CHAPTER 2
LITERATURE REVIEW

2.1. Literature Review

2.1.1. Previous Research

Ali, Chowdary and Gonzales (2013) aims *An Integrated Design Approach for Rapid Product Development* journal shown the integrated design approach using reverse engineering (RE), re-engineering (ReE), and rapid development (RpD) system to infuse agile characteristic in the proposed design and development process. It also explain about the integration of RE, ReE and RpD with unconventional approach achieving reduced lead times for design and development of products. Applicate that method to recover the broken clutch shoe design by using Computer Aided Design (CAD) model.

M. Hussain, CH. Rao and Prasad (2008) aims *Reverse Engineering : Point Cloud Generation with CMM for Part Modeling and Error Analysis* journal shown about the application of reverse engineering method in injection mould with two damaged cavities in the part without any drawing prints. There are two types of data collection : contact type and non-contact type. CMM is the tool to apply both method. The first method is collecting data from mechanical probes touching the surface at various points on part profile. It is very slow and most useful for inspection purpose. The second method is scanning, the probe is drawn along the surface of the object. This method is slightly less accurate than individual point method. Error analysis is made as a result comparison of the two methods.

Mansor (2002) aims *Free-Form Surface Models Generation using Reverse engineering Technique – An Investigation* journal shown an investigation of reverse engineering technique to generate free-form surface models in a Computer Aided Design system from physical objects. It involves data acquisition from the physical objects, registration of the data acquisition, data pre-processing, polygon mesh, segmentation, surface fitting and surface model generation. The applications of this technique widely used in many areas of research and industry such as surface models generation for space suits in aerospace industries, prostheses in medicine, antique parts in archaeology, car bodies in automotive industries, turbine blades in nuclear power generation, etc.

2.1.2 Present Research

This research will be conducted at PT. Doulton to maximize both of design and trial process in NPI department. This paper will show about design process using reverse engineering approach with two sources of data. The comparison between previous research and present research shown in table below:

Table 2.1 Comparison Between Previous and Current Research

Author	Title	Data Collection	Tools	Objective	Data
Ali, Chowdary and Gonzales (2013)	An integrated design approach for rapid product development	Contact	CMM	Recover broken part	Broken clutch shoe (existing product without technical drawing)
M. Hussain, CH. Rao and Prasad (2008)	Reverse Engineering : Point Cloud Generation with CMM for Part Modeling and Error Analysis	Contact and non-contact	CMM	Design and Error Analysis	Injection mould (existing product without technical drawing)
Mansor (2002)	Free-Form Surface Models Generation using Reverse engineering Technique – An Investigation	Contact and non-contact	3D scanning, CMM	Investigation	Physical object
Lamandau (2015)	Reverse Engineering Approach In Making Emirates Plate (Dia-25cm) Design At Pt Doulton	Contact	CMM	Design new product	Emirate Large Plate (Dia-25)cm technical drawing and existing product

2.2. Gap Analysis

Ali, Chowdary and Gonzales (2013) and M. Hussain, CH. Rao and Prasad (2008) use reverse engineering to get the design from existing product which are broken clutch shoe and injection mould. Both are processed without technical drawing data. M. Hussain, CH. Rao and Prasad (2008) using non-contact scanner and calculate the error analysis of both scanning process. Mansor (2002) make an investigation of reverse engineering method which is generated by using free-form surface generation in model making. Therefore, this research presents about making a design of Emirate Large Plate (Dia-25cm) with both technical drawing and existing product using reverse engineering approach.

2.3. Basic Theory

2.3.1. Ceramic

The word ceramic is derived from the Greek *keramos,* which means "potter's clay" or "pottery". It's origin is a Sanskrit term meaning "to burn". (Carter and Norton, 2013) The early Greeks used the word *keramos* when describing products obtained by heating clay-containing materials. The term has long included all products made from fired clay, including bricks, fireclay re-factories, sanitary-ware, tableware. (Carter and Norton, 2013).

a. Earthenware

   A type of clay that is soft when fired to make pottery and can be scratched with a knife. It is opaque and has an earthy or granular fracture. Made from soil that absorb water, fired at low temperature (900°C – 1060°C). Plastically and tought, but after the firing process it becomes fragile and has so many pore.

b. Terracotta

   A type of earthenware, is a clay-based unglazed or glazed ceramic where the fired body is porousIs one of the red soil. 'Terracotta' word came from Italian, means 'fired soil'. This material can be fired around 1200°C - 1300°C with adding some chamotte.

c. White Pottery

   Is one kind of white pottery, tough, can be fired at high temperature (1250°C). Plastically and can be used for casting material.

d. Stoneware

Is a though dense, impermeable and hard enough to resist scratching by a steel point. Can be fired in medium temperature (1150˚C) or the earthenware temperature, also can be fired in high temperature (1250˚C). Usually the color is grey or brownish because of the impurities in the clay used for its manufacture, and is normally glazed.

e. Porcelain

Porcelain is known as *Fine China.* The toughness, strength, and translucency of porcelain arise mainly from the formation of glass and the mineral mulita within the fired body at these high temperatures. Usually it is fired in kiln, temperature between 1250˚C - 1440˚C. Made from mixing kaolin, feldspar, silica, and formed by casting technique.

f. Bone China

A type of soft-paste porcelain that is composed of bone ash, felspath material, and kaolin. It has been defined as *ware with a translucent body* containing a minimum of 30% of phosphate derived from animal bone and calculated calcium phosphate. This mixture is fired around 1200 °C in two stages. First is a biscuit firing, then glost firing (temperature between 1040˚C – 1080˚C).

g. Raku

It is a traditional type of Japanese Pottery. It is traditionally characterized by being hand shaped rather than thrown; fairly porous vessels, which result from low firing temperatures; lead glazes; and the removal of pieces from the kiln while still glowing hot. The average temperature usually is between 750˚C – 1000˚C.

The material that is usually used in forming process, plastic and non-plastic. (Arkbuckle. 2014)

1. Various of Clay
   a. Kaolin

      Kaolin is clay contains kaolinit minerals as the biggest former. The characteristics of this clay are coarse grained and fragile. It is used for:

      1. White earthenware
      2. As a tiles former

3. Email mixture. Email is a mixture of ceramic and metal. It is used for making a pot or another household.

b. Ball Clay

This is the most plastic clay for ceramic. It is called ball clay because at the beginning this clay was sold in ball shaped. The characteristics of this clay are fine-grained, plastic, and containing carbon.

Usually this is used for white ceramic and email to obtain plastis traits that facilitate the formation, giving strength to the unfired goods that are not easily fragile.

c. Stoneware Clay

This material includes pottery because pottery goods at absorbing water, whereas the porcelain is solid. It includes soil sediments. On earth are found many kinds of stoneware containing feldspar incorporated in clay. The characteristics of this material are plastic, good drying, and the raw color is gray. Usually this material is widely used because it is resistant to acids and in the manufacturing of ceramic art, tiles and pipes.

d. Earthenware clay

Commonly is used in the manufacturing of bricks, crockeru, pots, and various other potteries. The characteristics are colored yellow or orange or red or brown after firing process, depending on the temperature, the raw color is gray.

e. Fire Clay

Including secondary soil type, as commonly found in the area of coal seam. It is highly resistant to high temperature, plastic, and coarse texture. The flame-retardant properties is not contain iron oxide.

f. Bentonite

A high plastic mineral. Not the type of clay despite having the same formula. This material is a volcanic rock weathering. The characteristics is fine soul particles, the composition contains a lot of silica.

2. Various of ceramic materials (non-plastic)

Is a non-plastic material that can be mixed to obtain satisfactory results. Besides being used for manufacturing of ceramic material, it is also used for manufacturing glaze. The materials are as follows:

a. Silica (SiO_2) or Glass

One of essential ingredient in all ceramic material or glaze as a glass forming. This material contains 99.5% of silica and the remaining consists of calcium carbonate or chrome. The functions of silica are to reduce cracking during drying, reduce losses during the firing process and enhance quality.

b. Flint

This material is widely used in parts of Europe for the manufacture of ceramics. High purity and fine crystals, it is commonly added to glaze material to reduce cracks.

c. Feldspar ($KnaO.Al_2O_3.6SiO_2$)

A group of minerals that comes from the crushed rock and can provide up to 25% of the flux in the ceramic body. Feldspar will melt and form molten glass which causes soil particles and the other attached to one another, because it is fused while the firing process. There are 12 kinds of feldspar, but commonly used are feldspar (orthoclase), soda feldspar (albite) and line feldspar (anchorite) each type containing alumina, silica, and flux. Its composition is diverse, materials that contain potassium (K^2O) are used for making ceramics and materials that contain natrium (Na^2O) are used in making glaze.

d. Calcite and Magnetite (CaO and MgO)

Both of these materials are used as flux ingredients in ceramic materials in small amounts. Flux material is called soil alkaline. It is classified as follows:

1. Calcium carbonate ($CaCO_3$) also called *'kalkspat'*. This material is in the form of limestone and the highest sources of calcium
2. Gips ($CaSO_4$). Rarely used in ceramic materials.
3. Dolomite ($CaCO_3MgCO_3$). Carbonate of calcium and magnesium.

The materials which include of soil alkaline always contain Ca. Ca is widely used in ceramic materials because it can make lower melting point of the overall materials, giving white color and prevent curvature during the process of combustion.

e. Aluminum (Al_2O_3)

Alumina or aluminum oxide can not be found in a pure but in the form of chemical combination with other minerals. Separated alumina can not be fused to a temperature of 2000°C, but when 5% alumina was added to the pure silica, the melting temperature will drop to 1545°C. Aside from being reproduce it can also create a matt effect and as a framework in bone china items.

f. Talc ($3MgO.4SiO_2.H_2O$)

Talc contains much magnesium so it is widely used as a glaze ingredient. It is used in some kind of the ceramic industries in electrical tools and ceramic art. This is because the ceramics material which is mixed with talc is highly resistant to sudden temperature changes. Other advantages of talc:

1. Glaze that contains talc can adapt without any cracks
2. Easy to use as a mixture of slip casting.

g. Chamotte or Grog

It is made of fire bricks or pieces of ceramics that has been fired at the first stage (biscuit) and after that it becomes hard finely ground into flour. Chamotte protect against deformation caused by the sudden contraction because chamotte particles larger than clay, the body becomes more porous, allowing fluid easily absorbed into the object surface during drying and burning starters.

h. Cornwall Stone ($1RO.1.16Al_2O_38.95SiO_2$)

Coral species which are grounded, not single minerals such as china clay or quartz. The composition is feldspar, quartz, mica, and fluorspar. It is used to give a white color on the body because the material is free of iron and is used in low and high temperature glazed.

i. Nepheline Selenite ($KnaO.AlO_3.4SiO_2$)

The advantage of using this material in glaze is this material contains more alkaline flux and less silica than feldspar and china stone. It is used as mixed ingredients of Earthenware glaze and stoneware, it works well with alkaline frit. Because of the flux and lack of impurities, this material is good for manufacturing the glassy earthenware body.

j. Peattie (Lithium Feldspar) ($Li_2O.Al_2O_3.8SiO_2$)

This material can be used both for the body and glaze. It is not used to provide a flux because economically it is very expensive and has a low power expansion.

k. Bone Ash (Calcium Phosphate) ($Ca_3(PO_4)_2$)

This material was prepared from cow bones which been pounded. It provides calcium and phosphorus pentoxide. Quality of the flux is derived from calcium phosphorus pentoxide. In preparing bone china, the UK is mixing 50% bone ash. This material is fused with china clay (kaolin) and china stone, form a resilient body and very thin. It is also used for opacity in glaze.

For the formation of the ceramic base material clay is done in several ways, namely:

1. Pinch

   Clay is pressed repeatedly until the desired shape objects. For example: vase, human form, animals, etc.

2. Coil

   Clay twisted with fingers and palms to form a cylindrical pipe or rope which the diameter and length is corresponding desired. After that the chirality formed to the desired shape. Example: tubes vase and free-form shapes.

3. Slab

   Clay is made into slabs with the same thickness using a roll. After the slab clay is done it can be shaped as desired. Example: making a box

4. Rotated

   Clay is put on the turntable and molded as desired. This formation produces cylindrical shapes. Example: cups, mugs, vases, etc.

5. With Jigger Machine

   The clay must be pulverized and smooth. The principle of the process is almost the same by rotated ways, the difference is a jigger as forming the ceramic surface.

6. Press

   For manufacturing the ceramics in this way, the clay must be harder. It is placed into the mold then pressed by hand or tool. The rest of the clay which is out of the mold must be trimmed or cut to follow the shape of the mould.

7. Casting

   For manufacturing in this way the clay must be liquid, often called slip (clay solution that is not too thin). This process begins by pouring the slip into plaster molds and allowed to stand for a few moments then the rest of the unused slip issued. The thickness of an object can be set with the settlement time because the mold is made from plaster which absorbs the water, then the formation process of ceramic wall is from drying slip close to the mold's wall.

8. Dry Pressing

   Clay is used in the form of powder and containing only about 10% - 20% of liquid. The pressure is enough to make it solid. The formation process is using a tool that has great compressive strength to form a desired ceramic. The advantage of this method is the material is used optimally, almost has no waste material. In addition, complex shapes can be done this way. Example: floor tile, plate or tray that has engraving on both sides.

After the forming process, drying clay is also very important. The purpose of drying process is giving strength to the clay so it can be complied into a furnace, and it removes excess moisture that can cause damage at the time of combustion. Some of good in drying process:

a. Aerated

   This method is the best one in an open area, but do not expose it to direct sunlight.

b. Heated

   Clay was put into the machine in which there is a cupboard-shaped shelf as a place to prepare the clay and the temperature has been set. This process is usually faster than the previous one.

The simple way to know whether the clay is dry or not:

a. Press the clay body or the bottom of the clay, if it still feels cold means they are not dry yet.
b. Put the clay on the glass, if after a while it appears blurred because of the moisture from the clay, the clay has not been dried properly.

Clay that has dried in the absence of cracks or deformed, then be prepared to be arranged into a furnace which subsequently fired. Ceramic combustion process can be divided into three groups:

1. Biscuit Firing

   Ceramic were fired first by the temperature combustion between 900˚C - 1060˚C for earthenware, 1150˚C – 1250˚C for stoneware, 1250˚C – 1400˚C for porcelain, 1040˚C – 1080˚C for bone china where the goods are become strong, not destroyed by water, and can produce color.

2. Glost Firing

   Biscuit which had been coated with glaze was burned at a certain temperature, so it is not easy to penetrate the water. Temperature for glost firing assortment starts from 980˚C – 1250˚C, depends on ceramic material and glaze used.

3. Overglaze Decoration Firing

   The ceramic that has been fired in glost firing is given the overglaze material, then it is fired with low temperature.

There are several ways to know if a ceramic that has been burned already cooked or not. Here are simple ways:

a. Water dripping into the ceramic, is the water quickly seeped or not. If so, then the ceramic needs to be burned again..
b. Scraping a sharp object on the biscuit, when scratched with a little pressure, the biscuit is still under cooked.

2.3.2. Reverse Engineering

During this period, a time limit in the development of a product is essential to meet the needs of the market which are changing continuously. If this is achieved, it can compete with competitors to conduct the product design which is fast and optimal in technical fields such as aerospace, automotive, ship dock and some fields that have products with complicated shapes and dimensions in the CAD model creation. In this case, reverse engineering is an efficient approach to significantly reduce the product development cycle.

Reverse engineering is a process used to remanufacture when a product does not have a complete data specification of the dimensions, shape, and contours.

Abella et al. (1994) RE describes as the basic concept of producing partly based on the original model without the use of a physical or engineering drawing. Yau et al. (1993), RE defined as the process of taking a new geometry of a component or part by means as simple as measuring with caliper or micrometer and redrawn, today has emerged a sophisticated technique that can translate data from x-ray or three-dimensional laser which is the data been transferred to a computer for data modeling CAD.

Formerly reverse engineering is only considered a cost-saving tool in the analysis of a product as the understanding and improvement. While, reverse engineering usually is used in the factory, is contributed to the evolution of the information produced products, both on the subsystem, configuration, components, or parametric level, which occur through the re-design process.

But today reverse engineering is used not as a tool to be used in solving the existing problems, but as a practical methodology to accept new challenges from a variety of new products increasingly complicated and complex. There are three basic stages of the reverse engineering process:

a. Scanning

   This phase is a scanning technique, we must have the correct strategy, prepare the part to be scanned, and scan to get the data that describe all the geometric features of the object such as steps, slots, pockets, and holes. There are two different types of scanners, contact and non-contact.

   1. Contact scanner

      Contact methods use sensing devices with mechanical arms, Coordinate Measurement Machines (CMM) and Computer Numerical Control (CNC) machines, to digitize a surface. There are two types of data collection techniques employed in contact methods : point-to-point sensing with touch trigger probes and analogue sensing with scanning probes. (These probes have a tolerance level between 0.01 to 0.02 mm, depend on the surface of the object and the size of the probe used).

      The advantages using contact scanner are high accuracy, low cost, ability to measure deep slots and pockets and insensitivity to color or transparency. Also there are some disadvantages : slow data collection and distortion of soft object by the probe.

2. Non-contact scanner

   In this method 2-D cross-sectional images and point clouds are captured by projecting energy source (light, sound, or magnetic field) onto an object; then either the transmitted or the reflected energy is observed.

   The advantages using non-contact scanner are no physical contact, fast digitizing of substantial volumes, good accuracy and resolution for common applications, ability to detect colors and ability to scan highly detailed object where mechanical touch probes may be too large to accomplish the task. Also there are some disadvantages : possible limitations for colored, transparent, or reflective surface and lower accuracy

b. Point processing

   At this stage the data that have been acquired will be processed and are selected in order to become a good surface. The data which have been taken are dots or often called point clouds. Several softwares have been served with menu that had ability to merge point clouds into a surface.

c. Application

   These steps depend on the need for a method of reverse engineering. For example we will do the process of scanning on a mold injection machine that had broken to get new mold, on the other side reverse engineering can be used in analysis or measuring of a product that has been made, whether in accordance with a CAD model or not. Reverse engineering can also be used in medical science in making of artificial bone on the original had been damaged and the results of the artificial exactly same with the original.

The following are the reason why we use reverse engineering:

1. The original product of the company has disappeared, but the request of their product from the customer is still there. Example: plane spare parts or other automotive.
2. A product data are unavailable because there are some of causes. As the conversion of the product of one carrier to other companies.
3. Making data for repeated production or improvement of existing products but has lost the original data.
4. To inspect a product is in accordance with the CAD model or not
5. As the tool to analyze good or bad a product of competitor.

6. Created the 3D CAD model of a statue to make of animated or movie.
7. Created the 3D CAD model of a sculpture or artwork that will be made in a smaller scale as a souvenir.
8. To a process of fittings of the footwear products in order to comply with a form of customer's foot.
9. Create the replica of bone and tooth in the medical field.

2.3.3. Coordinate Measuring Machine (CMM)

A decrease in the age of a product force companies to develop and produce products at the top level. The experts predict the arrival of a rapid manufacture through the use of a flexible manufacturing system. One of the results of this trend is the merger of Coordinate Measuring Machine (CMM) that allows company to do the data collection and verification process in a short time.

CMM is an electro-mechanic system designed to determine the coordinates point on the surface of object which done by the probe. This machine is available in various size and design with a variety of technologies. The most important in CMM is measuring a long-distance of x axis, y and z, and the resolution. This machine is measuring the displacement distance of the origin point of an object then recorded and processed into data of measurement using software that is included in CMM. Principally CMM is the inverse of CNC. In CNC the coordinate that is input produces a cutter movement on the x-axis, y and z, while in CMM contact between the probes by a work piece produce a coordinate. In addition if the CNC uses a circulated ball bearing, CMM uses air pad bearing so that the movement was very smooth. To guarantee the accuracy, the construction of CMM was made very rigid by using granite as a table or sphere of reference.

Controlling this machine can be done manually by an operator, while CNC is automatically controlled entirely by the existing program on the software.

Figure 2.1. Coordinate Measuring Machine (CMM)

CMM consists of several main components interrelated and affect the accuracy of the machine. The parts are:

a. Working table, a place of putting parts to be measured which is made of granite.
b. Support, is the leg to prop up the entire burden of CMM. Some CMM is furnished with air damper to reduce the vibration effects which produced by the environment around the CMM.
c. Air bearing, CMM uses air bearing as a foundation to move for the entire axis.
d. Axis Guide ways, is the track of all axis to move, having direct contact with air bearing. The average material made of aluminum, some of them also use granite stones. For a machine with higher accuracy is using ceramic material.
e. Motor, is the main part to drive the axis specifically to the automatically engine of just motorized using a joystick.
f. Joystick, is a control panel to facilitate the operators to operate machinery.
g. Controller, have various function: interface between pc and, motor driver as a resources for the engine movement, data storage for storing correction files or movement program of CMM, ADC, DAC, etc.
h. Probe head, works as a trigger for the CMM to record the touch point position. Some CMM equipped with non-contact probe head to get touching point that can reach hundreds or even thousands of points for the purposes of CAD/CAM. We can not directly touch the part but through intermediaries stylus serve as a feeler.

i. Sensors. CMM has many sensors to improve its accuracy. The sensors include: temperature sensor, overcurrent sensor, limit switch, home position sensor, air pressure sensor, reading head.
j. Linear scale. This unit is a transducer to change position to be a current or voltage. Using the software converts it into coordinate data.
k. Software. A linker between the user and machine.

Currently the best result in terms of accuracy and surface quality is obtained using contact system reverse engineering. It has the advantages of non-contact system, which are:

1. Prevent unnecessary data retrieval because it can make the scan results into a large memory.
2. The perpendicular view can be taken accurately.
3. The density of the data can not be determined automatically but manually and we can take the data freely.
4. Tiny detail can be captured accurately.

Reverse engineering-based methods have been around forty years ago. The first method of reverse engineering is Coordinate Measuring Machine (CMM). This is a machine that can provide data in the form of 3D shape of the original object. CMM measures the surface of an object using the contact probe, with a highly sensitive pressure device. It will be activated if there is direct contact with the object.

There are several types of CMM in determining accurate measurement, flexibility, time of the measurement process, the maximum work piece dimensions scalable and cost. Most types of CMM can be controlled manually by the operator or by a program. CMM which is driven by the operator called Manual CMM, while driven by a program called CNC CMM. The following are explanations of some CMM types:

a. Bridge Type

   For this type, the vertical arm (z-axis) is suspended vertically from a horizontal beam that is supported by two vertical posts in a bridge arrangement. The machine x-axis carries the bridge, which spans the object to be measured. This type of CMM can have a smaller footprint which is suitable for clear room or design laboratory type of facilities. Applications for this machine are the inspection of the machine component, free surface shape or varying (dies, metal, plastic, molds), inspection based of the points on the object, continue inspection. Figure 2.4. is examples of bridge type CMM.

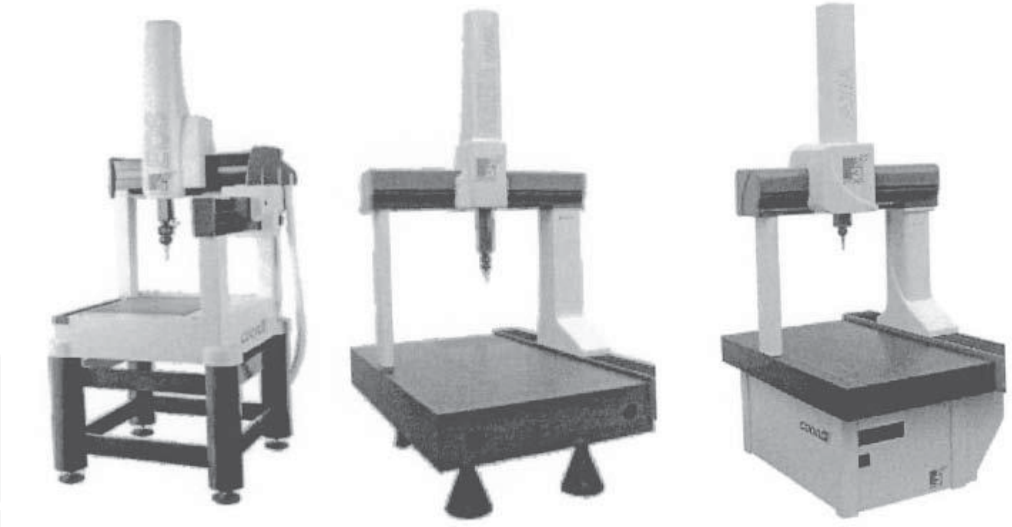

Figure 2.2. CMM Bridge Type (Kamrani, 2006)

b. Gantry Type

This class of machines is used for large part sizes which can span 4 meters or more. Gantry style machines employ a frame structure raised on side supports to span over the object to be measured or scanned. A horizontal beam traverses the length of the measured object. It is powered with dual drives to minimize the yaw or twisting of the side supports during traverse. A measuring arm is mounted on this horizontal beam that moves along the width of the object being measured. Gantry machines have a rugged construction as compared with other CMM. This type of machine has the best measuring volume to overall dimension ratio within CMM. Space for this machine is wider than the bridge type. The application of this machine is on an object that has a greater dimension and weight like pipes, automobile or motorcycle parts. Figure 2.5. is examples of gantry type CMM.

Figure 2.3. CMM Gantry Type (Kamrani, 2006)

c. Cantilever Type

In this machine, a vertical arm is supported by a cantilevered support structure. This type of open configuration allows for easy operator access to the object being measured. Heavy parts can be measured by placing them on the fixed table. However, due to the overhanging cantilever structure it has a lower 'system natural frequency affecting the speed of measurement. This type of system is suitable for longitudinal parts that fit along the length of the table and have smaller dimension in the other two axes. The application of this machine is for marking-out on models, cast and sheets which have free form surface. Examples of cantilever type CMM are shown in Figure 2.6.

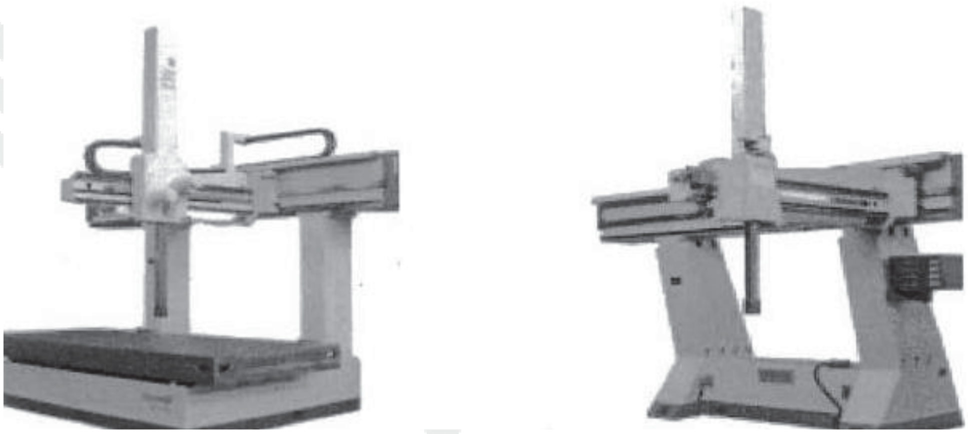

Figure 2.4. CMM Cantilever Type (Kamrani, 2006)

d. Horizontal Arm Type

Horizontal arm machines are widely used in the automotive industry. In this configuration the arm that supports the measuring probe is horizontally cantilevered from a movable vertical support. As a result, this style is sometimes referred to as cantilever design. It is also available in dual arms. The overhanging arms limit the dynamic stiffness of the machine affecting speeds of measurements. The applications of this machine are for large dimension components, measurement of free form body contour (automobile styling and aircraft aero foil shape). Figure 2.7. is example of horizontal arm type CMM.

Figure 2.5. CMM Horizontal Arm Type (Kamrani, 2006)

e. Articulated Arm Type

An articulated arm configuration is used for portable, or tripod mounted style machines. The articulating arm allows the probe to be placed in different directions with respect to the object being measured. These systems contain a series of counterbalanced six-degrees-of-freedom linkage arms. Each arm is provided with precision rotary transducers that encode the rotary motion of the linkages and calculates coordinates in 3D space. The measuring envelope of this type system is spherical, enabling measurement of hard to reach locations within components. Accuracy of measurements is largely affected by operator skill and is lower as compared to bridge style systems. These types of systems are manufactured with light weight alloy for high rigidity and low weight. The applications of this machine are for field use for wide range of applications, continuous measurement of free form surfaces (auto styling, aero-wing, aero foil contour, etc). Figure 2.8. is example of articulated arm type CMM.

Figure 2.6. CMM Articulated Arm Type (Kamrani, 2006)

2.3.4. Design as The Technical Language

Pictures generally are the information given to others to declare the aim of the creator. Pictures are used in engineering fields as the media to continue the information exactly and objectively, called as engineering language.

Information in the pictures can't be written with sentences, but it must be given in term of common symbols used in engineering language. The most important thing for designer is the designer can give exact pictures consider to the reader. For the reader, the most important thing in reading the pictures is how much information that he/she can get.

In engineering language, pictures have many functions. Based on the group there are three functions:

a. Arriving information

In arriving information, we have to consider about the readers of the pictures because the people is not only from the company itself but sub-contract people and foreign people that use different language. So the pictures have standards as engineering language system for supporting enough rules. Designers have to understand and notice this.

b. Keeping, lasting, and using information

In physical or non-physical project, we must have save able data as the reference to make it better or for next project. In this case, pictures are one of technical data that is effective where the technology of company is gotten and collected. Pictures also can be used as information for new plans.

c. Methods of thinking in keeping the information

In planning a project's concept, things in the mind can be formed in pictures by analyzing and then the pictures are seen carefully and evaluated. To get perfect result, this process needs to be done repeatedly.

In short term, drawing is not only an activity but drawing is used to enhance the mindset in the planning. An engineering academia without drawing prosperity will have less way in giving the important desires.

2.3.5. PowerSHAPE

PowerSHAPE is one of CAD software, product from Delcam. In powerSHAPE there are basic modules functionality and several specialized such as: PS-Draft (for making detail pictures), PS-Mold maker (for designing a mold), PS-Assembly (for making assembly process model from solid form), PS-Render (for showing pictures with good visual quality). (UAJY-Delcam Training Center, 2006)

Beside it, there are other instruments, these are the explanation:

1. Wireframe Modeling

   This is used to make a model from surface and solid. Compare to the other software, PowerSHAPE can give better wireframe in 2D or 3D model.

2. Surface Modeling

   It has six standard primitive surfaces, there are: Plane, Box, Sphere, Cylinder, Cone, and Torus. With standard primitive surfaces we don't need to make wireframe. Besides, the primitive surfaces' shape or size can be edited and modified as we wish.

3. Solid modeling

   In solid modeling we can make pictures from solid primitive. A solid can be made with joining some surfaces. A surface can be converted into solid.

4. Triangle modeling

   It is very useful for editing a STL file. With triangle modeling we can modify the shape and size freely.

In PowerSHAPE there are features to evaluate a CAD model before entering the next step. These features are very useful to avoid defect in machining process. After machining process sometimes there are unsmooth surfaces or unwanted dents. The features are:

a. Models Contents List

   The function is showing the amount of wireframe, curve, surface, and solid in a model.

b. Toggle Surface Inspection Mode

   Help to check the selected surface and leave the unselected surfaces.

c. Sectioning Dynamic

   Help to make sectional view. It helps users to see the thickness or the section result of the pictures.

d. Smoothness Shading

   Help in checking the surface smoothness of a picture before entering the machining process. It is noticed carefully by the company.

e. Undercut Shading

   Help to check whether there is undercut part or unreachable surface in three axis machine or not.

f. Curvature Shading

   Show the curves of the model.

g. Minimum Radius Shading

   Check the smallest radius in the model. It is very helpful in choosing the milling cutter that will be used in machining.

h. Thickness Shading

   Help to analyze the thickness of solid model.

i. Minimum Wall Thickness

   It is a minimum wall thickness' view in solid model.

j. Model Compare

   Compare two different models.

PowerSHAPE can read or export file from other CAD software like AutoCAD, IGS, ACIS, CATIA, Inventor, ArtCAM, Solidworks, and ProEngineer.

In PowerSHAPE, there is stencil feature. This feature helps user to make a design from JPEG picture, then make lines based on JPEG picture. This process is called tracing.

2.3.6. CMM Manager

CMM manager is one of software to run the CMM. This software can help users in measuring and checking from the CAD model directly. Beside it, users can simulate the measuring process to know there are any mistakes or not.

These are some of function in CMM Manager:

1. Walk-in Measurement

   CMM Manager fully supports walk-in checking, includes the machine setting, spot checking, fast dimension checking, and shows the checking report.

   Fully integrated environment supplies complete measurement working room to do some procedures, includes work piece's reference setting and report collecting point. Users can finish walk-in measurement in minutes with this software.

2. Teaching a part program

   In CMM application, a program is always created to record checking process command, so can be executed or run for repeated working. For modern manufacturing process, we very need program, so it doesn't only guarantee consistent checking but also make lower inspection time.

3. Running a part program

   After making and saving program, CMM-Manager enables users to take the finished program from the file and then run repeatedly to check the work piece. It will give advantage for the users because CMM can check automatically and consistently and minimize operator interaction in doing measurement.

4. Offline part programming

   CMM-Manager provides ability in teaching programs when it breaks from CMM itself in PC remote without CMM. The ability of offline program can make the CMM users to do the duties of actual product inspection freely. CMM-Manager calculates all needed parameters (measuring, checking, probe combustion, and good probe angle). Simulating inspection helps in program verification before doing CMM via online.

5. Graphical and test reporting

   CMM-Manager has ability in reporting to visualize and make documentation the checking result, make the report from CMM inspection result easily, fast, and accurately.

6. Complete GD and T Tolerance reporting

   CMM-Manager supports types of toleration in reporting. Every type contains a method to decide the value of toleration default so it can reduce time needed of the operator to make the report.

7. Reverse Engineering

   Measuring result can directly export to standard CAD file, such as IGES and DXF. Then it can be imported into CAD system that is used to achieve the reverse engineering order. This ability makes the need of the manual measurement tools disappear and avoids the non-accurate measurement.

In CMM-Manager there are some menus that help in scanning. There are:

a. Alignment Tab

   This is used to reset the measured or checked parts that have moved physically in CMM table. This can happen because of accident or because priority production needs to check different part. This menu disables lost in measurement previous data.

b. Features tab

   In this menu there are some tools that are used for giving command to measure, build fields, and edit.

c. Report tab

   This menu sets the reporting the measurement result that has done.

d. Program tab

   Set the measurement program from created commands.

e. Probe tab

Set and edit probe

f. Import / export tab

To import and export file that already did before

g. System tab

It contains about system setting in CMM Manager.

h. Display tab

Set the view of CMM Manager

i. Graphical report tab

Show the measurement result and the dimension of the work piece that want to be formed.