DESIGN FOR ASSEMBLY AND APPLICATION USING HITACHI ASSEMBLABILITY EVALUATION METHOD

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ABSTRACT

This project is described about application of Hitachi Assemblability Method (AEM) in Design for Assembly. Using this method, in the early design stage, product design quality is analyzed quantitatively and weakness in the design's assembly producibility are highlighted. The AEM is belongs to class of "point of" methods. The "perfect" part or assembly operation gets the maximum score, usually one hundred, and each element or difficulty is assigned a penalty. The main objective of this project are to determine and calculate the score of AEM for part (E_i) and the product AEM (E) score and also to redesign the current design using application of Hitachi Assemblability Evaluation Method(AEM). Mini radio was chosen as a product in order to accomplish the objective of Design for Assembly using application of Hitachi Assemblability Evaluation Method. The product was chosen because it has a high demand in the market. The mini radio need to disassemble to identified total number of part that contains to produce a whole mini radio. The disassemble part then, need to modeling in 3D using solidworks to show the explode view of the product. Improvement of product (redesign) also need to modeling in 3D using solidworks. Calculate of the score for reducing part and also the whole product by adding up the penalty for each process. The score need to do judgment either it obey the desirable value (above 80) or not. The score of AEM for part and product need to tabulate to give a clear view in order to achieve the main objective of this project to come out with the score. From this project, the component of mini radio have been reduce from 21 part to 16 part by combining some component that made from same material and not necessary component become one part. The assembly efficiency also has increase after modification. The significance of this project is, AEM score part and product can be determined and some of unknown penalty can be determine by reverse calculation. Enable to reduce part attaches in assembly process using application of Hitachi Assemblability Evaluation Method.

ABSTRAK

Projek ini menerangkan mengenai pengunaan *Hitachi Assembly Evaluation Method* dalam *Design for Assembly.* Mengunakan cara ini pada peringkat permulaam lakaran, kualiti lakaran produk dan yang berkenaan boleh dianalisis dan kelemahan lakaran produk boleh dikenalpasti. Cara ini tergolong dalam cara "*Point* of". Kebiasaannya, permasagan yang sempurna akan diberi markah sebanyak seratus peratus dan setiap kesulitan dalam proses pemasagan akan dikenakan denda. Tujuan utama projek ini adalah untuk menentukan skor AEM untuk bahagian atau kompenan dan skor AEM untuk produk serta mengubahsuai reka bentuk sedia ada dengan mengunakan konsep *Hitachi Assembleability Evaluation Method (AEM).* Produk yang dipilih untuk mencapai matlamat projek ini ialah radio mini. Produk ini dipilih kerana permintaan yang tinggi dalam pasaran. Radio mini perlu dihuraikan untuk mengetahui jumlah komponen yang terlibat dalam penghasilan radio mini. Produk yang telah dihuraikan perlu diunjurkan lukisan 3D mengunakan perisian solidworks untuk menunjukkan pecahan kompenan dalam produk mini radio. Unjuran lukisan 3D juga perlu untuk produk yang telah diubahsuai dan dibangunkan mengunakan perisian solidworks. Pengiraan skor untuk pengurangan komponen dan produk keseluruhannya dengan menambah penalti bagi setiap proses yang dilakukan. Skor yang diperolehi dinilai samada memenuhi nilai yang ditetapkan iaitu melebihi 80 atau tidak. Skor yang diperolehi dijadualkan untuk memberikan tafsiran yang jelas tentang objektif yang ditetapkan. Daripada projek ini jumlah kompenan dalam radio mini dapat dikurangkan daripada 21 kompenan kepada 16 kompenan dengan menyatukan kompenan yang terdiri dari bahan yang sama dan tidak mempunyai kepentingan. Sementara itu peratus keberkesanan produk juga telah meningkat selepas pengubahsuaian. Signifikasi daripada projek ini, skor AEM untuk komponen dan produk dapat ditentukan dan beberapa penalti yang tidak diketahui dapat juga ditentukan. Jumlah komponen dalam penghasilan radio mini dapat dikurangkan dengan mengunakan kaedah *Hitachi Assembleability Evaluation Method.*

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DFA   Design For Assembly

AEM   Assemblability Evaluation Method

UMP   Universiti Malaysia Pahang

Assy   Assembly

Effy   Efficiency

CHAPTER 1

INTRODUCTION

1.1   Introduction

Home appliance is one of the products that highly demand in the market nowadays. The change of the technology also changes the features of the home appliance product. In modern era nowadays, we can see how technology has change a lot of home appliance design and features in a market. The home appliance product in the market nowadays is more compact, light and user friendly and also in the same time offers the best price that affordable to buy. It's become a challenge to industry especially manufacturing industry that assembled home appliance product.

Industry that involves in production and assembly the home appliance product should be more competitive and creative in producing home appliance product in the same time can reduce the cost of assemble and also can reduce time of assembly. Therefore, design for assembly becomes a core for industry to improve the product and maintain the quality.

1.2   Project Background

The purposes of Design for Assembly (DFA) are to make the process of fabrication and assembly easier, reduce of cost, and simplify the product and also to make the product more reliable. If engineers can carry out their design in order to achieve Design for Assembly (DFA) analysis, they can protect product function and will learn that there is little chance that function will be seriously impaired.

There are several methods that widely use in industry to achieve Design for Assembly (DFA). The most widely use in industry nowadays is Boothroyd Dewhurst method, Hitachi Assembly Evaluation Method and Lucas Hull method. However, in this project is only focus on Design for Assembly using Hitachi Assembleability Evaluation Method (AEM).

The case study of this project is more on analysis a mini radio and improving the design. The target of this analysis is to evaluate score of AEM for each part and score of AEM for the product. The product was chosen because mini radio is home appliance that people always use in their daily life and still have a chance for design improvement.

1.3   Problem Statement

Design for Assembly is a tool for industry to reduce time and cost of assembly product in the same time can improve the quality of the product. Design for Assembly as the basic concurrent engineering studies to provide guidance to the design team in simplifying the product structure, to reduce manufacturing and assembly cost, and to quantify the improvement because before this most of them using an over the wall approach. Design for assembly also as a benchmarking tool to study competitor's products and quantify manufacturing and assembly difficulties. Therefore, this project focus on redesign current mini radio and reducing the part attaches except the electronic component.

1.4   Project Objective

The aims of this project are to:

1. Determine and calculate the part AEM scores (E_i) and the product AEM (E) score.
2. Redesign the current product by using application of Hitachi Assemblability Method.

1.5   Scope of study

The scopes of study are proposed in order to achieve the objective of this project:

1. Literature recitation on Design for Assembly (DFA) and various method of DFA like Boothroyd Dewhurst, Hitachi Assemblability Evaluation Method and Lucas Hull Method.
2. Gather the information about mini radio:
   - i)   Determine the each component function and total of the component to make finish product.
   - ii)   Determine the dimension of the current design and all the part.
   - iii)   3D modeling using solidworks software for current design and improve design.
3. Evaluate the AEM score for the part and product based on Hitachi Assembleability Method.
4. Tabulate the finding for part and product AEM score to give a clear view about the improvement design.

CHAPTER 2

LITERATURE REVIEW

2.1   Introduction

The purpose of this chapter is to provide information and review about the Design for Assembly (DFA) and the past research about Design for Assembly using various methods such as Boothroyd Dewhurst DFA, Hitachi Assembleabilty Evaluation Method (AEM) and Lucas Hull DFA.

2.2   Design for Assembly (DFA)

Design is a complex iterative creative process that begin with the recognition of a need desire and terminates with a product or process that uses available resources, energy and technology to fulfill the original need within some set of defined constraint. Assembly is a process of joining components into complex product.

Design For Assembly (DFA) is an approach to reduce the cost and time of assembly by simplifying the product and process through such means as reducing the number of parts, combining two part into one part, reducing or eliminating adjustments, simplifying assembly operations, designing for part handling, selecting fasteners for ease of assembly and minimizing parts tangling.

The purposes of DFA are to design a product for easy and economical production and also incorporate product design early in the design phase. Beside that, by using Design for Assembly we can improve quality, reduces cost and shortens time to design and manufacture.

2.3   Basic Approaches for implementing Design for Assembly

There are four basic approaches for implementing Design for Assembly (DFA) that have been identified which is design principles and rules, Quantitative evaluation procedures, Expert/ knowledge-based approach, Computer-Aided DFA methods

   I.   **Design principles and rules**

Design principles and rules are more based on human oriented knowledge. It also involve Collectively design data and convert assembly knowledge to design principles, rules and guidelines.

   II.   **Quantitative evaluation procedures**

It is based on evaluation procedure and also need to determine the assembly process operation by operation. Then, all the quantitative measured is calculated.

   III.   **Expert/ knowledge-based approach**

Expert or knowledge-based approach is based on knowledge and technology. It is a knowledge base, inference, communication and knowledge acquisition.

   IV.   **Computer- Aided DFA methods**

Design for Assembly (DFA) systems are integrated with CAD software. The purpose is the representation of technical objects and procedures for extraction and processing of assemblability attributes from 3D CAD models.

2.4 Design For Assembly (DFA) Guidelines

I. **Aim for simplicity**

The aim for simplicity is more focuses on minimize part numbers, part variety, assembly surface; simplify assembly sequences, component handling and insertion.

This is to make all the process in assembly faster and more reliable.

II. **Standardizes**

The purpose of this guidelines is to standardizes on material usage, components and aim as much off-the-shelf component as possible to allow improved inventory management, reduced tooling, and the benefits of mass production even at low volumes.

III. **Rationalizes product design**

Rationalizes product design is to standardize on materials, components and subassemblies throughout product families to increase economies of scale and reduce equipment and tooling costs. It also employs modularity to allow variety to be introduced late in the assembly sequence and simplify JIT production.

IV. **Use the widest possible tolerance**

By using the widest possible tolerance we can reduce the tolerance on non-critical components and thus reduce operations, and process times.

V. **Choose materials to suit function and production process**

Avoid choosing materials purely for functional characteristics and material choice must also favour the production process to ensure product reliability.

VI.   Minimize non-value adding operations

The minimization of handling, excessive finishing and inspection will reduce costs and lead time.

VII.   Design for process

Take advantage of process capability to reduce unnecessary components or additional processing such as the porous of nature of sintered component for lubricant retention. Besides that we need to design in features and functions to overcome process limitation, such as features to aid mechanical feeding. Design for process also needed to avoid unnecessary restriction of process to allow manufacturing flexibility process planning.

2.5   Various Method of Design for Assembly

There are various methods that have been using in Design for Assembly in industry nowadays such as:

- The DFA method exploited by Boothroyd Dewhurst Inc, USA
- The Hitachi Assemblability Evaluation Method (AEM) by Hitachi Ltd, Japan
- The Lucas Design for Assembly Methodology by Lucas-Hull, UK.

2.5.1 Boothroyd Dewhurst Method

Boothroyd and his colleagues, Swift and Redford was the first who analyzed automatics parts feeder such as vibratory bowls. Design of these items is more an art than a science, and boothroyd realized that some part are harder to feed automatically than others for reasons that could be avoided if part designers had more information. He then turned to manual assembly and identified two main phases of single assembly, namely handling (which includes grasping and orienting) and insertion. Each of these is also affected by part design.

Assembly Efficiency for Manual Assembly:

$$= \frac{3}{\qquad}$$

Where:

NM= theoretical minimum number of part

TM= total manual assembly time

2.5.2 Hitachi Assemblability Evaluation Method

The Assemblability Evaluation Method (AEM) is an effective tool developed by Hitachi Ltd. to improved design quality for better assembly producibility. The AEM has been widely used by the Hitachi Group as well as by more than 20 other well known companies around the world. Using this method, in the early design stage, product design quality is analyzed quantitatively and weakness in the design's assembly producibility are highlighted. In addition, the effects of design improvement are confirmed with respect to assembly cost.

Miyakawa, Iwata and Ohashi who have done research on the Hitachi Assemblability Evaluation Method said that the AEM is belongs to class of "point of" methods. Miyakawa and his colleague also said that in this method, the "perfect" part or assembly operation gets the maximum score, usually one hundred, and each element or

difficulty is assigned a penalty. There are twenty different operational circumstances, each with its own penalty. Each circumstance is accompanied by simple icon for identification, permitting the method to be applied easily with little training.

Based on Miyakawa and his colleagues, he said that the method is applied manually or with the aid of commercially available software. When a part or operation is fully evaluated, all the penalties are added up and subtracted from one hundred. If the score is less than some cut off value, say eighty, the operation or part is to be subjected to analysis to improves its score. The penalties and time estimates have been refined based on the experience of the entire Hitachi Corporation, which makes a wide range of consumer and industrial goods such as camcorders, television sets, microwave ovens, automobile components, and nuclear power stations.

The evaluation takes place in two stages. First, each operation is evaluated, yielding an evaluation score E_i for operation. If several operations are required on one part, an average score E is calculated. The score for the entire product is either the sum of all the individual part scores or the average of the part scores. In either case, it is possible that an assembly with fewer parts will have a higher score simply because fewer penalties are available to reduce it. In this case, the method clearly states, "reduction in part count is preferable to better score." However, the method does not include a systematic way of identifying which part might be eliminated.
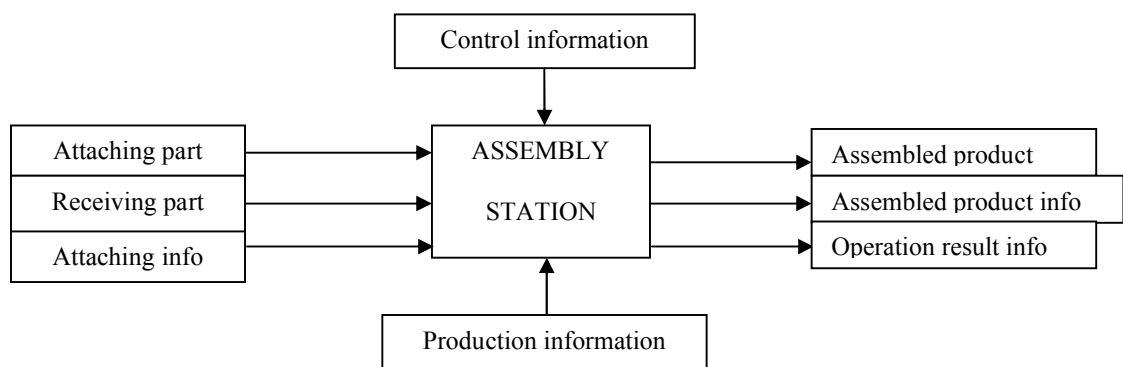

Figure 2.1: Assembly process

2.5.2.1 Basic process of evaluation index calculation

Figure 2.2: Process of evaluation
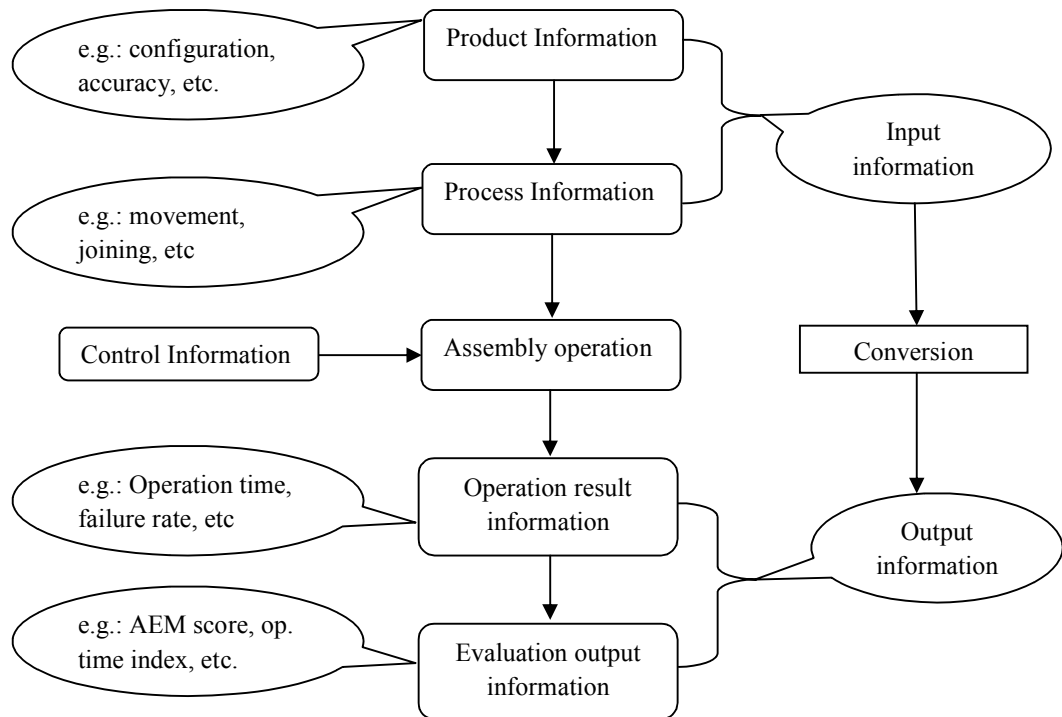
The basic information processing scheme of the evaluation system shown in Fig. 2 means the follows:

(a) Attaching operation time for a part is expressed as a function of basic and supplementary element coefficients.

(b) Using the estimated part attachment time value, the part AEM score is calculated. The product AEM score is calculated as the average value of the part AEM scores.

2.5.2.2 Calculation formulas for the evaluation

i. **Calculation of part attachment cost and time**

For a part "i", the attachment time $_aT_i$ and attachment cost $_aC_i$ are expressed by the following equation.

$$_aT_i = \sum {}_aT_{ij}$$
$$_aC_i = {}_aA \cdot {}_aT_i$$

Where:

$_aA$: shop rate of the assembly shop where part "i" is attached

$_aT_{ij}$: attaching time of part "i". (A part is attached by multiple operations sometimes such as "movement and joining". Subscripted prefix "$_a$" denotes "assembly".

The attachment time for the jth operation of part "i" can also be expressed as follows:

$$_aT_{ij} = f_1 \text{ (design factor, production environment factor)}$$

Where:

"Design factor" is a factor that influences attaching operation time.

$$_aT_{ij} = f_2 \text{ (basic coefficient, supplementary coefficient, production environment factor)}$$
$$= f_3 \text{ (structure coefficient)} \cdot {}_aT_{oi} = {}_aD_{ij} \cdot {}_aT_{oi}$$

Where:

$_aT_{oi}$: shop basic assembly time, a constant that reflect the average operation speed of the shop.

$_aD_{ij}$: structural coefficient that indicates the assembly operation complexity.

ii.   **Determination of design factors and basic elements**

The estimated attachment time $_aT_{ij}$ for the jth operation of part "i" and $_aT_i$ for part "i" are defined as follows:

$$_aT_{ij} = {}_aT_{oi} \cdot f_3({}_a\beta_{ii}, {}_a\lambda_{ij}, {}_a\mu_{ij}, {}_a\theta_{ij}, {}_a\gamma_{ij})$$

$$_aT_i = {}_aT_{oi} \cdot \sum f_3({}_a\beta_{ii}, {}_a\lambda_{ij}, {}_a\mu_{ij}, {}_a\theta_{ij}, {}_a\gamma_{ij})$$

Where:

$_a\beta_i$: Basic coefficient for the jth operation of the part "i". For ($\downarrow$), 1 is given.

$_a\lambda_{ij}$: size coefficient for the jth operation of the part "i". For the standard size, 1 is given.

$_a\mu_{ij}$: dimensional accuracy coefficient for the jth operation of part "i".

$_a\theta_{ij}$: configurational and orientational accuracy coefficient for the jth operation of part "i"

iii.   **Calculation of AEM score**

The part AEM Score $_aE_i$ is defined so that it decrease when the attaching difficulty of a part, i.e., assembly operation cost $_aC_i$, or operation time $_aT_i$ increase. More concretely, "part AEM Score $_aE_i$" for the part "i" is defined by the following formula:

$$_aE_i = f_4 \text{ (estimated assembly operation cost)}$$
$$= f_5 \text{ (design factor)}$$
$$= f_6 \text{ (element coefficient, supplementary coefficient)}$$
$$= 100 - \text{(part elimination score)}$$
$$= 100 - {}_a\tau[({}_aT_i / {}_aT_{bi}) - 1]$$

Where:

$_a\tau$:   constant value that determines the sensitivity of the AEM score to the attaching time increment

$_aT_{bi}$:   the part attachment operation time of a part the size of which is equivalent to that of part "i". all the other factors are the same as for standard conditions.

2.5.2.3 Symbol in Hitachi Assemblability Method

- Direction of motion of a part

Symbol	Penalty Point	Description of Operation
↓	0	Straight Downward
↑	30	Straight Upward
← →	20	Move Horizontally
↗ ↙	30	Move diagonally up/down
∩ C	30	Turn like a screw
R	40	Turn or lift the whole assembly to insert a part

- Fixture and forming requirement

Symbol	Penalty Point	Description of Operation
f	20	Hold a part for next one operation
F	40	Hold a part for more than next one operation
G	40	Deform a soft/flexible part (O-ring/gasket)
P	20	Bend or cut (wire,..)

- Joining and processing requirements

Symbol	Penalty Point	Description of Operation
B	20	Bond with adhesive or heat or lubricate a part
W	20	Weld

| S | 30 | solder |
| M | 60 | Machine a part to join |

- Other symbol without penalty point

Symbol	Penalty Point	Description of Operation
—	0	Base part for assembly
|	0	Pipe to keep track of assembly

- Additional 15% penalty point per each operation for a second operation and beyond:
  - Strong incentive for simpler assembly operation
  - More critical for automatic assembly

2.5.3 Lucas Hull DFA method

Although the Boothroyd Dewhurst method is widely used, it is based on timing each of the handling and insertion method. Although tables of data are available, the most accurate numbers are compiled through times studies in particular factories.

Lucas Corporation in the United Kingdom was developed the Lucas DFA method early year of 1980's. The Lucas Method is differing from Boothroyd method, where the Lucas Hull method is based on "point scale" which gives a relative measure of assembly difficulty. The method is based on three separate and sequential analyses. These are best described as part of the assembly sequence flowchart (ASF):

1. Specification
2. Design
3. Functional analysis (this is the first Lucas analysis)
   Possibly loop back to step 2 if the analysis yields problems
4. Feeding analysis (this is the second Lucas analysis)