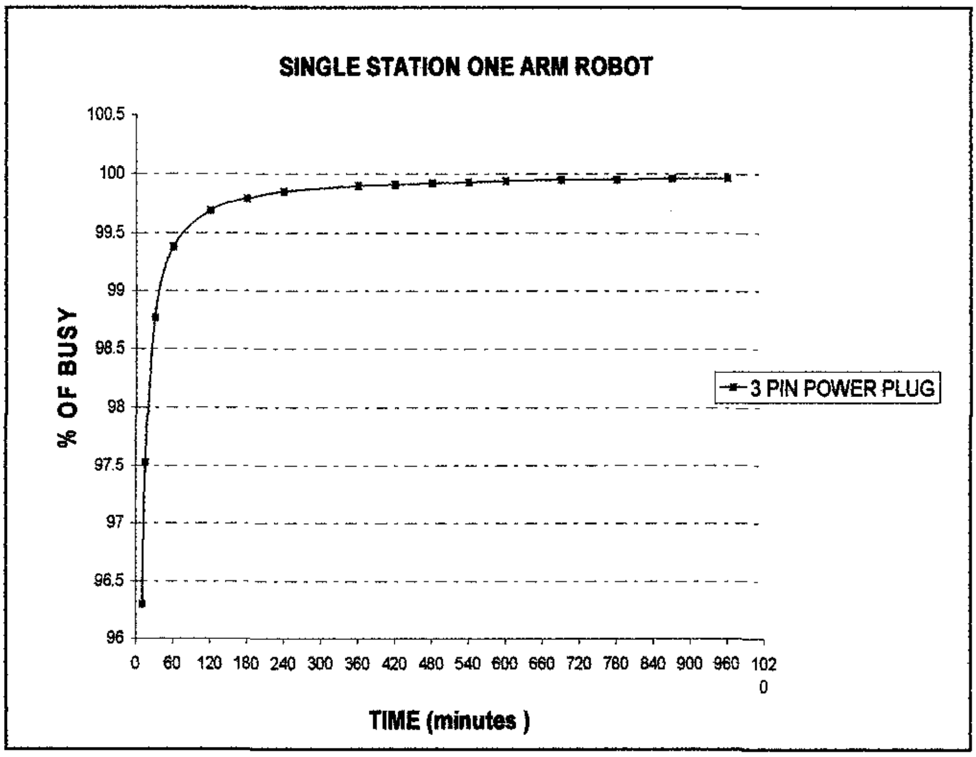


Figure 5.4:% of busy for every hour in single station one-arm robot assembly

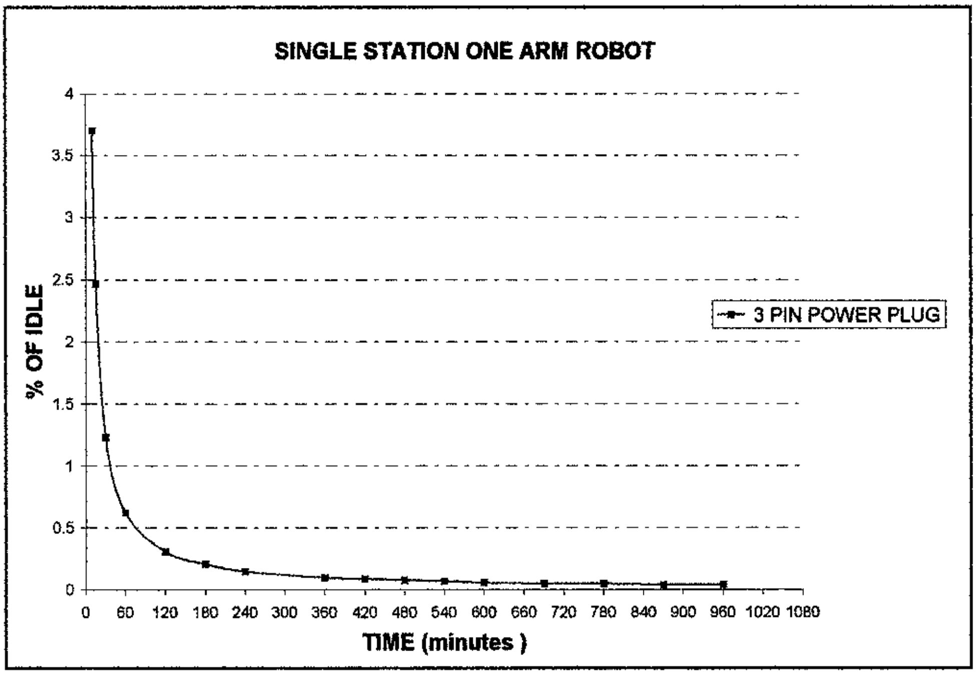


Figure 5.5:% of idle for every hour in single station one-arm robot assembly

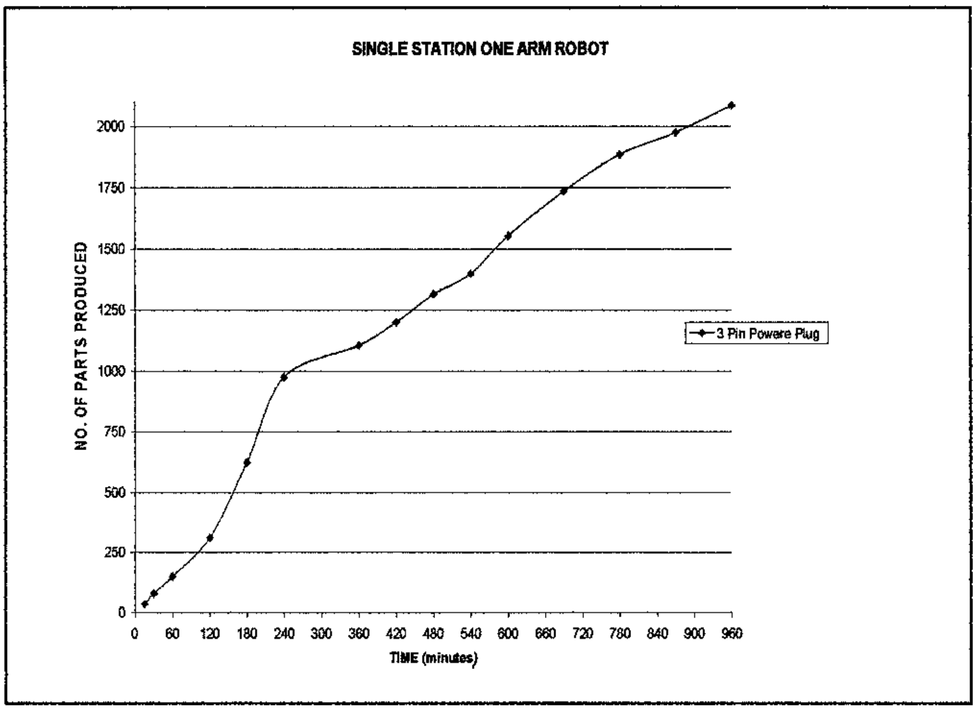


Figure 5.6: No of parts produced *for every hour in* single station one-arm robot assembly

5.1.3 Analysis for Single station Two -Arm Robot Assembly

From the simulation that has been done using WITNESS software, the results for single station two-arm robot assembly in daily operation (16 hrs) are tabulated below:

Single station Two-Arm Robot Assembly	
% of busy	99.98
% of idle	0.02
No of parts produced	3839

Table 5.9: Statistic from WITNESS simulation for the condition of robots in single station one arm robot assembly

Name	Base	Fuse clip sub	Live pin	Fuse	Ground pin sub	Neutral pin sub	Cover	Cover screw
No. Entered	3841	3840	3840	3840	3840	3840	3840	3840
No. Assembled	3839	3839	3839	3839	3839	3839	3839	3839
No. Rejected	0	0	0	0	0	0	0	0
W.I.P.	2	1	1	1	1	1	1	1

Table 5.10: Statistic from WITNESS simulation for the part to be assembled by the robots

Name	Table	B2	B3	B4	B5	B6	B7	B8	B9
Total In	3841	3840	3840	3.840	3840	3840	3840	3840	3840
Total Out	3839	3839	3839	3839	3839	3839	3839	3839	3839
Now In	0	0	0	0	0	0	0	0	0
Max	2	1	1	1	1	1	1	1	1
Min	0	0	0	0	0	0	0	0	0

Table 5.11: Statistic from WITNESS simulation for the condition at the buffer

Production Rate = No of parts produced / 16 hours

= 239.9375 units / hrs

Throughput Time = (16 hours / No of parts produced) * (60 minutes / 1 hr)

= 0.25 min / piece

The table and the graph in the next page will demonstrate the condition for every hour of single station two arm robots assembly for 3 pin power plug.

Time (minutes)	%of Busy	% of Idle	No of operations
15	97.05	1.97	69
30	99.02	0.98	169
60	99.51	0.49	369
120	99.75	0.25	619
180	99.84	0.16	939
240	99.88	0.12	1299
360	99.92	0.08	1616
420	99.93	0.07	1966
480	99.94	0.06	2266
540	99.95	0.05	2566
600	99.95	0.05	2866
690	99.96	0.04	3166
780	99.96	0.04	3466
870	99.97	0.03	3666
960	99.97	0.03	3839

Table 5.12: % of busy, % of idle and no parts produced *at various times (minutes) of single station two arm robot assemblies for 3 pin power plug*

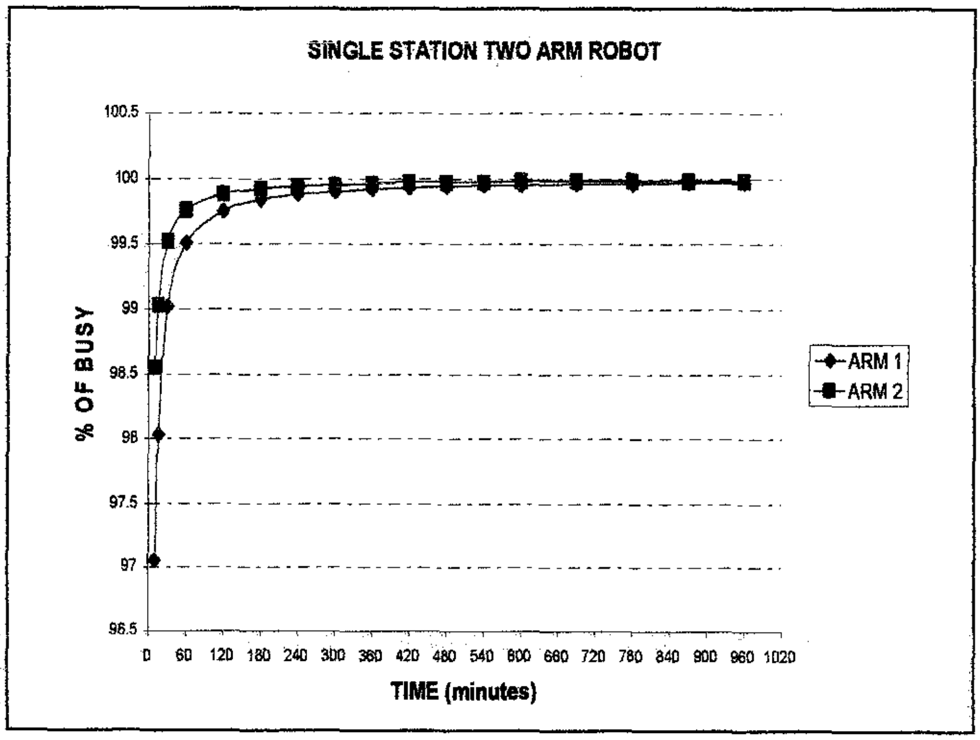


Figure 5.7:% of busy for every hour in single station two-arm robot assembly

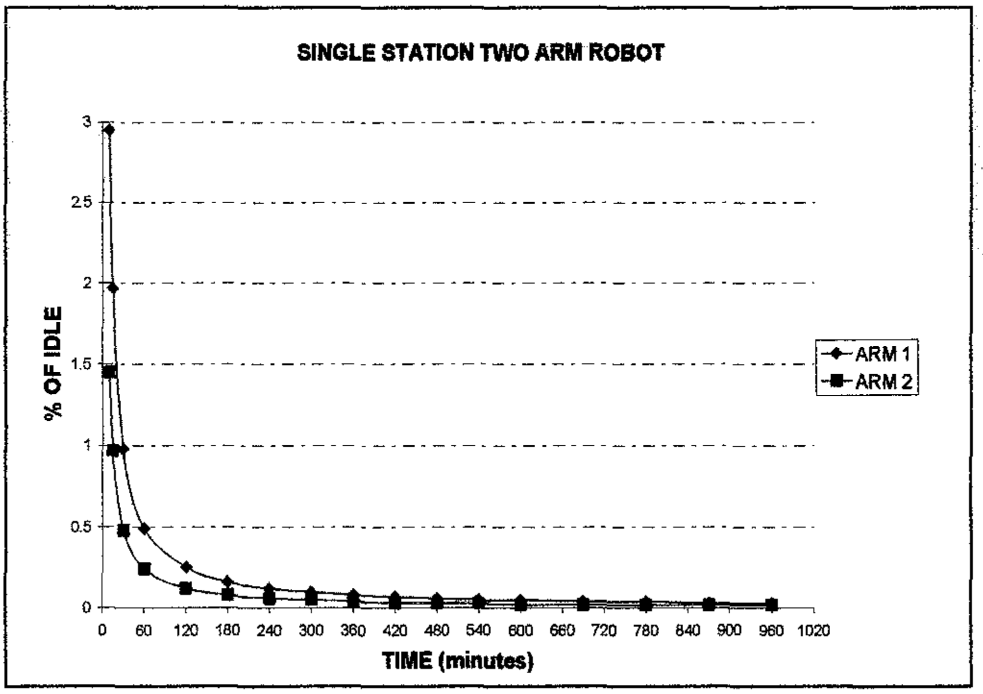


Figure 5.8: % of idle for every hour in single station two-arm robot assembly

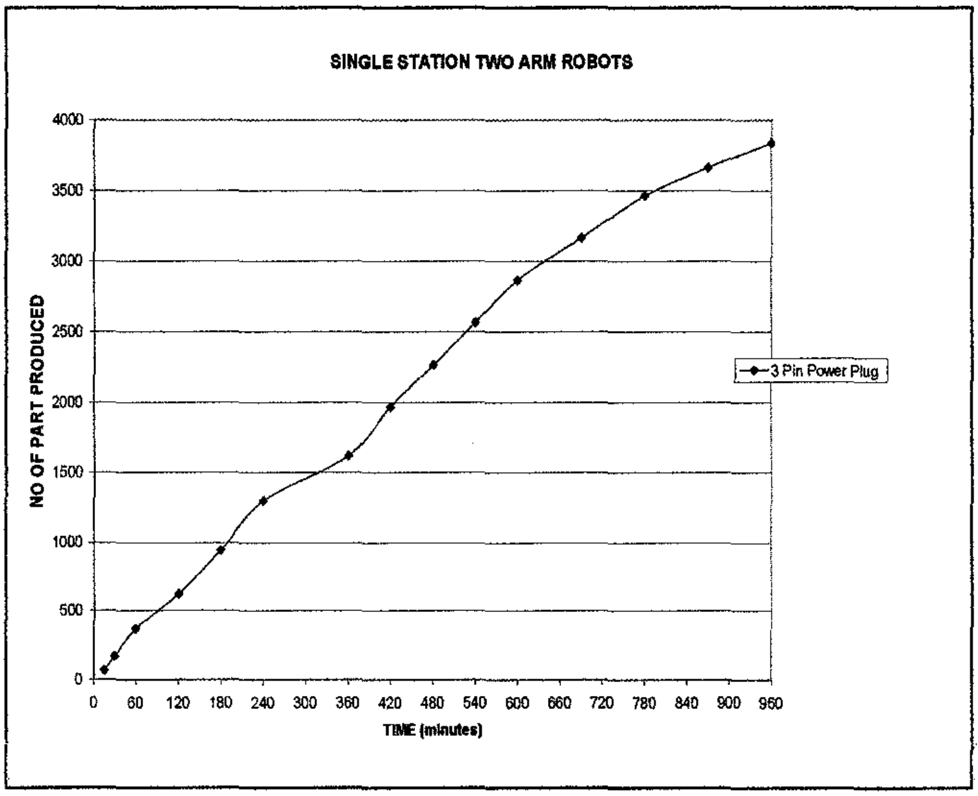


Figure 5.9: No of parts produced *for every hour in* single station one-arm robot assembly

5.1.4 Comparison of the result for various design layouts

	Manual Assembly	Single station one arm robot	Single station two arm robot
% of busy	99.93	99.96	99.98
% of idle	0.07	0.04	0.02
No of parts produced	1332	2085	3839
Production Rate (units/hr)	83.25	130.3125	239.9375
Throughput Time (min/pieces)	0.72	046	0.25

Table 5.13: Summary of the various method of assembly for 3 pin power plug

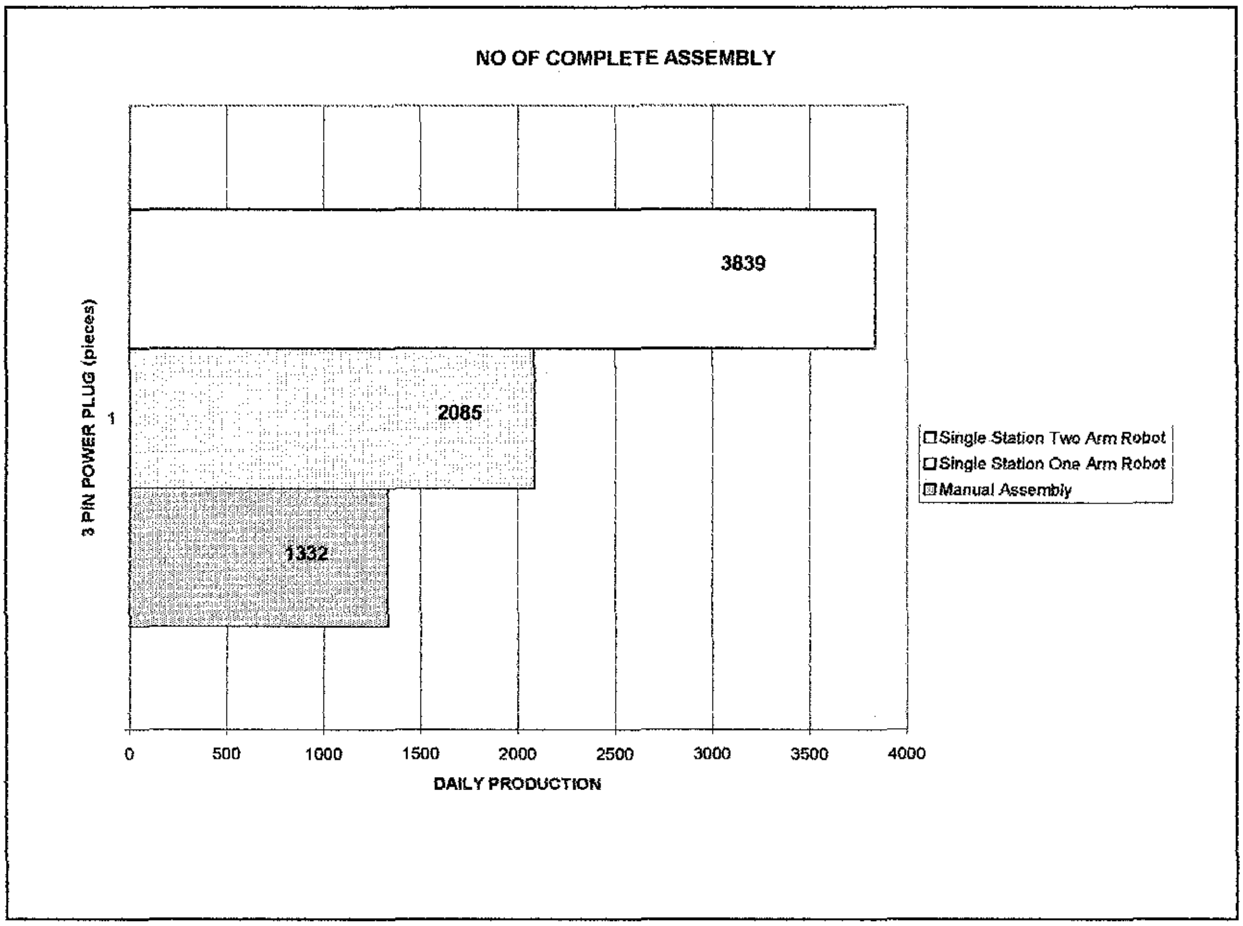


Figure 5.10: Comparison for daily production of 3 pin power plug

CHAPTER SIX

DISCUSSION

6.1 Modeling of 3 pin power plug using WITNESS

Before embarking on a detail study on automated assembly, it is necessary to analyze the product for manual assembly. This provides not only a benchmark for economic justification but also information on manual handling and assembly for any parts that do not lend themselves to automatic handling and assembly.

Based on the result in the Chapter Five for single station manual assembly, the percentage of busy is 99.97% while the percentage of idle is 0.03 %. The percentage of busy is high because all the insertion operation has to be done by the worker himself. The work in progress (WIP) is 2 at the end of daily operations. Note that the time required to complete the assembly operation is 43.2 second. The throughput time for the single station manual assembly is 0.72 min / pieces. The production rate for this type of assembly is 83.25 units / hrs. The number of 3 pin plug assembled by manual labor is 1332 pieces daily. The number is small maybe due to the human error in insertion operations while doing the job. In manual assembly, the high technology devices are not being used but the labor or human forces are important. The investments on expensive machinery can be eliminated, but the worker salaries need to be paid.

In single station one arm robot type of assembly, the robot does all the pick and insertion operation to the base of the plug that was fixed to the jig. Based on the result in for single station one-arm robot assembly, the percentage of busy is 99.96% while the percentage of idle is 0.04%.

The percentage of busy is high, because the robot need to swing the arm and pick the parts that has been loaded to the tray or pallet. It also has to come back to the original position where the base is fixed, and do the insertion process. The idle time is low because the robot doesn't have to stop the operation till the end of the day compared to the labor that will stop the operation during rest time.

The work in progress (WIP) is 1 at the end of daily operations. The number of part that accommodate buffer also is small and can be neglected. The throughput time for the single station manual assembly is 0.46 min/ pieces. The production rate for this type of assembly is 130.3125 units / hrs. The numbers of complete plug assembled by single station one arm robot are 2085 pieces daily. It clearly shows that the number of plug assembled daily by single station one arm robot nearly double the production of manual assembly.

In the single station two arm robots, it's necessary to decide the operation that can be done simultaneously. By determine it, the use of two arm robots can utilize. It maybe while the first arm doing insertion, the second arm picks the part for next assembly operations. Or both arm doing the insertion of different parts. By doing this (simultaneous operations) the cycle time that need to assemble all the parts can be reduced.

Based on the result in for single station one-arm robot assembly, the percentage of busy is 99.98% while the percentage of idle is 0.02%. The work in progress (WIP) is 1 at the end of daily operations. The number of part that accommodate buffer also is small and can be neglected. The throughput time for the single station two arm robots assembly is 0.25 min/ pieces. The production rate for this type of assembly is 239.9375 units / hrs. The numbers of complete plug assembled by single station two arm robots are 3839 pieces daily.

For indexing machines, even though the simulation cannot be done due to limitation in data that available, but through the calculation and table in chapter four it shows that the production rate is 342 pieces/ hr. The throughput time is 0.18 piece/ min. Meanwhile the production rate is 5472 pieces of 3 pin power plug daily.

From the result, it shows that the single station system with two robot arm yield the best results. However the capital investments are surely higher if compared to others type of assembly method.

6.2 Sensitivity analysis

One of the scopes of this project is to conduct the appropriate sensitivity analysis on the actual simulated model to improve production rate and capacity, throughput time and reduces work in progress.

The purpose of sensitivity analysis is to determine how the changes in the parameters entity will bring the significant different for the sets of result or output from the modeling work.

Among the sensitivity analysis that can be evaluated are to increased buffer capacity, running the production line in 3 shifts per day, introduces breakdown and setup time, utilization of the machines, increase the lot size (number of parts that comes together), and reduce handling or non operational time.

6.3 Project

The discussion in this section, explain some of the important issues that related to this project. Among the issues that been highlighted are magazines types, quality levels of parts, preventive maintenance, Machine design factors to reduce machine downtime due to the defective parts, advantage of robot assembly, and problem encountered.

6.3.1 Magazines Types

Part magazines provide one of the more convenient ways to present parts to the assembly system. The purposes of magazines are two fold; that are to present the parts in the same orientation to the robot and to decouple the manual handling process from the machine cycle time.[1]

If both requirements are met, the assembly system is able to operate automatically. Often, the requirements can be met with simple and inexpensive methods. Sometimes, however, questions concerning space requirements, precision, transportation, storage and cost must be carefully considered

It is important to make a distinction between a magazine and a buffer. The objective in using magazines is primarily to decouple the operator from the machine to avoid costly idle time when the operator has to wait for the machine or the machine has to wait for the operator. The magazine coupled directly to the assembly system creates opportunity for the operator to attend to other aspects of machine loading. The function of a buffer is to decouple one machine station from the adjacent station. The buffer accommodates the idle times that would occur if one station had to wait for another. A buffer eliminates varying imbalances between stations on a free-transfer, multi-station machine.

** Please refer to figure in the appendix 1B for different magazines configurations [1].*

6.3.2 Quality levels of parts.

If assembly of a completely new product is to be contemplated, the estimation of the quality levels of the parts may be extremely difficult. However, a large proportion of assembly machine feasibility studies are concerned with existing products, and in these cases, experiments can be performed to determine the quality levels of the various parts.

It should be remembered in such a study that defective part and, in many cases when the defective part do not generally create great difficulties when assembly is performed by hand. Often, the assembly worker can quickly detect and reject a defectives part and, in many cases, when the "defective part" is simply a nonparty, such as a pieces of swarf or a bar end, the assembly worker does not even attempt to grasp it but simply leaves it in the container to be discarded later.

This means that a study of quality levels must be conducted at the existing assembly stations, where the number of discarded parts and foreign bodies can be recorded. A further danger is that engineers are responsible for assembly processes often assume that 100% visual inspection results in 100% acceptable parts. This assumption that an inspection worker inspecting every part that is to be assembled will detect every defective part is clearly not valid.

The best procedure for estimating quality levels is for the investigator to observe the assembly work and note every defective part of foreign body that is discarded. Obviously, it is inadvisable to assume that the quality levels recorded cannot be improved upon, but it is necessary to estimate the cost of these improvements and to allow for this extra cost in the consultancy. Having noted the number of defective parts in a given batch, the investigation can then divided into two categories:

- Those parts that cannot be assembled but are normally, for example screw with no thread or slot
- those parts that can be assembled but are normally rejected by the operator, for example discolored or chipped parts

The number of parts falling within the first category allows estimates to be made of the assembly machine downtime and the number of those falling within the second category allows estimates to be made of the number of unacceptable or defective assemblies produces by the machines. Table 5.1 shows the effective quality levels of 3 pin power plug parts [1]

Parts	Fault	Number of faults in assembling 10,000 plugs	Percentage faults
Base subassembly	Chipped Earth pin will not assemble Live pin will not assemble Neutral pin will not assemble	10 170 20 30	0.10 1.70 0.20 0.30
Earth pin subassembly	No screw	41	0.41
Neutral pin subassembly	No screw	59	0.59
Live pin	Fuse will not assemble Fuse assembles unsatisfactorily	115 17	1.15 0.17
Fuse clip subassembly	Fuse will not assemble Fuse assembles unsatisfactorily	18 10	0.18 0.10
Fuse	Damaged	18	0.18
Cover	Chipped Cover screw hole blocked	10 200	0.10 2.00
Cover screw	No thread or slot	20	0.20

Table5.1: Quality levels of 3 pin power plug parts [1]

6.3.3 Preventive Maintenance

In a plant that is highly mechanized and automated, emergency maintenance problems are unavoidable. One way of reducing their frequency is for the company to have an appropriate preventive maintenance (PM) program. The objective of preventive maintenance is to service the equipment at periodic intervals to reduce the occurrence of emergency breakdown incidents. By servicing the machines in a planned and systematic fashion, it is expected that the number of equipment failures will be reduced, and that those which do occur will be less severe. In addition, PM can be accomplished more conveniently during times when the production equipment is not regularly operation.

For example, in the case of 3 pin power plug assembly, the PM can be performed during the third shift in a two shift plant. In robotics, PM consists of checking, cleaning and possibly replacing certain mechanical and electrical components of the robot at regular time intervals. The robot manufacturers usually include a recommended maintenance program in their operating manuals, indicating which components should be periodically serviced.

One of the measurers used to access the reliability of a piece of machinery or robot is mean time between failures (MTBF). This measure indicates how long, on average, the machinery will operate between breakdowns. When breakdown occurs, a certain amount of time is required to service the robot. The mean time to repair (MTTR) is the measure used to indicate how much time, on average, is spent repairing the robot for each breakdown. These two measures (MTBF and MTTR) can be combined to indicate the proportion of time that two robot is available for operation. This measure is called availability: [3]

$$\text{Availability} = \frac{\text{MTBF - MTTR}}{\text{MTBF}}$$

The effect of goods PM should be to increase the MTBF and to reduce the MTTR for an emergency breakdown situation. This would result in an increased in the availability of the equipment.

6.3.4 Machine design factors to reduce machine downtime due to the defective parts

The first objective in designing feeders and mechanism for use in automatic assembly is to ensure that the presence of a defective part will not result in damage to the machine. This possibilities does not generally exist where the part is moving under the action of its own weight (that is, sliding down a chute) or being transported on a vibratory conveyer. [1]

The next objective in design should be to ensure that a jammed part can be removed quickly from the machine. This can be facilitated by several means, some of which are follows:

- All feeders chute and mechanism should be readily accessible. External covers and shield should be avoided wherever possible.
- Enclosed feed tracks, feeders and mechanism should not be employed. Clearly, one of the least expensive forms of feed track is a tube down which the parts can be slide freely to the work head. However, a jam occurring in a closed tube is difficult to clear. Although probably more expensive to provide, open rails are preferable in this case so that the fault can be detected and cleared quickly.
- An immediate indication of the location of fault is desirable. This may be achieved by arranging that a warning light is switch on and a buzzer sounded when any operation fails. If the warning light is position at the particular work head, the technician will be able to locate the fault quickly.

The discussion above dealt with methods of reducing machines downtime caused by defective parts. Ideally, of course the defective parts are detected and rejected in feeding devices. Although it is generally not possible to perform complete inspection during feeding parts, it is sometimes possible to eliminate a considerable proportion of defective parts.

6.3.5 Advantage of robot assembly

Some of the main advantages in the use of assembly robots can be describe with reference to the conditions for the economic application of special purpose assembly machines: [1]

- Stability of product design. If the product designs changes, the robot can be reprogrammed accordingly.
- Production volume. As will be seen, a robot system can operate economically at much longer station cycle times than a high-speed automatic assembly machine.
- Style variations. A robot system can more readily be arranged to accommodate various styles of the same product.
- Part defects. First, it is interesting to note that a feeder jam caused by a faulty part causes much greater loss in production on a high speed transfer assembly machine than on a robot system with a relative long cycle time. In addition, the robot can be programmed to sense problems that may occur and to reattempt the insertion procedure.
- Part size. As will be seen later, a principle advantage of a robot used in assembly parts can be presented in patterns or arrays on pallets or parts trays. In this case, the severe restrictions on part size in high-speed automation do not apply.

When assembly robots are employed, further important possibilities exist for parts presentation:

- Some parts maybe presented partially oriented, and the robot can perform final orientation
- Identical parts maybe presented in pallets or part trays in fixed arrays
- Sets of different parts can be presented in parts trays (kits)
- Feeder might be used that can feed different parts simultaneously

Therefore, it can be conclude that a further advantage of the use of assembly robots is the widely increased alternatives allowed in the methods of parts presentation. Some of these alternatives will now be discussed in more details.

6.3.6 Problem Encountered

In order to perform the project successfully till the end, some problem arose. The problems are listed below:

- As a beginner user of this software, there is no training provided that should be a useful guidance on how to conduct the simulation work in the easier manner.

- Difficulty to handle advance features in the simulation interface. Some of the areas in the simulation work need the use of advance features, not only just the basic principle. Therefore, it makes the simulation work tough and challenging because the knowledge of this software is just at the surface.

- The licensed software that available in the laboratory also is very limited. The student version of this software cannot model the real layout because it cannot perform large amount of element and rule associated to the design. So, the time engaged with this simulation is very short that make it hard to follow the time frame.

- It is also difficult to find numerous case studies related to the manufacturing or assembly processes that had been verified. It is important to find the right case studies that are used as benchmark in the real manufacturing floor.

- All information and data available in the case study had to be evaluated weather it is logic and meaningful to simulate because in the simulation the design cannot be model realistically as in the real world.

CHAPTER SEVEN

CONCLUSION AND RECOMMENDATION

7.1 Recommendation

Based on the problem that was encountered during the project, several sets of recommendation were highlighted. Among others the recommendations are listed below:

- The number of computer that was installed with the licensed for this software should be added because the utilization is high. Therefore students can make do the benefits provide by this software. The software also is very useful and can perform various type of simulation that gives a perfect visualization on real manufacturing processes.
- The training provided from the company that address with this software should be frequently held or else should be promoted to staff and students that interested to learn more about the software. This is because the number or lecturer and technician that has this knowledge on how to use this software is too small.
- The training manual of WITNESS software should be read and understand well in order to make the simulation work easier without any doubt.
- In order to make sure that the data that was used in this project logic and practical, further discussion with the experience people that knows deeply about this subject and areas should be done.
- The result of the simulation has to be analyzed as deep as possible to avoid any misunderstanding and mistake.
- The knowledge on how to handle or use advanced features should be emphasized since the software very favorable.

7.2 Suggestion Future Work for Expansion and Continuation

Without doubt, it can be seen that this project modeling of manufacturing assembly line bring a lot of benefits in understanding the real manufacturing world. It will be good if this project be expanded in broader way and the continuation will highlight a few parameters that not being address here in this report.

Maybe for the next stages, the data series should be collected from real manufacturing floor. It is also interesting if the student later can make comparison with 2 or 3 manufacturing floor that assembles the same product. The operations time and assembly processes maybe are not the same that would bring different results. The student will go to the plant of factory to collect the data. Therefore the all the information needed to do the simulation can be gathered successfully prior to the design layout in the WITNESS software. This could bring valuable experience to the student because the data is collected by them not depending on the case study that written by someone else.

The project work can be conducted not only for manufacturing floor, but also to model filling a tank in the plant, phone call rate, ship that enters and leaves the jetty or harbor, power and free network view and many more like the demo file in the WITNESS software

Finally, the continuation of this project should also reduces or if can should eliminate the problem that was encountered during the completion of this project. This is because; the problem is already listed in this report, so precaution steps should be taken to avoid the mistake from occurring again.

7.3 Conclusion

This project involves modeling of manufacturing assembly line. Therefore, a case study involving investigation of three pin power plug assembly line is to be considered for computer based modeling using WITNESS.

Modeling using WITNESS software allows a prediction of the possible output that will be the answer for future consideration of assembly processes in real manufacturing world. Therefore, the result from modeling or simulation work may assist in choosing the better layout of manufacturing floor that will yield the desired outcome of production rate.

This project highlight or propose a few alternatives of design layout that are suitable for the three pin power plug assembly plant via modeling using WITNESS software. It also provides a sensitivity analysis to improve the production capability and output rate. The sensitivity analysis

From my point of view, WITNESS gives me greater breadth and depth of information about modeling and simulation. Perhaps the results of this project have significantly assisted in understanding the real implementation of manufacturing assembly line.

Finally, WITNESS is among one of the powerful tools to do a simulation for a manufacturing assembly lines. Therefore further exploration on how to use the software should be enhanced in order to fully utilize the benefit and capability of the simulation.

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APPENDICES

Appendix 1A

Classification of manual insertion

MANUAL INSERTION – ESTIMATED TIMES (seconds)

Key:

- PART ADDED but NOT SECURED
- PART SECURED IMMEDIATELY
- SEPARATE OPERATION

Part added but not secured

			after assembly no holding down required to maintain orientation and location (3)				holding down required during subsequent processes to maintain orientation or location (3)			
			easy to align and position during assembly (4)		not easy to align or position during assembly		easy to align and position during assembly (4)		not easy to align or position during assembly	
			no resistance to insertion	resistance to insertion (5)	no resistance to insertion	resistance to insertion (5)	no resistance to insertion	resistance to insertion (5)	no resistance to insertion	resistance to insertion (5)
			0	1	2	3	6	7	8	9
addition of any part (1) where neither the part itself nor any other part is finally secured immediately	part and associated tool (including hands) can easily reach the desired location	0	1.5	2.5	2.5	3.5	5.5	6.5	6.5	7.5
	part and associated tool (including hands) cannot easily reach the desired location: due to obstructed access or restricted vision (2)	1	4	5	5	6	8	9	9	10
	part and associated tool (including hands) cannot easily reach the desired location: due to obstructed access and restricted vision (2)	2	5.5	6.5	6.5	7.5	9.5	10.5	10.5	11.5

Part secured immediately

			no screwing operation or plastic deformation immediately after insertion (snap/press fits, circlips, spire nuts, etc.)		plastic deformation immediately after insertion						screw tightening immediately after insertion	
					plastic bending or torsion			riveting or similar operation				
			easy to align and position with no resistance to insertion (4)	not easy to align or position during assembly and/or resistance to insertion (5)	easy to align and position during assembly (4)	not easy to align or position during assembly: no resistance to insertion	not easy to align or position during assembly: resistance to insertion (5)	easy to align and position during assembly (4)	not easy to align or position during assembly: no resistance to insertion	not easy to align or position during assembly: resistance to insertion (5)	easy to align and position with no torsional resistance (4)	not easy to align or position and/or torsional resistance (5)
			0	1	2	3	4	5	6	7	8	9
addition of any part (1) where the part itself and/or other parts are being finally secured immediately	part and associated tool (including hands) can easily reach the desired location and the tool can be operated easily	3	2	5	4	5	6	7	8	9	6	8
	part and associated tool (including hands) cannot easily reach desired location or tool cannot be operated easily: due to obstructed access or restricted vision (2)	4	4.5	7.5	6.5	7.5	8.5	9.5	10.5	11.5	8.5	10.5
	part and associated tool (including hands) cannot easily reach desired location or tool cannot be operated easily: due to obstructed access and restricted vision (2)	5	6	9	8	9	10	11	12	13	10	12

Separate operation

		mechanical fastening processes (part(s) already in place but not secured immediately after insertion)				non-mechanical fastening processes (part(s) already in place but not secured immediately after insertion)				non-fastening processes	
		none or localized plastic deformation				metallurgical processes					
							additional material required				
		bending or similar processes	riveting or similar processes	screw tightening or other processes	bulk plastic deformation (large proportion of part is plastically deformed during fastening)	no additional material required (e.g. resistance, friction welding, etc.)	soldering processes	weld/braze processes	chemical processes (e.g. adhesive bonding, etc.)	manipulation of parts or sub-assembly (e.g. orienting, fitting or adjustment of part(s), etc.)	other processes (e.g. liquid insertion, etc.)
		0	1	2	3	4	5	6	7	8	9
assembly processes where all solid parts are in place	9	4	7	5	12	7	8	12	12	9	12

Figure1A: Classification of manual insertion – estimated times

Appendix 1B

Types of magazines

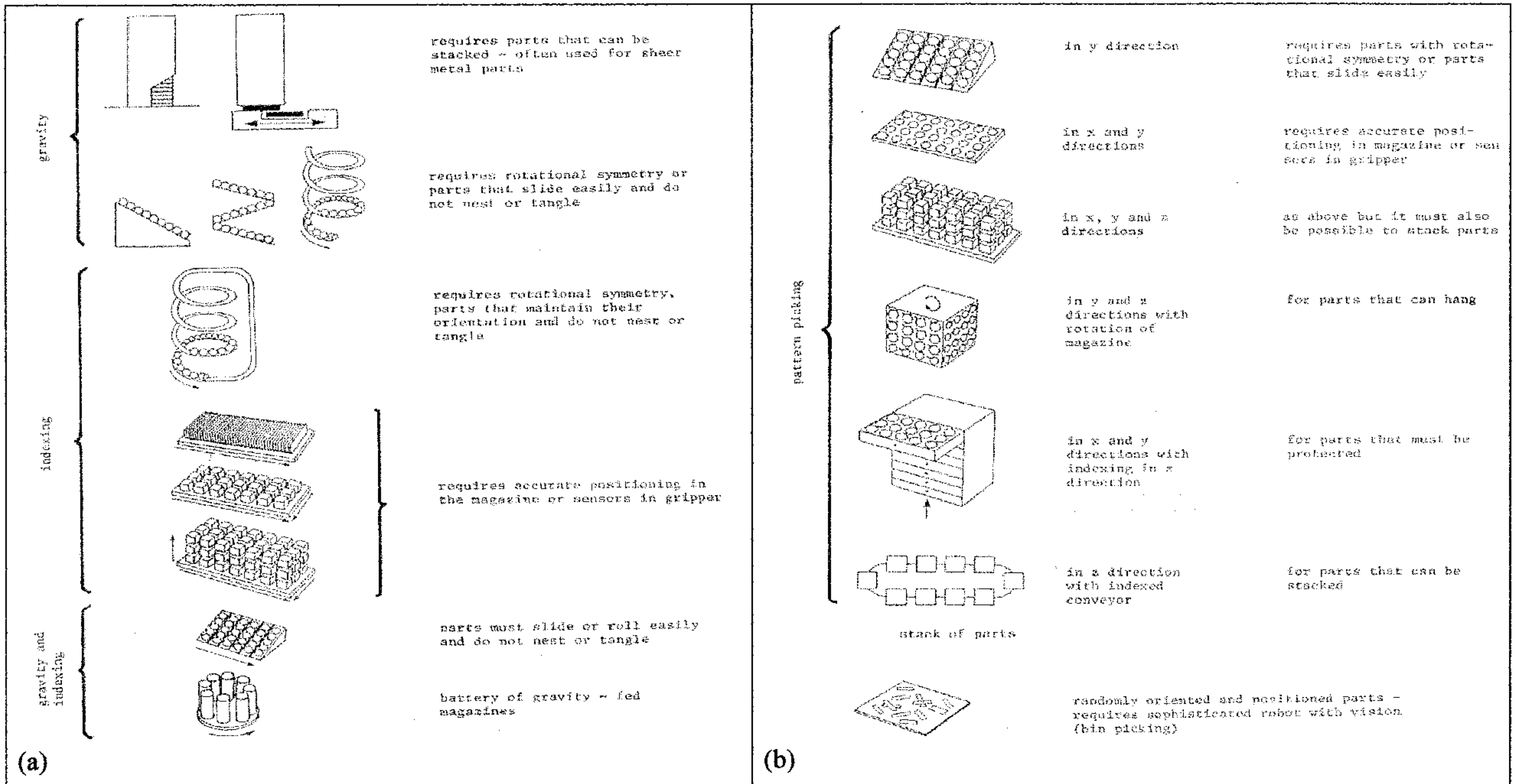

Figure 1B : (a) Part magazine configuration: part presentation at a single location; (b) Part magazine configuration: part presentation at a multiple location