The Computer-Integrated Manufacturing System for a Mold and Die Company

by

Ms. Ma Pa Pa Htet

A Final Report of the Three-Credit Course
CE 6998 Project

Submitted in Partial Fulfillment
of the Requirements for the Degree of
Master of Science
in Computer and Engineering Management
Assumption University

November 2006

The Computer-Integrated Manufacturing System for a Mold and Die Company

by
Ms. Ma Pa Pa Htet

A Final Report of the Three-Credit Course
CE 6998 Project

Submitted in Partial Fulfillment
of the Requirements for the Degree of
Master of Science
in Computer and Engineering Management
Assumption University

November 2006

Project Title	The Computer-Integrated Manufacturing System for a Mold and Die Company
Name	Ms. Ma Pa Pa Htet
Project Advisor	Dr. Chamnong Jungthirapanich
Academic Year	November 2006

The Graduate School of Assumption University has approved this final report of the three-credit course, CE 6998 PROJECT, submitted in partial fulfillment of the requirements for the degree of Master of Science in Computer and Engineering Management.

Approval Committee:

(Dr. Chamnong Jungthirapanich)
Advisor and Program Coordinator

(Prof. Dr. Srisakdi Charmonman)
Chairman

(Assoc. Prof. Somchai Thayarnyong)
CHE Representative

November 2006

ABSTRACT

This project paper studies the Computer-Integrated Manufacturing (CIM) systems in the mold and die manufacturing industries. The existing system of Kyocera Chemical (Thailand) Limited (KCTL) is taken as a model for implementing the CIM systems in the mold and die manufacturing industries.

Literature reviews are made on automation, productions systems and Computer-Integrated Manufacturing (CIM). Onsite survey and analysis are done at KCTL so as to produce the existing system and analyse the requirements at the company. Survey data and collected data from the company as well as other collected facts and information regarding the CIM systems are compiled as raw materials for the project. Further studies are carried out on the current CAD/CAM software and hardware providers, CNC machines, and smart EDM machines are made so as to satisfy the requirements at the company, so also to come up with ideas on proposed system. Industrial safety standards and environmental impacts in implementing CIM systems ate later studied so as to adjust the company's weak points. The CAD/CAM evaluations (especially on CimatronE version 8), CNC machine evaluations (especially on 5axis machines), and smart EDM evaluations are also collected so as to provide facts in implementing the proposed system.

The conclusions and recommendations give the overall ideas and suggestions for achieving the goals by implementing the CIM systems, which contributes great success not only to KCTL, but also for the mold and die manufacturing industries as a whole.

ACKNOWLEDGEMENTS

In bringing up this project paper to a success, I am deeply indebted to many persons. Many people have contributed their invaluable support towards my project physically, mentally, and some financially.

I would like to express my sincere gratitude to Dr. Chamnong Jungthirapanich, my project advisor, for his invaluable advice, time, suggestions, recommendations and encouragement throughout the whole project processing period up to the last minute. Secondly, I would like to thank Dr. Akajate Apikajornsin, for his initiative teachings and guidance towards Automation and Computer-Integrated Manufacturing (CIM).

I would like to thank Mr. Hidehiro Iwase, Managing Director, Kyocera Chemical (Thailand) Limited, KCTL, for giving me a chance to conduct the interview and survey at the company's office meeting room and factory. I would also like to thank the two persons from the CAD/CAM department of KCTL, Mr. Hideaki Takano, General Manager and Chief Engineer, and Mr. Banluesak Thongngao, Assistant Engineer and Manager, for their valuable practical answers towards my survey questions and their sincere personal opinions towards the future trend of CAD/CAM and CIM visions. I also would like to show my deep appreciations to Ms. Ma Nilar, the coordinator of KCTL, for her expertise in interpretation throughout the interview and survey.

I also would like to thank all my friends for their valuable help in some areas.

Finally, I would like to express my deep gratitude to my parents, who let me come into this wonderful world and brought me up to this stage.

TABLE OF CONTENTS

Chapter Page

LIST OF FIGURES

LIST OF TABLES

I. INTRODUCTION

1.1 Background of the project

Nowadays, globalization is pushing most of the global industries to improve their manufacturing strategies since the global market competition is getting wider and higher. Among those industries, mold and dies industries are one of the most important industries using turning edge technologies to change the industrial trends around the globe. Mentioning the turning edge technology in mold and die industries, Automation, Production systems and Computer-Integrated Manufacturing (CIM) are the fundamental concepts of the industries' overall processes.

These three systems have a very high impact on the global industries. The three are always growing with incredible technologies and their encroachments in the industrial sectors are also clearly seen. The evolution of the manufacturing systems or the implementation of the CIM systems can be seen in most areas of the mold and die industries around the world. The CIM systems for mold and die industries are developing with high technology and its implementations are also considerably very high in the point of investment.

Here in Thailand, we have many leading international companies providing the best technology and market knowledge of user requirements, market opportunities, technology trends, strategic planning, and competitive information. ASEAN's Only Machinery and Technology Trade Exhibition & Conference for Mold & Die Manufacturing - 14th Edition was held between **1-4** June, 2006 at the Bangkok International Trade & Exhibition Centre (BITEC). This year's exhibition was filled with more than one hundred local and international manufacturers and distributors, which was counted only in the InterMold Thailand 2006 section. Together with that Assembly

Technology, Automotive Manufacturing 2006 (co-located with Automotive Electronics 2006), and InterPlas Thailand 2006 were on the exhibition, too.

Although the exhibition and conference were held, most of the small companies would not dare to implement CIM systems as the implementation would have very high investment and risk associated with implementation of CIM tools and systems. Also, the structure of manufacturing in Thailand is used to with the labor-intensive manufacturing, which, actually, is also changing to the technology-intensive manufacturing so as to compete in the global market. Thailand, however, is still having advantage on cheap migrant labors form the neighboring countries like Myanmar (Burma), Cambodia, and Laos. Thus, Thai mold and die industries are still having barriers to invest in the implementation of CIM systems in their manufacturing society.

On the other hand, most of the mold and die companies are still reluctant to implement the total CIM systems and its application tools as of weak budgeting, few qualified professional staffs, and options with cheap labor, and thus, still coping with the old traditional manufacturing systems. The dark side of the old traditional manufacturing systems is that in the long run, they will face lower product quality, slower manufacturing, low customer demand, higher labor cost, weak design, longer lead time, and so on.

So, what is CIM? What kind of company should implement CIM systems? Why should the company implement CIM systems? What are the most important features of CIM systems?

The term Computer-Integrated Manufacturing (CIM) includes the extensive use of computer systems to design the products, plan the production, control the operations, and perform the various business-related functions in a manufacturing firm. For example, Mold and die manufacturers of automotive parts, or electrical and electronic components should implement CIM systems. The most important quality or feature of CIM is integrating the fundamental elements of the company: physical integration through the linking of hardware and software systems; logical integration through shared common company's information or data; philosophical integration based on a new sense of purpose and direction in every entity in the company. To increase productivity, to reduce labor cost, to improve product quality, to reduce manufacturing lead time, and to accomplish process that cannot be done manually, the company should implement CIM systems.

Therefore, Computer-Integrated Manufacturing (CIM) systems, which I believe, is the best solution not only for the mold and die industries in Thailand alone, but also for the other types of industries in other countries around the world.

1.2 Objectives of the project

The objectives of this project are

- to study the mold and die manufacturing trends
- to apply the Computer-Integrated Manufacturing (CIM) Systems in mold and die manufacturing industries
- to implement and analyse the Computer-Aided Design/Computer-Aided manufacturing (CAD/CAM) systems in mold and die manufacturing industries
- to study the impacts of CIM on the socioeconomic and environmental factors

1.3 Scope of the project

Since the Computer-Integrated Manufacturing (CIM) includes all of the engineering functions of Computer-Aided Design/Computer-Aided manufacturing (CAD/CAM), and the firm's business functions that are related to the manufacturing, the scope of CIM is wider than that of CAD/CAM.

In this project, the paper will concentrate more on the scope of CAD/CAM, however, the scope of CTM will not be reduced. Thus, the problems and solutions for the designing department, manufacturing department, manufacturing control department, and factory operations will be focused from the CAD/CAM perspective.

IL LITERATURE REVIEW

2.1 Definitions

Definitions are made to give the readers clear meanings, bright visions, and, the most importantly, the understandable explanation of a statement, a word, or a phrase. Sometimes, it can be in words, and/or in symbols, but they also have meanings.

2.1.1 Manufacturing

Many engineering groups and academics have defined many definitions for manufacturing from their own perspectives.

Manufacturing, in the 1990s, is defined as a collection of interrelated activities that includes product design and documentation, material selection, planning, production, quality assurance, management, and marketing goods (Rehg, 1994).

In general, nowadays, *manufacturing* is defined as a process in which the application of physical and chemical processes are used to make alterations in the geometry, properties, arid/or the appearance of a given starting material to make parts or products; manufacturing also includes the joining of multiple parts to make assembled products. Accomplished manufacturing processes involve a combination of machinery, tools, power, and manual labor (Groover, 2001).

2.1.2 Production System

The *production system* is defined as the collection of people, equipment, and procedures organized to accomplish the manufacturing operations of a company (or other organization). Production systems can be divided into two categories or levels as in Fig (2.1) (Groover, 2001):

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

2. *Manufacturing support systems:* This is the 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, portions of the production system are automated and/or computerized. However, production systems include people. People make these systems work. In general, direct labors (blue collar workers) are responsible for operating the facilities, and professional staffs (white collar workers) are responsible for the manufacturing support systems (Groover, 2001).

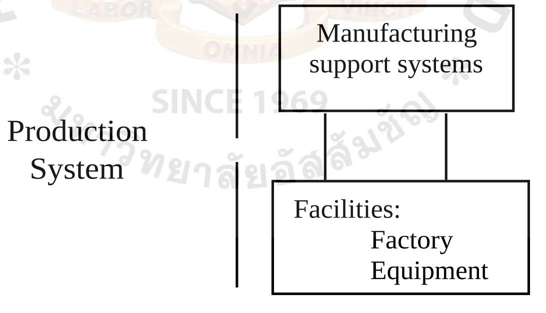


Figure 2.1. The production system consists of facilities and manufacturing support systems (Groover, 2001).

2.1.3 Production Quantity

- Low Production : 1-100 unit/year
- Medium Production : 100-10,000 unit/year
- High Production : 10,000 — Ms unit/year

2.1.4 Product Variety

- product variety is inversely proportional with production quantity

2.1.5 Automation

Automation is defined as a technology concerned with the application of mechanical, electronic, and computer-based systems to operate and control production. It is implemented using a program of instructions combined with a control system that executes the instructions (Groover, 2001).

The automation in the production system can be divided into two parts;

1. Automation of the manufacturing systems in the factory, and
2. Computerization of the manufacturing support systems.

Nowadays, in some production systems, the two parts overlap to some extent where Computer-Integrated Manufacturing (CIM) is implemented.

2.1.6 Computer-Integrated Manufacturing (CIM)

From the point of the Computer and Automaton Systems Association (CASA) of the Society of Manufacturing Engineering (SME), *Computer-Integrated Manufacturing (CIM)* is defined as the integration of the total manufacturing enterprise through the use of integrated systems and data communications coupled with new managerial philosophies that improve organizational and personnel efficiency (Rehg, 1994).

In modern texts, the term *Computer-Integrated Manufacturing (CIM)* is defined as the pervasive use of computer systems to design the products, plan the production, control the operations, and perform the various business-related functions needed in a manufacturing firm. True CIM involves integrating all of these functions in one system that operates throughout the enterprise (Groover, 2001).

2.1.7 Computer-Aided Design (CAD)

Computer-Aided Design (CAD) is defined as the use of computer systems to support the product design function (Groover, 2001).

2.1.8 Computer-Aided Manufacturing (CAM)

Computer-Aided Manufacturing (CAM) is defined as the use of computer systems to perform functions related to manufacturing engineering, such as process planning and numerical control part programming (Groover, 2001).

2.1.9 CAD/CAM

CAD/CAM is defined as the use of computer systems to perform both Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) when the two systems are integrated into a single system (Groover, 2001).

2.2 Reasons

2.2.1 Reasons for CIM and Automation

Most companies use incredibly large amount of investments and take high risks for implementing Automation and Computer-Integrated Manufacturing (CIM) systems in their industries, why? They have very good reasons for that as we follow through the following points (Groover, 2001):

1. **To increase labor productivity:** Implementing Automation and CIM systems in a manufacturing operation usually increase production rate and labor productivity, which means greater output per hour of labor input.
2. **To reduce labor cost:** The labor cost is always increasing, which continues to be the trend in the global industrialized societies. As of this, implementing CIM and automation have become economically justifiable to overtake manual operations. Machines and computers are increasingly being substituted instead of human labors to reduce unit product cost.
3. **To mitigate the effects of labor shortages:** There is a general shortage of labor in many advanced nations, and this has stimulated the development of automated operations as a substitute for labor.
4. **To reduce or eliminate routine manual and clerical tasks:** An argument can be put forth that there is social value in automating operations that are routine, boring, fatiguing, and possibly irksome. Automation such tasks serves a purpose of improving the general level of working conditions.
5. **To improve worker safety:** By automating a given operation and transferring the worker from active participation in the process to a supervisory role, the work is made safer. The safety and physical well-being

of the worker has become an objective in many industrialized countries as they try to improve their workers' working conditions, welfare, and safety. This has encouraged a process to develop more for automation and CIM systems.

6. **To improve product quality:** Automation and CIM systems not only results in higher production rates than manual operations, it also performs the manufacturing process with greater uniformity and conformity to quality specifications. Reduction of fraction defect rate is one of the chief benefits of automation and CIM systems.

7. **To reduce manufacturing lead time:** CIM and Automation help to reduce the elapsed time between customer order and product delivery, providing a competitive advantage to the manufacturer for future orders. By reducing manufacturing lead time, the manufacturer also reduces work-in-process inventory.

8. **To accomplish processes that cannot be done manually:** Certain operations cannot be accomplished without the aid of a machine. These processes have requirements for precision, miniaturization, or complexity of geometry, which cannot be achieved manually. Examples include certain integrated circuit fabrication operations, rapid prototyping processes based on computer graphics (CAD) models, and the machining of complex, mathematically defined surfaces using computer numerical control (CNC). These processes can only be realized by computer controlled systems.

9. **To avoid the high cost of not automating:** There is a significant competitive advantage gained in implementing CIM systems and automation for a manufacturing plant. The advantage cannot easily be

demonstrated on a company's project authorization form. The benefits of automation often show up in unexpected and intangible ways, such as in improved quality, higher sales, better labor relations, and better company image. Companies without CIM systems and Automation are likely to find themselves at a competitive disadvantage with their customers, their employees, and the general public in the face of global market.

2.2.2 Manual Labor in Production Systems (Groover, 2001)

Situations that manual labor is preferred more than automation are:

1. Task too technologically difficult to automate,
2. Short Product life cycle,
3. Customized product,
4. Un predictable demand, and
5. Reduced risk of product failure.

2.2.3 Labor in Manufacturing Support Systems (Groover, 2001)

Even if all of the manufacturing systems in the factory are automated, there will still be a need for the following kinds of work to be performed:

1. Equipment Maintenance
2. Programming and computer operation
3. Engineering project work
4. Plant Management

2.3 The Relationship between Automation and CIM (Groover, 2001)

In a manufacturing firm, the physical production activities that take place in the factory can be distinguished from the information-processing activities, such as product design and production planning that usually occur in an office environment. The physical activities include all of the processing, assembly, material handling, and inspection operations that are performed on the product in the factory. These operations come in direct contact with the product during manufacture.

The relationship between the physical activities and the information-processing activities in the Mikell P. Groover's model is redrawn as in Fig (2.2) (Groover, 2001)

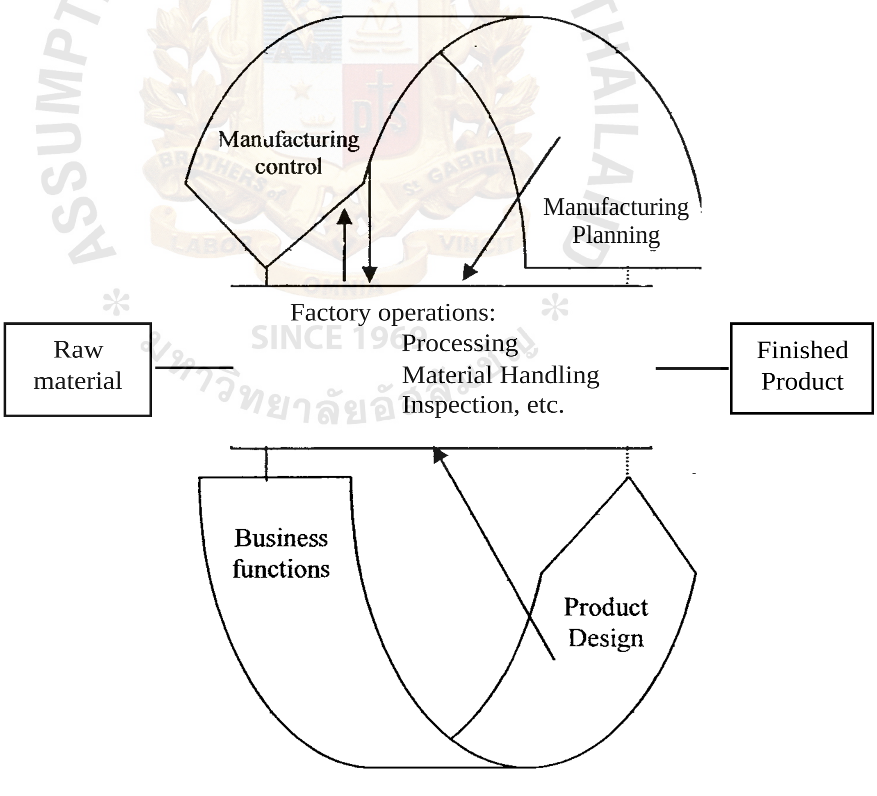


Figure 2.2. Model of manufacturing showing factory operations and the information-processing activities for manufacturing support (Groover, 2001)

Raw materials flow into one end of the factory and finished products flow out the other end. The physical activities take place inside the factory. In the Mikell P. Groover's model, the information-processing activities form a ring that surrounds the factory, providing the data and knowledge required to successfully produce the product. These information-processing activities are accomplished to implement the four basic manufacturing support functions identified as in Fig (2.2): (1) business functions, (2) product design, (3) manufacturing planning, and (4) manufacturing control. These four functions form a cycle of events that must accompany the physical production activities but do not directly touch the product (Groover, 2001).

1. **Business Functions:** The business functions are the principal means of communicating with the customer. They are, therefore, the beginning and the end of the information-processing cycle. The functions included in this section are sales and marketing, sales forecasting, order entry, cost accounting, and customer billing.

2. **Product Design:** If the product is to be manufactured to *customer design,* the design will have been provided by the customers. The manufacturer's product design department will not be involved. If the product is to be produced to *customer specifications,* the manufacturer's product design department may be contracted to do the design work for the product as well as to manufacture it. If the product is *proprietary,* the manufacturing firm is responsible for its development and design. The department of the firm that is organized to accomplish product design might include research and development, design engineering, drafting, and perhaps a prototype shop.

3. **Manufacturing Planning:** The information and documentation that constitute the product design flows into the manufacturing planning function.

The information-processing activities in manufacturing planning include process planning, master scheduling like making the master production schedule (MRS), requirements planning like material requirements planning (MRP), and capacity planning.

4. **Manufacturing Control:** Manufacturing control is concerned with managing and controlling the physical operations in the factory to implement the manufacturing plans. The flow of information is from planning to control. Information also flows back and forth between manufacturing control and the factory operations. The functions included in the manufacturing control are shop floor control, Inventory control, and quality control.

2.4 Ten Strategies for Automation and Production Systems (Groover, 2001)

1. Specialization of operations.
2. Combined operations.
3. Simultaneous operations.
4. Integration of operations.
5. Increased flexibility.
6. Improved material handling and storage.
7. On-line inspection.
8. Process control and optimization.
9. Plant operations control.
10. **Computer-integrated manufacturing (CIM)**

2.5 Manufacturing Industries (Groover, 2001)

Industry consists of enterprises and organizations that produce and/or supply goods and/or services. Specific industries can be put in the primary, secondary and tertiary categories, based roughly on the International Standard Industrial Classification (ISIC) used by the United Nations (UN), as follows:

1. Primary: Agriculture, Forestry, Fishing, Mining, Livestock, Quarries, Petroleum... etc
2. Secondary: Aerospace, Computer, Automotive, Electronics... etc.
3. Tertiary - Banking, Communication, Education, Entertainment, Repair and maintenance... etc.

2.6 Manufacturing Operations (Groover, 2001)

There are certain basic activities that must be carried out in a factory to convert raw materials into finished products. Limiting our scope to a plant engaged in making discrete products, the factory activities are:

1. Processing and Assembly Operation
2. Material Handling
3. Inspection and Test
4. Coordination and Control

2.7 Level of Automation (Groover, 2001)

The concept of automated systems can be applied to various levels of factory operations, One normally associates automation with the individual production machines. However, the production machine itself is made up of subsystems that may themselves be automated. For example, one of the important automation technologies is numerical control (NC). A modern numerical control (NC) machine tool is an automated system. However, the NC machine itself is composed of multiple control systems. Any NC machine has at least two axes of motion, and some machines, nowadays, have up to five axes. Each of these axes operates as a positioning system, and is, in effect, itself an automated system. Similarly, a NC machine is often part of a larger manufacturing system, and the larger system may itself be automated. For example, two or three machine tools may be connected by an automated part handling system operating under computer control. The machine tools also receive instructions (e.g., part programs) from the computer. Thus, we have three levels of automation and control included here (the positioning system level, the machine tool level, and the manufacturing system level). In general, we can identify five possible levels of automation in production plant. They are defined next, and their hierarchy is depicted in Fig (2.3) (Groover, 2001).

1. Device level: This is the lowest level in our automation hierarchy. It includes the actuators, sensors, and other hardware components that comprise the machine level The devices are combined into the individual control loops of the machine; for ex ample, the feedback control loop for one axis of a CNC machine or one joint of an industrial robot.

2. **Machine level:** Hardware at the device level is assembled into individual machines. Examples include CNC machine tools and similar production equipment, industrial robots, powered conveyors, and automated guided vehicles. Control functions at this level include performing the sequence of steps in the program of instructions in the correct order and making sure that each step is properly executed.

3. **Cell or system level:** This is the manufacturing cell or system level, which operates under instructions from the plant level. A manufacturing cell or system is a group of machines or workstations connected and supported by a material handling system, computer, and other equipment appropriate to the manufacturing process. Production lines are included in this level. Functions include part dispatching and machine loading, coordination among machines and material handling system, and collecting and evaluating inspection data.

4. **Plant level:** This is the factory or production systems level. It receives instructions from the corporate information system and translates them into operational plans for production. Likely functions include: order processing, process planning, inventory control, purchasing, material requirements planning, shop floor control, and quality control.

5. **Enterprise level:** This is the highest level, consisting of the corporate information system. It is concerned with all of the functions necessary to manage the company: marketing and sales, accounting, design, research, aggregate planning, and master production scheduling.

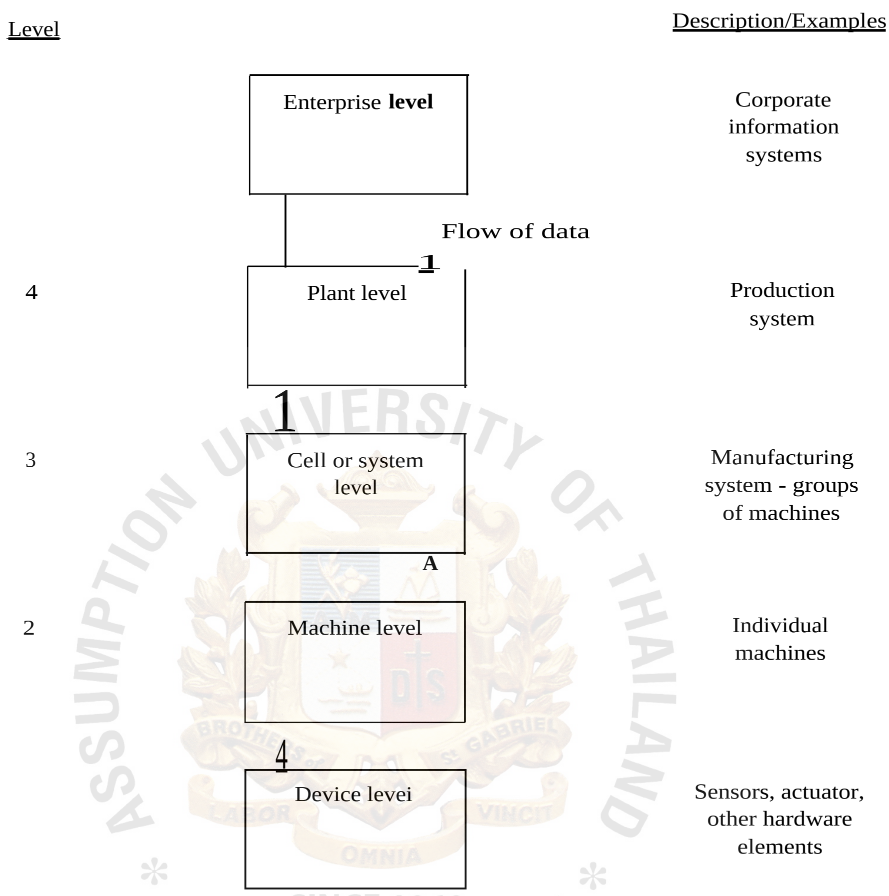


Figure 2.3. Five levels of automation and control in manufacturing (Groover, 2001).

2.9 Forms of Computer Process Control (Groover, 2001)

There are various ways in which computers can be used to control a process.

1. Computer Process monitoring:
   - Process Data
   - Equipment Data
   - Product Data
2. Direct Digital control
3. Numerical Control and Robotics
4. Programmable Logic Controllers (PLC)
5. Supervisory Control
6. Distribute Control system and PC

2.9.1 Numerical Control (Groover, 2001)

Numerical control (NC) is a form of programmable automation in which the mechanical actions of a machine tool or other equipment are controlled by alphanumeric data. The alphanumerical data represent relative positions between a workhead and a workpart as well as other instructions needed to operate the machine. The workhead is a cutting tool or other processing apparatus, and the workpart is the object being processed. When the current job is completed, the program of instructions can be changed to process a new job. The capability to change the program makes NC suitable for low and medium production. It is much easier to write new programs than to make major alterations of the processing equipment.

Numerical control can be applied to a wide variety of processes. The applications can be divided into two categories: (1) machine tool applications, such as drilling. milling, turning, and other metal working; and (2) nonmachine tool application, such as assembly, drafting, and inspection. The common operating feature of NC in all of these applications is control of the workhead movement relative to the workpart.

The concept for NC dates from the late **1940s.** The first NC machine was developed in 1952 (Historical Note 6.1).

Basic Components of an NC System (Groover, 2001)

An NC system consists of three basic components:

1. A program of instructions,
2. A machine control unit, and
3. Processing equipment.

    1. The *program of instructions* is the detailed step-by-step commands that direct the actions of the processing equipment. In machine tool applications, the program of instructions is called a *part program,* and the person who prepares the program is called a *part programmer.* In these applications, the individual commands refer to positions of a cutting tool relative to the worktable on which the workpart is fixtured. Additional instructions are usually included, such as spindle speed, feed rate, cutting tool selection, and other functions. The program is coded on a suitable medium for submission to the machine control unit. For many years, the common medium was 1-inch wide punched tape, using a standard format that could be interpreted by the machine control unit. Today, punched tape has largely been replaced by newer storage technologies in modern machine shops. These technologies include magnetic tape, diskettes, and electronic transfer of part programs from a computer.

2. In modern NC technology, the *machine control unit* (MCU) consists of a microcomputer and related control hardware that stores the program of instructions and executes it by converting each command into mechanical actions of the processing equipment, one command at a time. The related hardware of the MCU includes components to interface with the processing equipment and feedback control elements. The MCU also includes one or more reading devices for entering part programs into memory. The type of readers depends on the storage media used for part programs in the machine shop (e.g., punched tape reader, magnetic tape reader, floppy disk drive).The MCU also includes control system software, calculation algorithms, and translation software to convert the NC part program into a usable format for MCU. Because the MCU is a computer, the term computer numerical control (CNC) is used to distinguish this type of NC from its technological predecessors that were based entirely on hard-wired electronics. Today, virtually all new MCUs are based on computer technology; hence, when we refer to NC in this review and elsewhere, we mean CNC.

3. The third basic component of an NC system is the *processing equipment* that performs useful work. It accomplishes the processing steps to transform the starting work-piece into a completed part. Its operation is directed by the MCU, which in turn is driven by instructions contained in the part program. In the most common example of NC, machining, the processing equipment consists of the worktable and spindle as well as the motors and controls to drive them.

NC Coordinate Systems (Groover, 2001)

To program the NC processing equipment, a standard axis system must be defined by which the position of the workhead relative to the workpart can be specified. There are two axis systems used in NC, one for flat and prismatic workparts and the other for rotational parts. Both axis systems are based on the Cartesian coordinate system.

The axis system for flat and prismatic parts consists of the three linear axes (x, y, z) in the Cartesian coordinate system, plus three rotational axes (a, b, c). In most machine tool applications, the x-and y-axes are used to move and position the worktable to which the part is attached, and the z-axis is used to control the vertical position of the cutting tool. Such a positioning scheme is adequate for simple NC applications such as drilling and punching of flat sheet metal. Programming of these machine tools consists of little more than specifying a sequence of x-y coordinates.

(The a-, b-, and c- rotational axes specify angular positions about the x-, y- and z-axes, respectively. To distinguish positive from negative angles, the right-hand-rule is used. Using the right hand with the thumb pointing in the positive linear axis direction (+x, +y, or +z), the fingers of the hand are curled in the positive rotational direction. The rotational axes can be used for one or both of the following: (1) orientation of the workpart to present different surfaces for machining or (2) orientation of the tool or workhead at some angle relative to the part. These additional axes permit machining of complex workpart geometries. Machine tools with rotational axis capability generally have either four or five axes: three linear axes plus one or two rotational axes. Most NC machine tool systems do not require all six axes.

NC Part Programming (Groover, 2001)

NC part programming consists of planning and documenting the sequence of processing steps to be performed on an NC machine. The part programmer must have a knowledge of machining (or other processing technology for which the NC machine is designed) as well as geometry and trigonometry. The documentation portion of part programming involves the input medium used to transmit the program of instructions to the NC machine control unit (MCU). The traditional input medium dating back to the first NC machines in the 1950s is 1-inch wide punched tape. More recently, the use of magnetic tape and floppy disks have been growing in popularity as storage technologies for NC. The advantage of these input media is their much higher data density.

Part programming can be accomplished using a variety of procedures ranging from highly manual to highly automated methods. The methods are: (1) manual part programming, (2) computer-assisted part programming, (3) part programming using CAD/CAM, and (4) manual data input.

NC Part Programming Using CAD/CAM (Groover, 2001)

A CAD/CAM system is a computer interactive graphics system equipped with software to accomplish certain tasks in design and manufacturing and to integrate the design and manufacturing functions. One of the important tasks performed on a CAD/CAM system is NC part programming. In this method of part programming, portions of the procedure usually done by the part programmer are instead done by the computer. Recall that the two main tasks of the part programmer in computer-assisted programming are (1) defining the part geometry and (2) specifying the tool path. Advanced CAD/CAM systems automate portions of both of these tasks.

Geometry Definition Using CAD/CAM (Groover, 2001)

A fundamental objective of CAD/CAM is to integrate the design engineering and manufacturing engineering functions. Certainly one of the important design functions is to design the individual components of the product. If a CAD/CAM system is used, a computer graphics model of each part is developed by the designer and stored in the CAD/CAM data base. That model contains all of the geometric, dimensional, and material specifications for the part.

When the same CAD/CAM system, or a CAM system that has access to the same CAD data base in which the part model resides, is used to perform NC part programming, it makes little sense to recreate the geometry of the part during the programming procedure. Instead, the programmer has the capability to retrieve the part geometry model from storage and to use that model to construct the appropriate cutter path. The significant advantage of using CAD/CAM in this way is that it eliminates one of the time-consuming steps in computer-assisted part programming: geometry definition. After the part geometry has been retrieved, the usual procedure is to label the geometric elements that will be used during part programming. These labels are the variable names (symbols) given to the lines, circles, and surfaces that comprise the part. Most systems have the capacity to automatically label the geometry elements of the part and to display the labels on the monitor. The programmer can then refer to those labeled elements during tool path construction.

If the NC programmer does not have access to the data base, then the geometry of the part must be defined. This is done by using similar interactive graphics techniques that the product designer would use to design the part. Points are defined in a coordinate system using the computer graphics system, lines and circles are defined from the points, surfaces are defined, and so forth, to construct a geometric model of the part. The advantage of using the interactive graphics system over conventional computer-assisted part programming is that the programmer receives immediate visual verification of the definitions being created. This tends to improve the speed and accuracy of the geometry definition process.

Tool Path Generation Using CAD/CAM (Groover, 2001)

The second task of the NC programmer in computer-assisted part programming is tool path specification. The first step in specifying the tool path is to select the cutting tool for the operation. Most CAD/CAM systems have tool libraries that can be called by the programmer to identify what tools are available in the tool crib. The programmer must decide which of the available tools is most appropriate for the operation under consideration and specify it for the tool path. This permits the tool diameter and other dimensions to be entered automatically for tool offset calculations. If the desired cutting tool is net available in the library, an appropriate tool can be specified by the programmer. It then becomes part of the library for future use.

The next step is tool path definition. There are differences in capabilities of the various CAD/CAM systems, which result in different approaches for generating the tool path. The most basic approach involves the use of the interactive graphics system to enter the motion commands one-by-one, similar to computer-assisted part programming. Individual statements in APT (Automatically Programmed Tooling) or other part programming language are entered, and the CAD/CAM system provides an immediate graphic display of the action resulting from the command, thereby validating the statement.

A more-advanced approach for generating tool path commands is to use one of the automatic software modules available on the CAD/CAM system. These modules have been developed to accomplish a number of common machining cycles for milling, drilling, and turning. They are subroutines in the NC programming package that can be called and the required parameters given to execute the machining cycle.

When the complete part program has been prepared, the CAD/CAM system can provide an animated simulation of the program for validation purposes.

Computer-Automated Part Programming (Groover, 2001)

In the CAD/CAM approach to NC part programming. several aspects of the procedure are automated. In the future, it should be possible to automate the complete NC part programming procedure. We are referring to this fully automated procedure as computer-automated part programming. Given the geometric model of a part that has been defined during product design, the computer-automated system would possess sufficient logic and decision-making capability to accomplish NC part programming for the entire part without human assistance.

This can most readily be done for certain NC processes that involve well-defined, relatively simple part geometries. Examples are point-to-point operations such as NC drilling and electronic component assembly machines. In these processes, the program consists basically of a series of locations in an x-y coordinate system where work is to be performed (e.g., holes are to be drilled or components are to be inserted).These locations are determined by data that are generated during product design. Special algorithms can be developed to process the design data and generate the NC program for the particular system. NC contouring systems will eventually be capable of a similar level of automation. Automatic programming of this type is closely related to computer-automated process planning (CAPP).

2.9.2 PROGRAMMABLE LOGIC CONTROLLER (PLC) (Groover, 2001)

A programmable logic controller (PLC) can be defined as a microcomputer-based controller that uses stored instructions in programmable memory to implement logic, sequencing, timing, counting, and arithmetic functions through digital or analog input/output (I/O) modules for controlling machines and processes. PLC applications are found in both the process industries and discrete manufacturing, but it is primarily associated with the latter industries to control machines, transfer lines, and material handling equipment. Before the PLC was introduced around 1970, hard-wired controllers composed of relays, coils, counters timers, and similar components were used to implement this type of industrial control (Historical Note 8.1) (Groover, 2001).

There are significant advantages in using a PLC rather than conventional relays, timers, counters, and other hardware elements. These advantages include:

1. Programming the PLC is easier than wiring the relay control panel,
2. The PLC can be reprogrammed whereas conventional controls must be rewired and are often scrapped instead,
3. PLCs take less floor space than do relay control panels,
4. Reliability of the PLC is greater, and maintenance is easier,
5. PLC can be connected to computer systems more easily than relays, and
6. PLCs can perform a greater variety of control functions than can relay controls.

Components of the PLC (Groover, 2001)

The basic components of the PLC are the following:

1. Processor,
2. Memory unit,

3. Power supply,

4. I/O module, and

5. Programming device.

These components are housed in a suitable cabinet designed for the industrial environment.

2.10 Product Design and CAD/CAM in the Production System

2.10.1 PRODUCT DESIGN AND CAD (Groover, 2001)

Product design is a critical function in the production system. The quality of the product design (i.e., how well the design department does its job) is probably the single most important factor in determining the commercial success and societai value of a product. If the product design is poor, no matter how well it is manufactured, the product is very likely doomed to contribute little to the wealth and well-being of the firm that produced it. If the product design is good, there is still the question of whether the product can be produced at sufficiently low cost to contribute to the company's profits and success. One of the facts of life about product design is that a very significant portion of the cost of the product is determined by its design. Design and manufacturing cannot be separated in the production system. They are bound together functionally, technologically, and economically. Let us begin our discussion of product design by describing the general process of design. We then examine how computers are used to augment and automate the design process.

2.10.2 The Design Process (Groover, 2001)

The general process of design is characterized as an iterative process consisting of six phases:

1. Recognition of need,
2. Problem definition,
3. Synthesis,
4. Analysis and optimization,
5. Evaluation, and
6. Presentation.

   1. *Recognition of need* involves the realization by someone that a problem exists for which some corrective action can be taken in the form of a design solution. This recognition might mean identifying some deficiency in a current machine design by an engineer or perceiving of some new product opportunity by a salesperson.
   2. *Problem definition* involves a thorough specification of the item to be designed. This specification includes the physical characteristics, function, cost, quality, and operating performance.
   3. *Synthesis and Analysis* are closely related and highly interactive in the design process. Consider the development of a certain product design: Each of the subsystems of the product must be conceptualized by the designer, analyzed, improved through this analysis procedure, redesigned, analyzed again, and so on. The process is repeated until the design has been optimized within the constraints imposed on the designer. The individual components are then synthesized and analyzed into the final product in a similar manner.

4. *Evaluation* is concerned with measuring the design against the specifications established in the problem definition phase. This evaluation often requires the fabrication and testing of a prototype model to assess operating performance, quality, reliability, and other criteria. The final phase in the design procedure is the presentation of the design.
5. *Presentation* is concerned with documenting the design by means of drawings, material specifications, assembly lists, and so on. In essence, documentation means that the design data base is created.

2.10.3 Application of Computers in Design (Groover, 2001)

Computer-aided design (CAD) is defined as any design activity that involves the effective use of the computer to create, modify, analyze, or document an engineering design. CAD is most commonly associated with the use of an interactive computer graphics system, referred to as a CAD system. The term CAD/CAM system is also used if it supports manufacturing as well as design applications.

There are several good reasons for using a CAD system to support the engineering design function:

- **To increase the productivity of the designer:** This is accomplished by helping the designer to conceptualize the product and its components. In turn, this helps reduce the time required by the designer to synthesize, analyze, and document the design.
- **To improve the quality of the design:** The use of a CAD system with appropriate hardware and software capabilities permits the designer to do a more complete engineering analysis and to consider a larger number and

variety of design alternatives. The quality of the resulting design is thereby improved.

- **To improve design documentation:** The graphical output of a CAD system results in better documentation of the design than what is practical with manual drafting. The engineering drawings are superior, and there is more standardization among the drawings, fewer drafting errors, and greater legibility.
- **To create a manufacturing data base:** In the process of creating the documentation for the product design (geometric specification of the product, dimensions of the components, materials specifications, bill of materials, etc.), much of the required data base to manufacture the product is also created.

With reference to the six phases of design defined previously, a CAD system can beneficially be used in foar of the design phases namely:

1. Synthesis (Geometric modeling)
2. Analysis and optimization (Engineering analysis)
3. Evaluation (Design review and evaluation)
4. Presentation (Automated drafting).

Geometric Modeling (Groover, 2001)

Geometric modeling involves the use of a CAD system to develop a mathematical description of the geometry of an object. The mathematical description, called a geometric model, is contained in computer memory. This permits the user of the CAD system to display an image of the model on a graphics terminal and to perform certain operations on the model. These operations include creating new geometric models from basic building blocks available in the system, moving the images around on the screen, zooming in on certain features of the image, and so forth. These capabilities permit the designer to construct a model of a new product (or its components) or to modify an existing model.

There are various types of geometric models used in CAD. One classification distinguishes between two-dimensional (2-D) and three-dimensional (3-D) mode. Two-dimensional models are best utilized for design problems in two dimensions, such as flat objects and layouts of buildings. In the first CAD systems developed in the early 1970s, 2-D systems were used principally as automated drafting systems. They were often used for 3-D objects, and it was left to the designer or draftsman to properly construct the various views of the object. Three-dimensional CAD systems are capable of modeling an object in three dimensions. The operations and transformations on the model are done by the system in three dimensions according to user instructions. This is helpful in conceptualizing the object since the true 3-D model can be displayed in various views and from different angles.

Geometric models in CAD can also be classified as being either wire-frame models or solid models. A wire-frame model uses interconnecting lines (straight line segments) to depict the object. Wire-frame models of complicated geometries can become somewhat confusing because all of the lines depicting the shape of the object are usually shown, even the lines representing the other side of the object. Techniques are available for removing these so-called hidden lines, but even with this improvement wire-frame representation is still often inadequate.

Solid models are a more recent development in geometric modeling. In solid modeling, an object is modeled in solid three dimensions, providing the user with a vision of the object very much like it would be seen in real life. More important for engineering purposes, the geometric model is stored in the CAD system as a 3-D solid model, thus providing a more accurate representation of the object. This is useful for calculating mass properties, in assembly to perform interference checking between mating components, and in other engineering calculations.

Finally, two other features in CAD system models are color and animation. Some CAD systems have color capability in addition to black-and-white. The value of color is largely to enhance the ability of the user to visualize the object on the graphics screen. For example, the various components of an assembly can be displayed in different colors, thereby permitting the parts to be more readily distinguished. Animation capability permits the operation of mechanisms and other moving objects to be displayed on the graphics monitor.

Engineering Analysis (Groover, 2001)

After a particular design alternative has been developed, some form of engineering analysis often must be performed as part of the design process. The analysis may take the form of stress-strain calculations. heat transfer analysis, or dynamic simulation. The computations are often complex and time consuming, and before the advent of the digital computer, these analyses were usually greatly simplified or even omitted in the design procedure. The availability of software for engineering analysis on a CAD system greatly increases the designer's ability and willingness to perform a more thorough analysis of a proposed design. The term computer-aided engineering (CAE) is often used for engineering analyses performed by computer. Examples of engineering analysis software in common use on CAD systems include:

- ***Mass properties analysis,*** which involves the computation of such features of a solid object as its volume, surface area, weight, and center of gravity. It is especially applicable in mechanical design. Prior to CAD, determination of these properties often required painstaking and time-consuming calculations by the designer.

- *Interference checking:* This CAD software examines 2-D geometric models consisting of multiple components to identify interferences between the components. It is useful in analyzing mechanical assemblies, chemical plants, and similar multicomponent designs.
- *Tolerance analysis:* Software for analyzing the specified tolerances of a product's components is used for the following functions: (1) to assess how the tolerances may affect the product's function and performance, (2) to determine how tolerances may influence the ease or difficulty of assembling the product, and (3) to assess how variations in component dimensions may affect the overall size of the assembly.
- *Finite element analysis:* Software for finite element analysis (FEA), also known as **finite element modeling (FEM),** is available for use on CAD systems to aid in stress-strain, heat transfer, fluid flow, and other engineering computations. Finite element analysis is a numerical analysis technique for determining approximate solutions to physical problems described by differential equations that are very difficult or impossible to solve. In FEA, the physical object is modeled by an assemblage of discrete interconnected nodes (finite elements), and the variable of interest (e.g., stress, strain, temperature) in each node can be described by relatively simple mathematical equations. By solving the equations for each node, the distribution of values of the variable throughout the physical object is determined.

Kinematic and dynamic analysis: Kinematic analysis involves the study of the operation of mechanical linkages to analyze their motions. A typical Kinematic analysis consists of specifying the motion of one or more driving members of the subject linkage, and the resulting motions of the other links are determined by the analysis package. Dynamic analysis extends Kinematic analysis by including the effects of the mass of each linkage member and the resulting acceleration forces as well as any externally applied forces.

- ***Discrete-event simulation:*** This type of simulation is used to model complex operational systems, such as a manufacturing cell or a material handling system, as events occur at discrete moments in time and affect the status and performance of the system. For example, discrete events in the operation of a manufacturing cell include parts arriving for processing or a machine breakdown hi the cell. Measures of the status and performance include whether a given machine in the cell is idle or busy and the overall production rate of the cell. Current discrete-event simulation software usually includes an animated graphics capability that enhances visualization of the system's operation.

Design Evaluation and Review (Groover, 2001)

Design evaluation and review procedures can be augmented by CAD. Some of the CAD features that are helpful in evaluating and reviewing a proposed design include:

- **Automatic dimensioning** routines that determine precise distance measures between surfaces on the geometric model identified by the user.
- **Error checking.** This term refers to CAD algorithms that are used to review the accuracy and consistency of dimensions and tolerances and to assess whether the proper design documentation format has been followed.
- **Animation of discrete-event simulation solutions.** Discrete-event simulation was described above in the context of engineering analysis. Displaying the solution of the discrete-event simulation in animated graphics is a helpful means of presenting and evaluating the solution. Input parameters, probability distributions, and other factors can be changed to assess their effect on the performance of the system being modeled.
- **Plant layout design scores.** A number of software packages are available for facilities design, that is, designing the floor layout and physical arrangement of equipment in a facility. Some of these packages provide one or more numerical scores for each plant layout design, which allow the user to assess the merits of the alternative with respect to material flow, closeness ratings, and similar factors.

The traditional procedure in designing a new product includes fabrication of a prototype before approval and release of the product for production. The prototype serves as the "acid test" of the design, permitting the designer and others to see, feel, operate, and test the product for any last-minute changes or enhancements of the design. The problem with building a prototype is that it is traditionally very time consuming; in some cases, months are required to make and assemble all of the parts. Motivated by the need to reduce this lead time for building the prototype, several new approaches have been developed that rely on the use of the geometric model of the product residing in the CAD data file. We mention two of these approaches here: (1) rapid prototyping and (2) virtual prototyping.

Rapid prototyping is a general term applied to a family of fabrication technologies that allow engineering prototypes of solid parts to be made in minimum lead time. The common feature of the rapid prototyping processes is that they fabricate the part directly from the CAD geometric model. This is usually done by dividing the solid object into a series of layers of small thickness and then defining the area shape of each layer. For example, a vertical cone would be divided into a series of circular layers, each circle becoming smaller and smaller as the vertex of the cone is approached. The rapid prototyping processes then fabricate the object by starting at the base and building each layer on top of the preceding layer to approximate the solid shape. The fidelity of the approximation depends on the thickness of each layer. As layer thickness decreases, accuracy increases. There are a variety of layer-building processes used in rapid prototyping. The most common process, called **stereolithography,** uses a photosensitive liquid polymer that cures (solidifies) when subjected to intense light. Curing of the polymer is accomplished using a moving laser beam whose path for each layer is controlled by means of the CAD model. By hardening each layer, one on top of the preceding, a solid polymer prototype of the part is built.

Virtual prototyping, based on virtual reality technology, involves the use of the CAD geometric model to construct a digital mock-up of the product, enabling the designer and others to obtain the sensation of the real physical product without actually building the physical prototype. Virtual prototyping has been used in the automotive industry to evaluate new car style designs. The observer of the virtual prototype is able to assess the appearance of the new design even though no physical model is on display. Other applications of virtual prototyping include checking the feasibility of assembly operations, for example, parts mating, access and clearance of parts during assembly, and assembly sequence.

Automated Drafting

CAD systems can be used as automated drafting machines to prepare highly accurate engineering drawings quickly. It is estimated that a CAD system increases productivity in the drafting function by about fivefold over manual preparation of drawings.

2.10.4 CAD SYSTEM HARDWARE (Groover, 2001)

The hardware for a typical CAD system consists of the following components:

(1) One or more design workstations,

(2) Digital computer,

(3) Plotters, printers, and other output devices, and

(4) Storage devices.

In addition, the CAD system would have a communication interface to permit transmission of data to and from other computer systems, thus enabling some of the benefits of computer integration.

Design Workstations (Groover, 2001)

The workstation is the interface between computer and user in the CAD system. Its functions are the following:

a. Communicate with the CPU,

b. Continuously generate a graphic image,

c. Provide digital descriptions of the image,

d. Translate user commands into operating functions, and

e. Facilitate interaction between the user and the system.

The design of the CAD workstation and its available features have an important influence on the convenience, productivity, and quality of the user's output. The workstation must include a graphics display terminal and a set of user input devices. The display terminal must be capable of showing both graphics and alphanumeric text. It is the principal means by which the system communicates with the user. For optimum graphics display, the monitor should have a large color screen with high resolution.

The user input devices permit the operator to communicate with the system. To operate the CAD system, the user must be able to accomplish the following:

(1) Enter alphanumeric data,

(2) Enter commands to the system to perform various graphics operations, and

(3) Control the cursor position on the display screen.

To enter alphanumeric data, an alphanumeric keyboard is provided. A conventional typewriter-like keyboard allows the designer to input numerical and alphabetic characters into the system. The alphanumeric keyboard can also be used to enter commands and instructions to the system. However other input devices accomplish this function more conveniently. Special function keypads have been developed to allow entry of a command in only one or two keystrokes. These **special**

keypads have from 10 to 50 function keys, depending on the system. However, each key provides more than one function, depending on the combination of keys pressed or which software is being used. Another input device for *entering commands* to a CAD system is the **electronic tablet,** an electronically sensitive board on which an instruction set is displayed, and commands are entered using a puck or electronic pen.

Cursor control permits the operator to position the cursor on the screen to identify a location where some function is to be executed. For example, to draw a straight line on the screen, the endpoints of the line can be identified by locating the cursor in sequence at the two points and giving the command to construct the line. There are various cursor control devices used hi CAD, including pucks, mouses, joysticks, trackballs, thumbwheels, light pens, and electronic tablets. An input device for entering coordinates from an existing drawing into the CAD system is a **digitizer,** which consists of a large flat board and an electronic tracking element such as a puck that can be moved across the surface of the board to record x- and y-coordinate positions.

Digital Computer

CAD applications require a digital computer with a high-speed central processing unit (CPU), math coprocessor to perform computation-intensive operations, and large internal memory. Today's commercial systems have 32-bit processors, which permit high-speed execution of CAD graphics and engineering analysis applications.

Several CAD system configurations as in Fig (2.5) (Groover, 2001) are available within the general arrangement. Let us identify three principal configurations:

(a) Host and terminal,

(b) Engineering workstation, and

(c) CAD system based on a personal computer (PC).

The host and terminal was the original CAD configuration hi the 1970s and early 1980s when the technology was first developing. For many years, it was the only configuration available. In this arrangement, a large mainframe computer or a minicomputer serves as the host for one or more graphics terminals. These systems were expensive, each installation typically representing an investment of a million dollars or more. The powerful microprocessors and high-density memory devices that are so common today were not available at that time. The only way to meet the computational requirements for graphics processing and related CAD applications was to use a mainframe connected to multiple terminals operating on a time-sharing basis. Host and terminal CAD systems are still used today in the automotive industry and other industries in which it is deemed necessary to operate a large central database.

An engineering workstation is a stand-alone computer system that is dedicated to one user and capable of executing graphics software and other programs requiring high-speed computational power. The graphics display is a high-resolution monitor with a large screen. Engineering workstations are often networked to permit exchange of data files and programs between users and to share plotters and data storage devices.

A PC-based CAD system is a PC with a high-performance CPU and medium-to-high resolution graphics display screen. The computer is equipped with a large random access memory (RAM), math coprocessor, and large-capacity hard disk for storage of the large applications software packages used for CAD. PC-based CAD systems can be networked to share files, output devices, and for other purposes. Starting around 1996, CAD software developers began offering products that utilize the excellent graphics environment of Microsoft Windows NTTM, thus enhancing the popularity and familiarity of PC-based CAD.

When the engineering workstation is compared with the PC-based system, the former is superior in terms of most performance criteria. Its capacity to efficiently accomplish 3-D geometric modeling and execute other advanced software exceeds that of a PC, and this makes the workstation more responsive and interactive than a PC-based CAD system. However, the performance characteristics of PCs are improving each year, and the prices of engineering workstations are dropping each year, so that the distinction between the two types is becoming blurred.

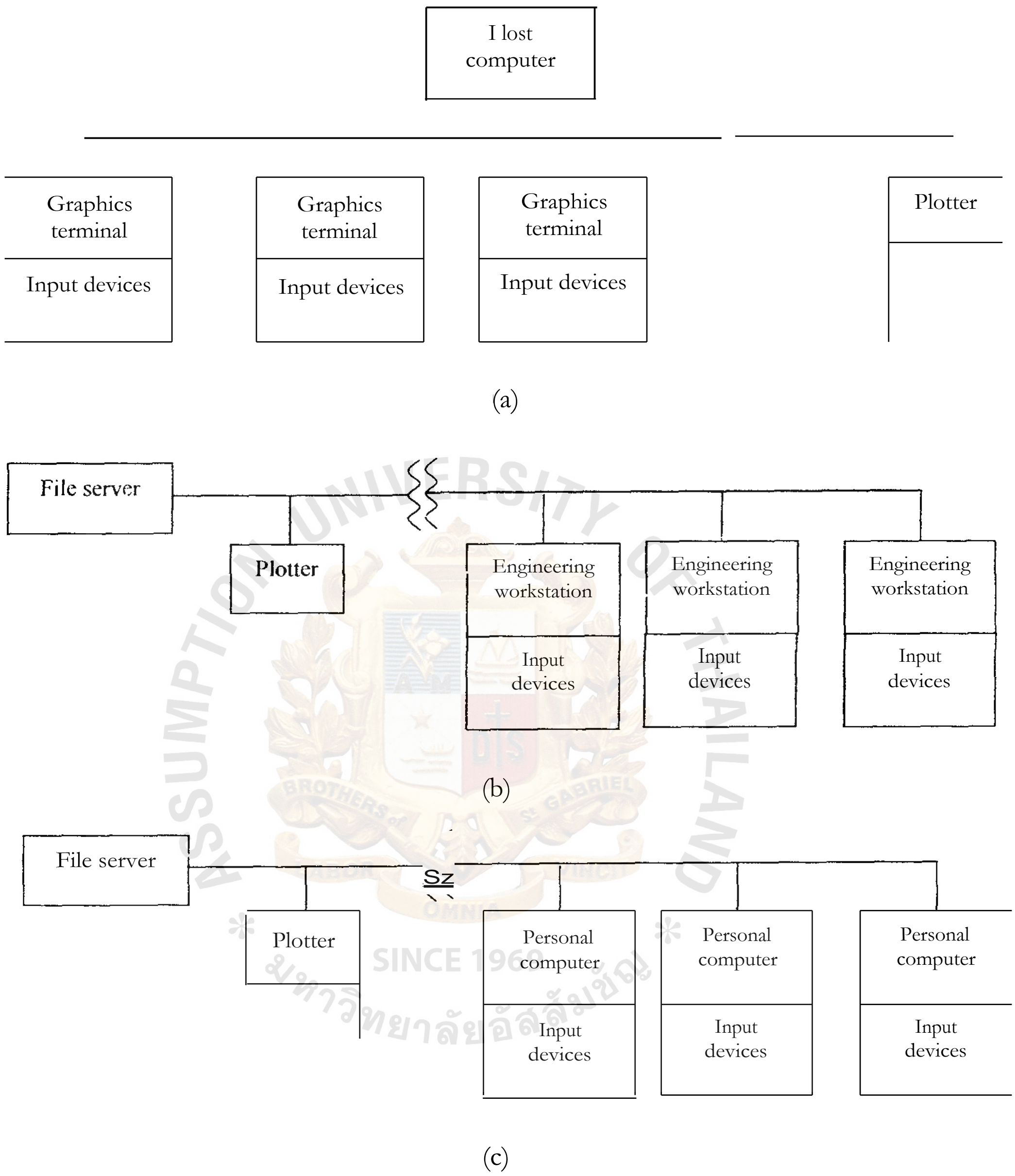


Figure 2.5. Three CAD system configurations: (a) host and terminal, (b) engineering workstation, and (c) CAD system based on a PC (Groover, 2001).

Plotters and Printers (Groover, 2001)

The CRT display is often the only output device physically located at the CAD workstation. There is a need to document the design on paper. The peripherals of the CAD system include one or more output devices for this purpose. Among these output devices are the following:

- **Pen plotters:** These are x-y plotters of various types used to produce high accuracy line drawings.
- **Electrostatic plotters:** These are faster devices based on the same technology as photocopying. The resolution of the drawings from electrostatic plotters is generally lower than those made by a pen plotter.
- **Dot-matrix printers:** In the operation of these printers, small hammers strike an ink ribbon against the paper to form a drawing consisting of many ink dots.
- **Ink jet printers:** These are similar to dot-matrix printers except that the dots are formed by high-speed jets of ink impacting the paper.

Storage Devices

Storage peripherals are used in CAD systems to store programs and data files. The storage medium is usually a magnetic disk or magnetic tape. Files can be retrieved more quickly from magnetic disks, which facilitate loading and exchange of files between CPU and disk. Magnetic tape is less expensive, but more time is required to access a given file due to the sequential file storage on the tape. It is suited to disk backup, archival files, and data transfer to output devices.

2.10.5 CAM, CAD/CAM, AND CIM (Groover, 2001)

The terms CAM, CAD/CAM, and CIM are briefly explained in the introduction. Let us explain and differentiate these terms more thoroughly here. The term computer integrated manufacturing (CIM) is sometimes used interchangeably with CAM and CAD/CAM. Although the terms are closely related, our assertion is that CIM possesses a broader meaning than does either CAM or CAD/CAM.

Computer-Aided Manufacturing (Groover, 2001)

Computer-aided manufacturing (CAM) is defined as the effective use of computer technology in manufacturing planning and control. CAM is most closely associated with functions in manufacturing engineering, such as process planning and numerical control (NC) part programming. CAM can be divided into two broad categories:

(1) Manufacturing planning and

(2) Manufacturing control.

Manufacturing Planning (Groover, 2001)

CAM applications for manufacturing planning are those in which the computer is used indirectly to support the production function, but there is no direct connection between the computer and the process. The computer is used "off-line" to provide information for the effective planning and management of production activities The following list surveys the important applications of CAM in this category:

- Computer-aided process planning (CAPP). Process planning is concerned with the preparation of route sheets that list the sequence of operations and work centers required to produce the product and its components. CAPP systems are available today to prepare these route sheets.

- Computer-assisted NC part programming. The subject of part programming for NC was discussed earlier. For complex part geometries, computer-assisted part programming represents a much more efficient method of generating the control instructions for the machine tool than manual part programming is.
- Computerized machinability data systems. One of the problems in operating a metal cutting machine tool is determining the speeds and feeds that should be used to machine a given workpart. Computer programs have been written to recommend the appropriate cutting conditions to use for different materials. The calculations are based on data that have been obtained either in the factory or laboratory that relate tool life to cutting conditions.
- Development of work standards. The time study department has the responsibility for setting time standards on direct labor jobs performed in the factory. Establishing standards by direct time study can be a tedious and time-consuming task. There are several commercially available computer packages for setting work standards. These computer programs use standard time data that have been developed for basic work elements that comprise any manual task. By summing the times for the individual elements required to perform a new job, the program calculates the standard time for the job.

Cost estimating. The task of estimating the cost of a new product has been simplified in most industries by computerizing several of the key steps required to prepare the estimate. The computer is programmed to apply the appropriate labor and overhead rates to the sequence of planned operations for the components of new products. The program then sums the individual component costs from the engineering bill of materials to determine the overall product cost.

- Production and inventory planning. The computer has found widespread use in many of the functions in production and inventory planning. These functions include: maintenance of inventory records, automatic reordering of stock items when inventory is depleted, production scheduling, maintaining current priorities for the different production orders, material requirements planning, and capacity planning.
- Computer-aided line balancing. Finding the best allocation of work elements among stations on an assembly line is a large and difficult problem if the line is of significant size.

Manufacturing Control (Groover, 2001)

The second category of CAM applications is concerned with developing computer systems to implement the manufacturing control function. Manufacturing control is concerned with managing and controlling the physical operations in the factory. These management and control areas include:

- Process monitoring and control. Process monitoring and control is concerned with observing and regulating the production equipment and manufacturing processes in the plant. The applications of computer process control are pervasive today in automated production systems. They include transfer lines, assembly systems, NC, robotics, material handling, and flexible manufacturing systems.
- Quality control. Quality control includes a variety of approaches to ensure the highest possible quality levels in the manufactured product.

- Shop floor control. Shop floor control refers to production management techniques for collecting data from factory operations and using the data to help control production and inventory in the factory.
- Inventory control. Inventory control is concerned with maintaining the most appropriate levels of inventory in the face of two opposing objectives: minimizing the investment and storage costs of holding inventory and maximizing service to customers.
- Just-in-time production systems. The term just-in-time refers to a production system that is organized to deliver exactly the right number of each component to downstream workstations in the manufacturing sequence just at the time when that component is needed. The term applies not only to production operations but to supplier delivery operations as well.

CAD/CAM (Groover, 2001)

CAD/CAM is concerned with the engineering functions in both design and manufacturing. Product design, engineering analysis, and documentation of the design (e.g., drafting) represent engineering activities in design. Process planning, NC part programming, and other activities associated with CAM represent engineering activities in manufacturing. The CAD/CAM systems developed during the 1970s and early 1980s were designed primarily to .address these types of engineering problems. In addition. CAM has evolved to include many other functions in manufacturing, such as material requirements planning, production scheduling, computer production monitoring, and computer process control. It should also be noted that CAD/CAM denotes an integration of design and manufacturing activities by means of computer systems.

The method of manufacturing a product is a direct function of its design. With conventional procedures practiced for so many years in industry, engineering drawings were prepared by design draftsmen and later used by manufacturing engineers to develop the process plan. The activities involved in designing the product were separated from the activities associated with process planning. Essentially a two-step procedure was employed. This was time-consuming and involved duplication of effort by design and manufacturing personnel. Using CAD/CAM technology, it is possible to establish a direct link between product design and manufacturing engineering. In effect, CAD/CAM is one of the enabling technologies for concurrent engineering. It is the goal of CAD/CAM not only to automate certain phases of design and certain phases of manufacturing, but also to automate the transition from design to manufacturing.

In the ideal CAD/CAM system, it is possible to take the design specification of the product as it resides in the CAD data base and convert it into a process plan for making the product, this conversion being done automatically by the CAD/CAM system. A large portion of the processing might be accomplished on a numerically controlled machine tool. As part of the process plan, the NC part program is generated automatically by CAD/CAM. The CAD/CAM system downloads the NC program directly to the machine tool by means of a telecommunications network. Hence, under this arrangement, product design, NC programming, and physical production are all implemented by computer.

Computer Integrated Manufacturing (CIM) (Groover, 2001)

Computer integrated manufacturing (CIM) includes all of the engineering functions of CAD/CAM, but it also includes the firm's business functions that are related to manufacturing. The ideal CIM system applies computer and communications technology to all of the operational functions and information processing functions in manufacturing from order receipt, through design and production, to product shipment.

The CIM concept is that all of the firm's operations related to production are incorporated in an integrated computer system to assist, augment, and automate the operations. The computer system is pervasive throughout the firm, touching all activities that support manufacturing. In this integrated computer system, the output of one activity serves as the input to the next activity, through the chain of events that starts with the sales order and culminates with shipment of the product.

Customer orders are initially entered by the company's sales force or directly by the customer into a computerized order entry system. The orders contain the specifications describing the product. The specifications serve as the input to the product design depaarnent. New products are designed on a CAD system. The components that comprise the product are designed, the bill of materials is compiled, and assembly drawings are prepared.

The output of the design department serves as the input to manufacturing engineering, where process planning, tool design, and similar activities are accomplished to prepare for production. Many of these manufacturing engineering activities are supported by the CIM system.

Process planning is performed using CAPP. Tool and fixture design is done on a CAD system, making use of the product model generated during product design. The output from manufacturing engineering provides the input to production planning and control, where material requirements planning and scheduling are performed using the computer system. And so it goes, through each step in the manufacturing cycle. Full implementation of CIM results in the automation of the information flow through every aspect of the company's organization.

III. THE EXISTING SYSTEM

3.1 Background of the Company

The name of the company is KYOCERA CHEMICAL (THAILAND) LIMI1ED. Its institution, at first, was started as SANKO TOCHEMI MANUFACTURING (THAILAND) LTD as of February 6, 1996, which later changed to TOSHIBA CHEMICAL (THAILAND) LTD as of January 10, 2000, and lastly, as of August 1, 2002, renamed to KYOCERA CHEMICAL (THAILAND) LTD. The company was approved by Board of Investment (BOI), Thailand, as of March 20, 2000. The Managing Director of the company is Mr. Hidehiro Iwase. The company is located at Rojana Industrial Park, (59), Moo (9), Thanu, U-THAI, Phranakorn Sri Ayutthaya 13210, Thailand.

The main products of the company are mold and dies. The company also provides parts and repair services. The company has been operating since March 29, 2000. The main equipments of the company are CAD/CAM (Computer-Aided-Design/Computer-Aided-Manufacturing), NC (Numerical Control) machines, EDMs (Electric Discharge Machines), and Milling machines. The company has a total of 86 employees excluding 5 Japanese staffs.

The correspondent bank of the company is Mitsuitsumito Bank. The main customers of the company are TOSHIBA CONSUMER PRODUCTS (THAILAND) CO., LTD, TOSHIBA CARRIER (THAILAND) CO., LTD, TOYOTA MOTOR THAILAND CO., LTD, TOYODA GOSEI (THAILAND) CO., LTD, TS TECH (THAILAND) CO., LTD, KUMI (THAILAND) CO., LTD, NISSEN CHEMITEC (THAILAND) LIMITED, and HITACHI CHEMICAL AUTOMOTIVE PRODUCTS

(THAILAND) CO., LTD. The main suppliers are JUTHA WAN METAL LTD, UMETOKU THAILAND CO., LTD, and FUTABA JTW (THAILAND) LTD.

3.2 Features of the Company's die

1. Technical analysis meeting user's requirements provides a die of higher productivity.
2. 3D CAD/CAM system assures delivery of a high quality die in a short delivery term through a total system ranging from design through machining.
3. A variety of molding methods and dies of high cost performance.
4. Various molding dies (Production of prototype and mass-production dies for injection molding, compression molding, transfer molding, multi-color molding, blow molding, SMC, etc.) are available.

3.3 Scope of the Company

Kyocera Chemical (Thailand) has been contributing to users with 50 years history and accumulated experiences in molding parts and dies. Starting from molding parts and dies using own-made thermosetting resins, Kawaguchi Works has expanded the capacity of manufacturing equipment and working forces year by year as an exclusive Injection dies and molds manufacturers to respond to growing demands from domestic and overseas market for thermoplastics while seeking for production expansion and technology development.

Molding Division introduced large-sized injection molding machines to meet demands for larger plastic products and is also developing a new molding technology to meet demands for engineering and super-engineering plastics, mainly of mechanical parts. The section offers accumulated technology on secondary machining, (like Painting, Hot-Stamping, Printing, Assembling, etc.), as well.

Molding Die Division has reduced the die-sinking time and improved the die precision by operating three-dimensional CAD/CAM systems and groups of advanced NC machines with the DNC system for a long period of time without operator's attendance.

Design Section: Product specifications, received from user, are put to rigid technical analysis from all points of view, for the design of molding dies fully meeting user requirements. Then, design is developed with 3-D CAD/CAM system to get product quality and molding productivity meeting the specification.

Machining Section: Production of high precision and quality dies in a short time is implemented by the machining center using NC data of the CAD/CAM system. The machining center also uses Electric Discharge Machine (EDM), Wire-cut Electric Discharge Machine (WEDM) and graphite electrode machine.

Finishing Section: Government-licensed senior technicians (70%) well versed with molding dies are constantly in pursuit of higher die precision to improve molding productivity and product quality.

Die Evaluation Test: In the final die evaluation test, samples are molded with the company's injection molding machine (maximum press: 1,600 tons) to check general performance and molding productivity of dies.

Mold-related business: The Company's business covers overall thermoplastic resin molding operation such as molding, painting, hot stamping and plastic plating, as well as product/die design and die production.

3.4 Typical Flowchart of the Company's Molding Die Manufacturing Process

The following manufacturing process is the explanation for the Fig (3.1).

The typical flowchart of the KCTL's molding die manufacturing process starts form the product design section, where the customer part drawings of product and die specifications are analyzed technically for any corrections of modifications to be added before the version upgrading proposal for molding and products are forwarded to die design section. In die design section, the approved design is changed into definition of die specification like NC part programs, G-codes (machine language) and so on by using 3D CAD/CAM for the machining section. After the data translations are done from the die design section, the design programs are respectively sent by using DNC system to the NC machines, EDM machines, milling machines and grinding machine.

The finishing section, die spotter, ultrasonic wrapper and hand tools are used in finishing the die. In the die evaluation section, samples are molded with the company's injection molding machine (maximum press: 1,600 tons) to check general performance and molding productivity of dies. A 3D measuring instrument with a built in microprocessor is also used in the evaluation for precision. If the customer order is only to the die part, the finalized die, which is not rejected by the quality control team, is then delivered to the customer.

The injection molding and molding section, which is no longer the part of KCTL, sometime has to go on with the injection molding testing with compound materials and super engineering materials for fabrication and product delivery.

3.5 CAD/CAM Process

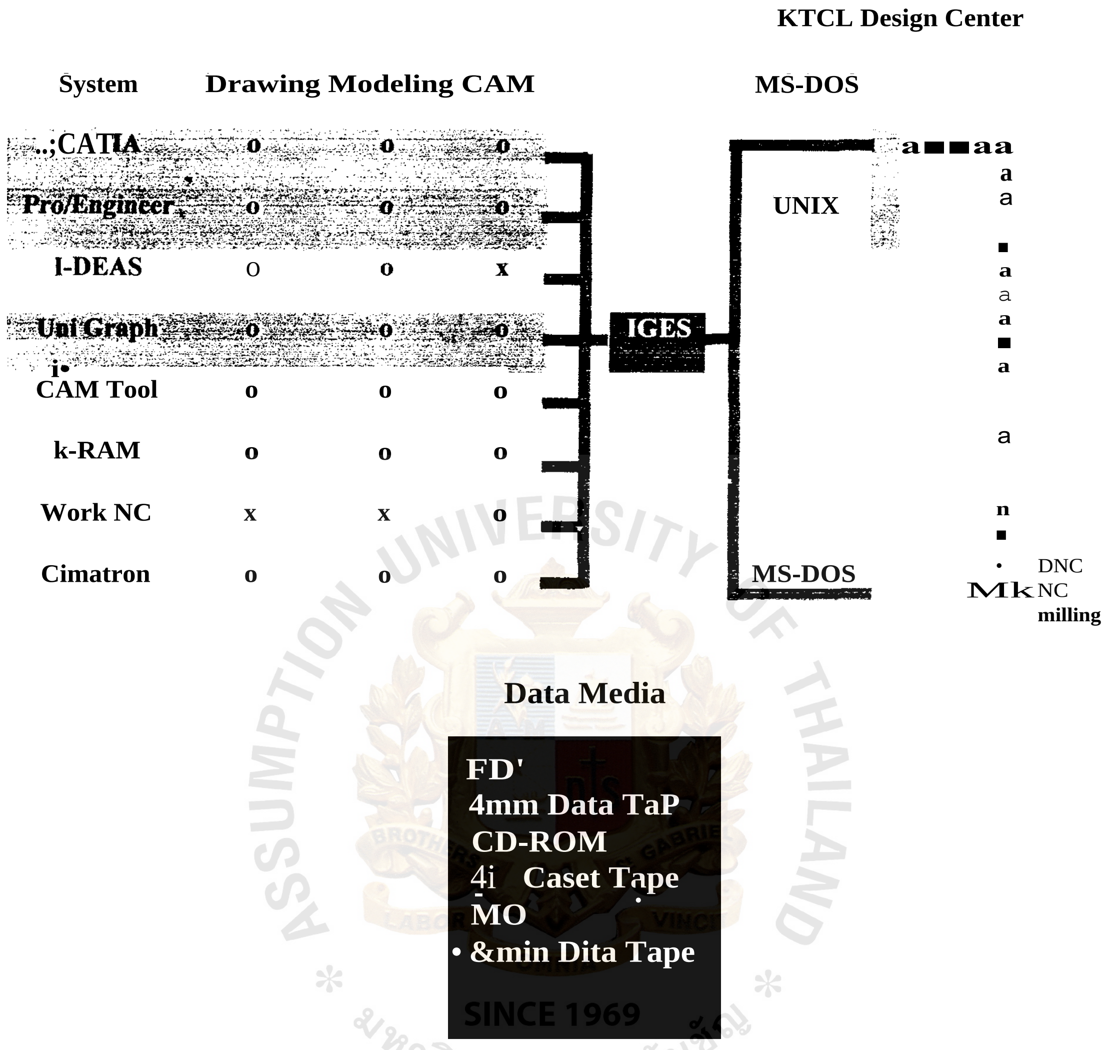


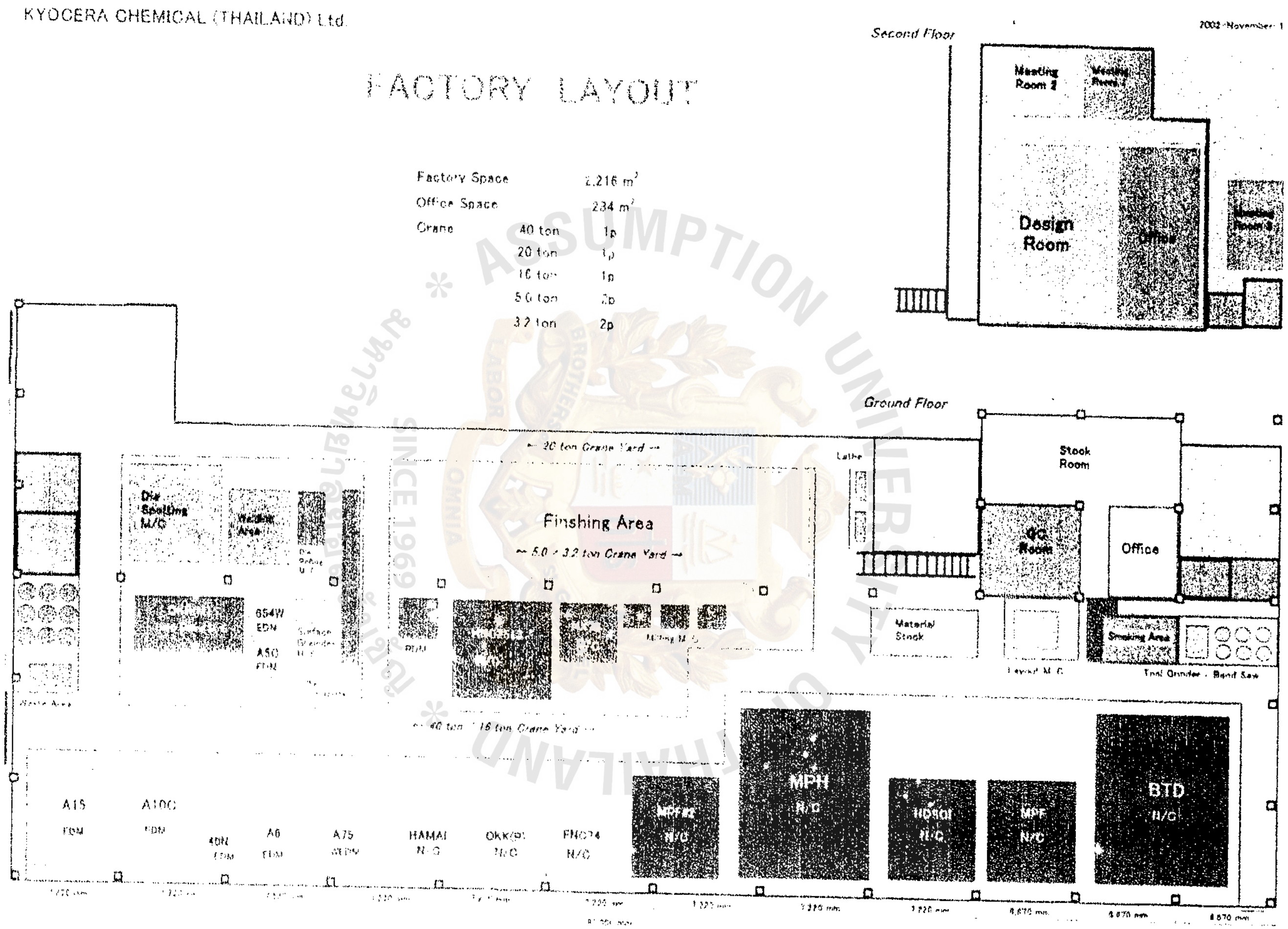
Figure 3.2. Flow of CAD/CAM Process

Figure (3.2) is the CAD/CAM process diagram. Different CAD systems are used by different manufacturing industries, thus, optional items like CATIA, Uni Graph (UG), Pro/Engineer (Pro!E), I-DEAS, k-RAM, and so on are provided at the beginning so as to check their compatibility and functions where available processes are marked as "o" where as the unavailable functions are marked as "x". The reliable data translations are done through the process and the smooth transition is made through I-GES system. Finally, the translated data is sent to DNC system to the NC machines, EDMs and so on.

3.6 KCTL's Factory Layout and its Major Production Equipments and Systems

In Fig (3.3), KCTL's factory layout is illustrated. The factory floor occupies the area of 2,216 square meters where as the office occupies 284 square meters on the second floor. The factory's second floor, as of the figure, has the company's office room, three meeting rooms and design room. The design room is the CAD/CAM room, where the initial designs and data translations are made. Later the data is transferred to DNC system for the machines, which are located on the ground floor. The material handling is done by cranes and hoists. The middle crane yard has 40-ton and 16-ton crane. The finishing area has 5-ton and 3.2-ton cranes. The upper side of the plant has 20-ton crane yard covering the finishing area up to the die spotting machine. Right under the office floor, the space is occupied by the quality control room, quality control team's office and stock room.

Table (3.1) shows the major manufacturing equipments and systems (hardware and softwares) lists those are in use of KCTL. The CAD/CAM system in use is Cimatron IT version by Cimatron Ltd. The DNC software and system for the machines are installed by reverse corp from Japan. Machining center has Toshiba machines, NC machines, some old milling machines, Wire-cut EDM machines, EDM machines, grinding machines, die spotting machine, precision forming grinding machine, and layout machine. Most of the machines and systems (software and hardware) are purchased in Thailand. But some are purchased from Japan. The machine's location can be checked with their specification in Fig (3.3). The factory layout and the table list are subject to change, if there are any modifications done by KCTL.



KCTL's Factory Layout

Table 3.1. Major Production Equipments and Systems Lists

	Manufacturer	Specification	Qty	Table Size (in mm)
CAD/CAM	Cimatron	Cimatron90	18	
DNC system	Reverse Corp	PC	8	
11-Boring & Milling Machine	Toshiba Machine	BTD-13	1	3000X2000X1600
Machining Center	Toshiba Machine	MPH2630	1	3500X2600X800
Machining Center	Toshiba Machine	MPF2114	1	1800X1400X715
Machining Center	Toshiba Machine	MPF2114	1	1800X1400X715
Machining Center	Makino	HNC2513A60	1	2500X1300X800
Machining Center	OKK	PVC55	I	I 020X560X520
NC/Copy Milling Machine	Hosoi	FNC-1620	I	2000X1200X850
NC-Grinding-Machining Center	Hamai	ME-6	1	1250X650X550
Machining Center	Makino	FNC74-A20	1	700X450X450
Copy Milling Machine	OKK	MH-10TC	1	2000X1000X750
Electric Discharge Machine (EDM)	Sodick	Al 5C	1	1500(+500)X800X700
Electric Discharge Machine (EDM)	Sodick	Al OC	I	1900X800X500
Electric Discharge Machine (EDM)	Sodick	A65-SLT	I	650X450X350
Electric Discharge Machine (EDM)	Sodick	4ONC	1	420X350X320
Electric Discharge Machine (EDM)	Sodick	A5C	1	700X500X320
Wire cut EDM	Sodick	A750W	1	750X450X315
Surface Grinder Machine	Okamoto Machine Tool	PSG-65DX	I	650X500X522
Radial Drilling Machine	Okamoto Machine Tool	PFG-500DXPL	1	600X140X300
Die Spotting Press	Amino	DSP-300	I	3000X2000 (300 ton)

Milling Machine	Sizuoka	VI1R-A	1	820X300X450
Milling Machine	Supermax	YCM-2VA	1	1000X406X450
Milling Machine	Huron	NU4	1	1100X700X500
Precision Forming Grinding Machine	Okamoto Machine Tool	ACC450DXA	1	510X150X400
Layout Machine CAD/CAM	Fujioka	BK-I500	1	1500X1200X1500

3.7 KTCL's CAD/CAM flow charts and DATA flow charts

Operation procedures of CAD/CAM

The following are the brief explanations of the operation procedure flow charts of CAD/CAM team and customer relationships.

Customer Part Drawing (CPD) control

The following operation procedure is the explanation for Fig (3.4). At the beginning stage, marketing department (actually which is controlled by the CAD team denoted as "A" in Fig (3.6)) receives Customer Part Drawing (CPD) from the customer. CPD is then put into the job filing, where the job number is given. Every CPD is then named with the initial letter CD- ...... , if in case of any changes are done on the new CPD the job number will be counted continuously. After that, staff will make extra copies for the CPD, which are then stamped for each individual section so as to distribute to CAM section and QC Section respectively. This distribution is done with the guidance of the CAD/CAM manager, denoted as "B" in Fig (3.6).

Document Control staffs take the responsibility for keeping the documents, which are the CPD files for both CAM section and QC Section. The CAD/CAM manager then stamps "Control" to indicate that the document was controlled. Moreover, Document Control's staffs, in case, they have to review the CPD, the CAD/CAM manager replaces the old CPD with a new copy of CPD. If in case of CAD disposes the copy of old CPD, the manager then provides the new copy of CPD to CAD team.

Customer DATA Control

The following operation procedure is the explanation for Fig (3.5).

The CAD/CAM general manager, denoted as "A" in Fig (3.5), receives the customer DATA from the marketing. The DATA is then checked by "A". If any error or flaw is observed, "A" informs the customer so as to proceed back to the marketing department, else the DATA will be forwarded to separate and save each customer's file in HDD directory M:Drive/Customer Directory. The task is done by "A", CAM Supervisor "B" and CAM leader "C". After this, the DATA is saved by "A/B/C" as Read only file so as to protect the Customer files as well as to protect the Customer Directory. "A/B/C" also create back up files after that.

Then, "A/B/C" print out the DATA files to check the detail of the drawing. If in case of finding any problem regarding the drawings, the DATA will be sent back to "A" for rechecking so as to inform the customer for any reconsideration, else the DATA is forwarded to filing. The filing will then be done by taking the record of the file name, received date, receiver, model name, and model no. After these tasks are done by "A/B/C", the DATA is forwarded to the in charge of CAD/CAM, denoted as "D" in Fig (3.5), so as to copy the file into the Work Directory. Then the DATA file is forwarded to design mold, if there is any problem observed by "D", the DATA will be sent back to "A" for rechecking so as to inform the customer for any reconsideration, else the DATA is proceeded to continue the design process.

Computer-Aided Design (Mold Parts Drawing)

The following operation procedure is the explanation for Fig (3.6).

The assembly drawing and mold part list produced from the end part of CPD from Fig (3.4) is then forwarded for the complementation plan done by CAD Team "A" and CAD/CAM manager "B". In this level, CAD schedule (E.g. FM-04-CAD/CAM-019) is created. Also the complemented plan is sent to the CAD team "A" to change the assembly drawing formats by using Cimatron IT software.

After checking the reformatted drawings, if any errors is observed by "A", the drawing will then redirected back to the complementation planning level where "A" and "B" redo the initial stage activities, else the drawing is forwarded to "B" for approval. If the drawing is not approved by "B", the drawing will then again be redirected back to the complementation planning level where "A" and "B" redo the initial stage activities, else the drawing is forwarded to design and program for Core Drawing, Cavity Drawing, Parts Drawing, Wire Cut Part Drawing, EDM Drawing. Wire Cut EDM Drawing, Mold Material Order List, Mold Standard Part Order List.

Computer-Aided Manufacturing (CAM)

The following operation procedure is the explanation for Fig (3.7).

Once the CAD Team has finished up with the drawings, the data are forwarded to CAM section where CAM TEAM (A), CAM LEADER (B) and CAM SUPERVISOR (C) have to draw the implementation plan for the product. At this stage CAM schedule is produced (E.g. FM-04-CAD/CAM-3230). Also "A, B, C" forwarded implementation plan with the drawing and files so as to modify the designs into Cimatron IT format. If any error or rejection is found by B or C after that stage, the plan will then be sent back to the initial stage so as to draw the implementation plan again by "A. B, C", else the design is forwarded for the approval. If B or C disapproves the forwarded design, the plan will then be sent back to the initial stage so as to draw the implementation plan again by "A, B, C", else the design will then be forwarded for order list, changing codes and writing list and programs for the machine DATA: Core NC DATA, Cavity NC DATA, Part NC DATA, Wire cut NC DATA, EDM NC DATA, Wire cut EDM NC DATA, EDM material order list.

Quality Plan

The following steps of quality plan are the brief explanation for Table 3.2.

1. CAD/CAM Team checks mold structure design of customer part drawing arid model whether to modify the design or not before forwarding it to the next step.
2. CAD Team then reviews the mold structure, if there is any error or NG (No Good) points, the team forward the design back to the first step for redesign. Else, the design is forwarded to the next step.
3. The customer checks the mold specifications done by the CAD Team for approval. If the customer observes NG points on the mold, the customer sent the design back to the first step for redesign. Else, the design is approved and forwarded to the next step.
4. The CAD/CAM section draws the mold specification and assembly drawings to be forwarded to the quality control (QC) section and CAM Team.
5. CAM Team works on the part drawing, data translations and part programming for the production section.

6. Purchase Team check the specifications for the order list, purchase list and drawings so as to find a supplier before forwarding the tasks and materials to the QC section.

7. QC Team checks the invoice, purchase order, materials and drawing. If any NG points are found, the purchase team will be informed to return all the stuffs to the supplier and redo all the jobs. Else, the purchased stuffs and drawing are forwarded to the production section.

8. Machining process is done at this step.

9. While the machining process is in process, QC Team inspects for any NG. If any NG is found, the team will inform production manager, else, the process is forwarded to next step.

10. The finished workpiece is checked by finishing supervisor.

11. The finished workpiece is inspected by QC Team for any NG. If any NG is found, the team will inform production manager to make some small adjustment. else, the process is set up to the next step.

12. The customer makes their own trial run to check if there is any NG. If any NG is found, the customer will inform to the design general manager and manufacturing general manager. Else, the product will be placed to the next step.

13. If there is no problem in the step 12, final inspection and invoice are done by the marketing section for the product delivery. But if there any NG found in the step 12, the marketing section will cancel the car for the product delivery.

OPERATION PROCEDURE	Document No.	OP-04-CAD-7.5.4	Approved	
Customer Part Drawing Control	Revised	2	Checked	
	Effective Date	10-Aug-48	Prepared	

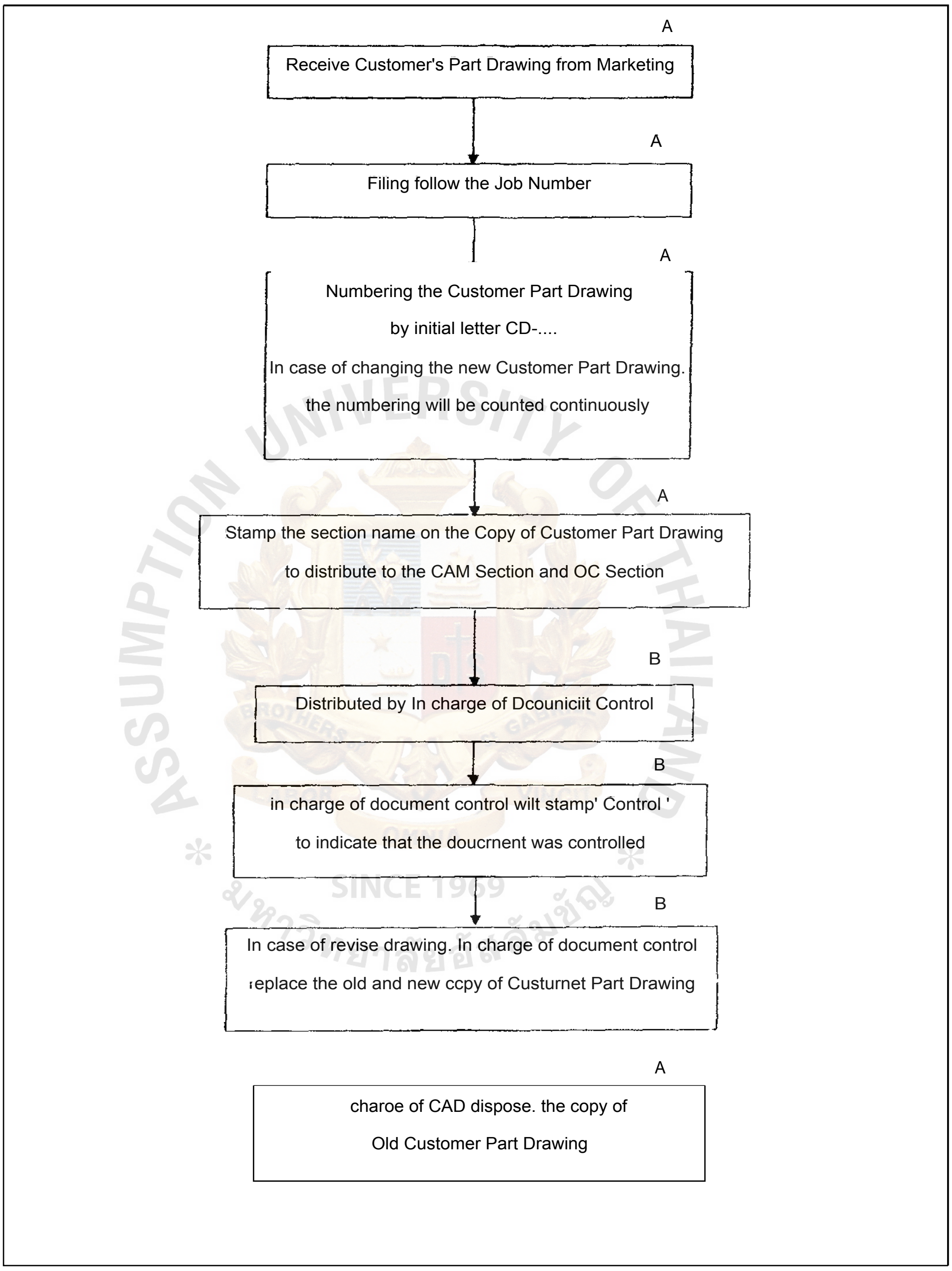


Figure 3.4. Customer Part Drawing control

OPERAPON PROCEDURE	Document No.	OP-04-GAGA-7.5.4	Apploved	
Customer DATA Control	Reused	C	Checked	
	Eficc::tve *Gate*	12, Nov :.?,	*Prepared*	

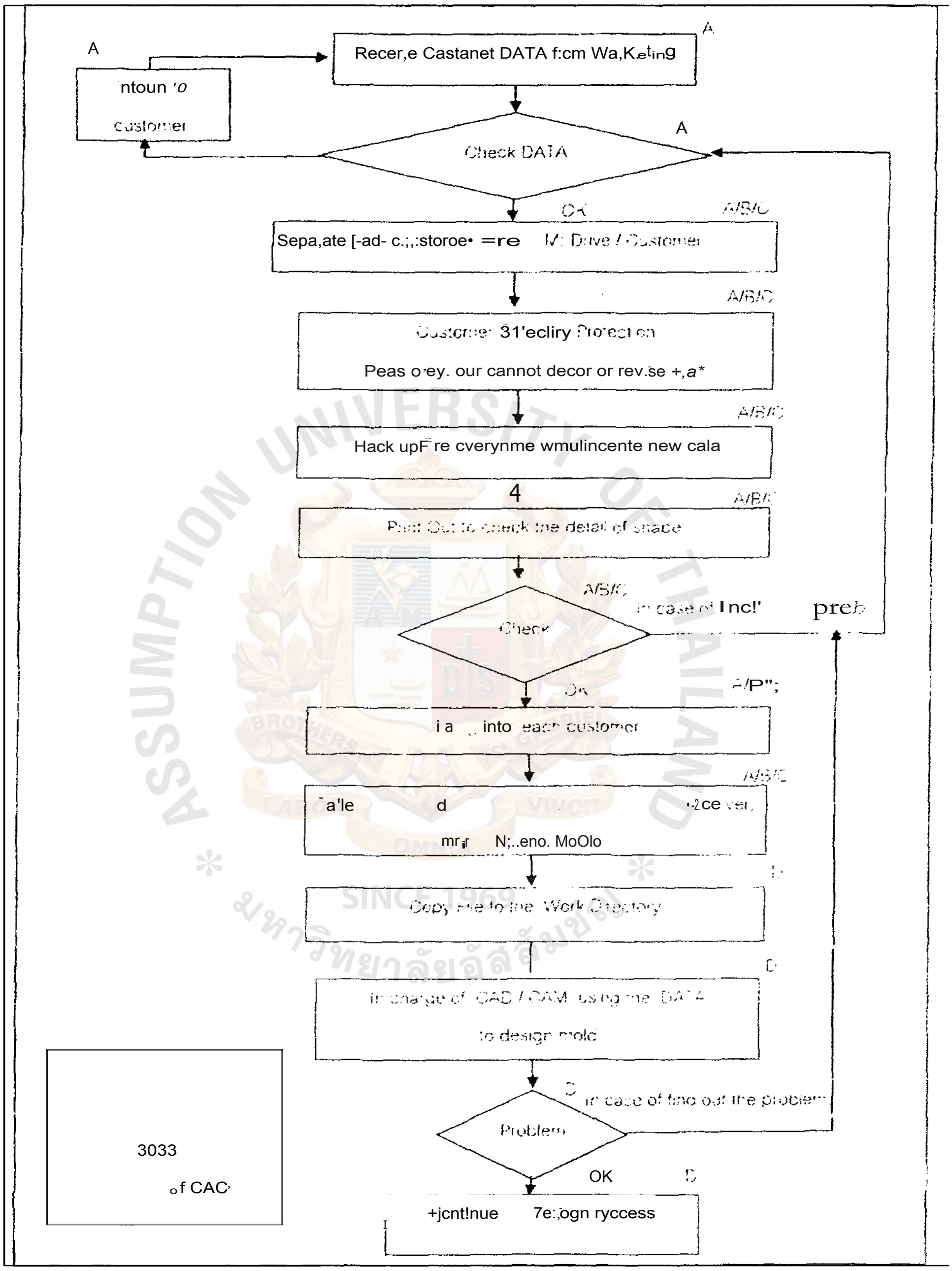


Figure 3.5. Customer DATA Control

OPERATION PROCEDURE	Document No.	OP-03-CAD-7.5(2)	Approved	
Computer Aid Design	Revised	3	Checked	
(Mold Parts Drawing)	Effective Date	10-Aug-05	Prepared	

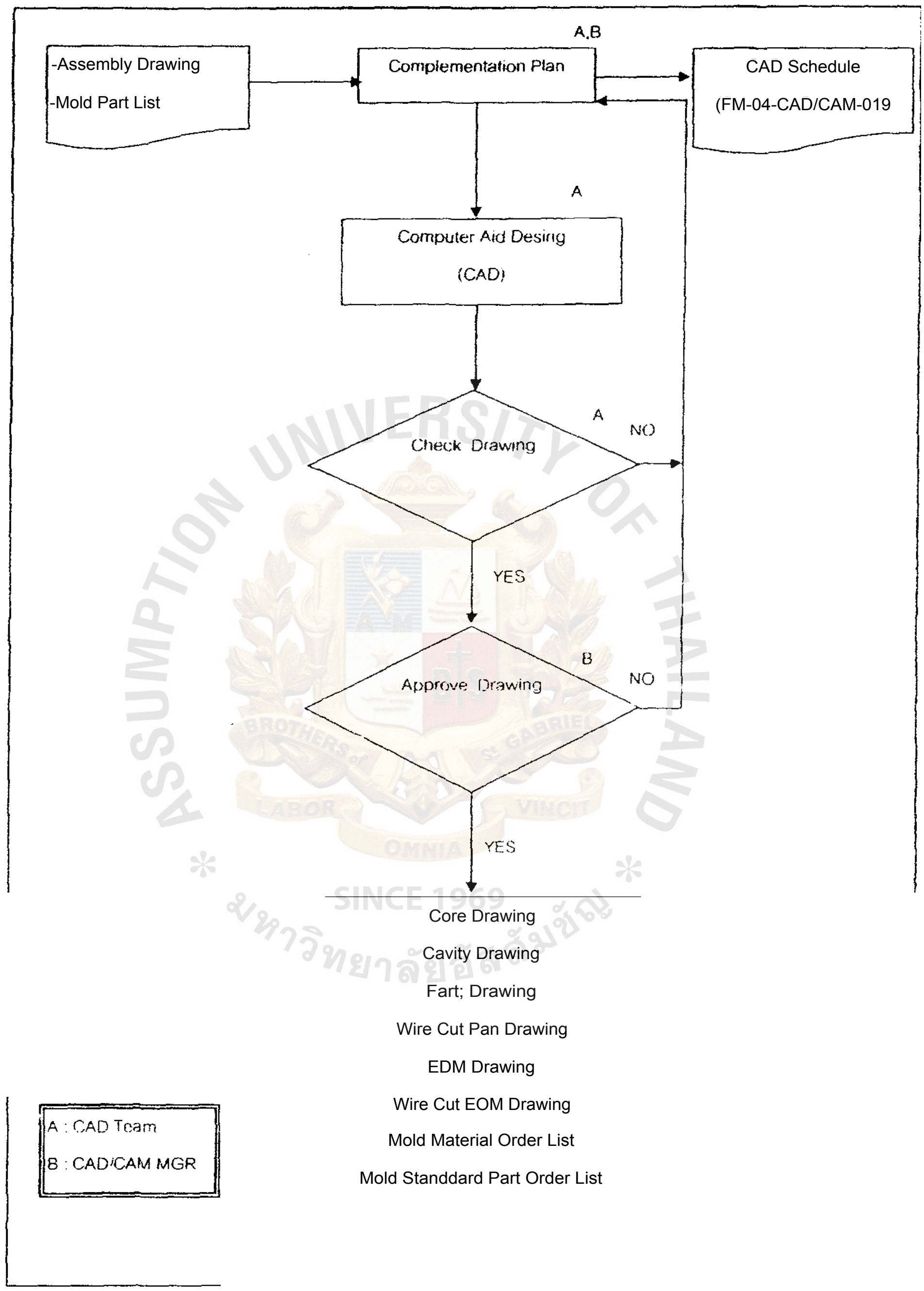


Figure 3.6. CAD (Mold Parts Drawing)

OPEYAT ON PROCIDURE	Document Nn.	OP-04-CAM-7.f.,	ApprovoA	
Computer Aid Manufacturing	Revised	0	Checked	
	Effective Date	10•00-01	.pa'ed	

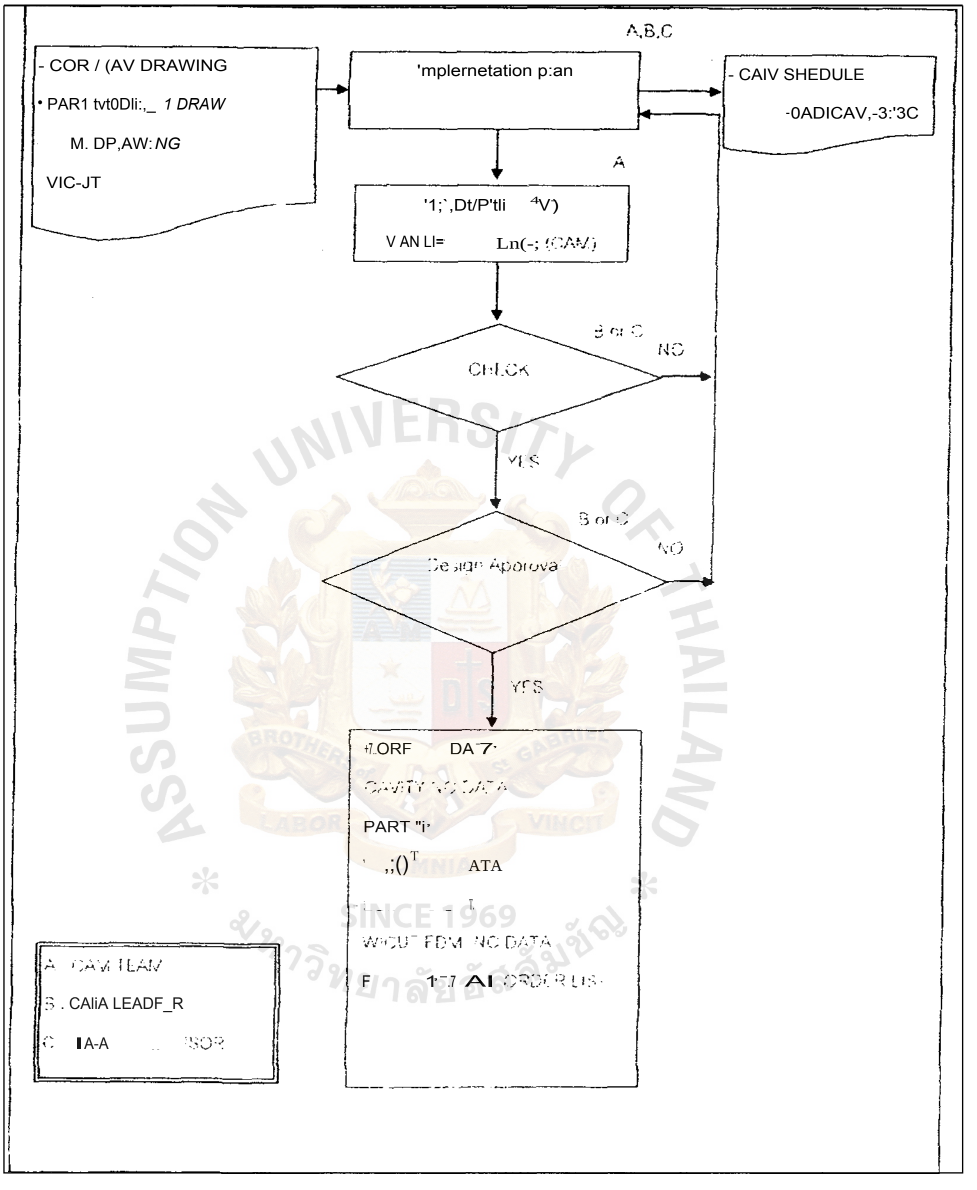


Figure 3.7. Computer-Aided Manufacturing

Quality Plan Flow Chart and Overall Operation Procedures of KCTL

KYOCERA CHEMICAL (THAILAND) Ltd.

Ho* Chart

3.8 KTCL's current situation

Kyocera Chemical (Thailand) Limited (KCTL) has been developing its business strategies and manufacturing performances by implementing Computer-Integrated Manufacturing (CIM) systems in its company since 1996. Although the company can be considered as a good initiative model for the mold and die manufacturing industries, it is still on its track to complete the full implementation of CIM systems as the scope of CIM is very widely defined.

Here in Thailand, there are more than 100, local and international, mold and die manufacturing industries. But large mold and die makers for auto parts are still fewer compared to that of electronic and other plastic mold and die makers. Also, one of the most important factors in considering the full implementation of CIM systems is Thailand's goal of becoming the Detroit of Asia, which will bring more customers from the auto manufacturing giants like Ford, Honda, Nissan, Mazda, Mitsubishi, Toyota ... etc. Thus, the company is in need of reviewing the existing systems, modifying the existing systems, upgrading the existing systems and developing the next generation CIM systems so as to increase its competitiveness not only for the local market, but also for the global market as a whole.

3.9 The industry trends

Nowadays, Industry trends are supporting more competitive edges not just only to lower the cost, trim production time; they also provide increase in quality. An overriding trend is the evolution of industries to make improvements in technology, machine accuracy, control technology, modeling software, which are letting the mold and die manufacturing industries to provide masterpiece that is very close to or exactly what the customer wants.

As the accuracy and precision is counted for the quality: workpieces are not finished by hand, with grinding or other methods.

"What is assumed, of course, is the human factor: designers, programmers, machinists and other skilled employees who contribute to the company's competitive edge. Talented, innovate and well-trained, these employees can collaborate with customers on designs that contain production costs while streamlining production. *(http://www.moldmakingtechnologv.corn)"*

Specific trends and technologies might include *(littp://www.moldmakingtechnologv.com):*

- 3-D printing (3DP). 3DP allows proto-types to be rendered quickly from CAD drawings. Thousands of thin layers of powder are used to create a 3-D model. Because the process bypasses patternmaking, it can hurry moldmaking straight to prototyping and casting. Reports have been heard of foundries reducing casting time from 17 to three days.
- Increased use of high-speed machining to reduce hand finishing of molds. Machining centers with light, fast, accurate milling passes now can machine a surface to its intended finish and dimensions and, by doing so; eliminate the need for hand finishing.

  Side-by-side machining. The number of setups and operations are reduced with side-by-side machining as compared to the use of conventional machining. The core and cavity of a mold are machined side-by-side--as left- and right-hand faces—from a single workpiece on a multitasking machine. Accuracy is enhanced as both mold halves retain perfect orientation to each other until separation.

- Parallel machining. Large mold components are machined in segments on smaller machining centers with high volumetric accuracy for significant savings in equipment and time. The finished segments are assembled into a complete core or cavity. In some cases, the segments can be designed to fit, as inserts, into packets in the mold base.
- Five-axis gun-drilling. The number of setups required to complete a mold by drilling deep holes at angles that are not parallel to the machine's axis are significantly reduced. The gun-drilling is done without special fixtures.
- Zero/negative stock machining. The cost and time of mold building is reduced as the extra stock on the cores and cavities of molds is eliminated. The piece goes from milling machine to mold press to perfect molded part in one shot. The need for benching also may be practically eliminated. The use of programming software that programs accurately and cuts true to the surface data is critical.
- Use of automated machine loading and unloading systems. Automation allows for more efficient use of labor.
- Rapid tooling (RT) technology. RT technology has evolved toward building molds that provide up to 40 percent faster cycles than would be possible with conventional technology. At the same time, RT applications have shifted from prototype to full production tooling. New RT approaches minimize or eliminate warpage and internal stresses from uneven cooling while boosting productivity by drawing heat more quickly from hard-to-cool features.
- Rapid prototyping (RP) processes help speed products to market with progress being made in using metals and other materials.

- Use of advanced manufacturing modeling software. This software simplifies mold design, a task that can be tedious and demanding. Time savings of up to 80 percent are being reported.

3.10 The mold and die industry's impact on Environment

Every industry has impact in all respect to our society, economic, and, the most importantly, our environment. The World Health Organization (WHO) states that, "In its broadest sense, environmental health comprises those aspects of human health, disease, and injury that are determined or influenced by factors in the environment. This includes the study of both the direct pathological effects of various chemical, physical, and biological agents, as well as the effects on health of the broad physical and social environment, which includes housing, urban development, land-use and transportation, industry, and agriculture."

The term "environment" is defined by the four elements, fire, air, water, and soil. As the impact of the environment on society cannot be predicted, the environmental protection must be done in every aspects of society. Countries, Nations, States, and individual efforts to ensure clean air and safe supplies of food and water, to manage sewage and municipal wastes, and to control or eliminate vector-borne illnesses are necessities to improvements in public health in every society. Unfortunately. there are imbalances in polluters and cleaners. In the past, research and activism in environmental epidemiology and toxicology has often faced with the capitalists, who are protected by the investment laws.

Further research is needed to address these and other problems so as to improve the science and management of health effects, natural disasters on societies caused by the industrial impacts.

Issues regarding the air quality, water quality, toxic wastes and global warming are always the socioeconomic and environmental factors, which we usually face with the manufacturing industries.

The industries by-products and chain effects of the industries are often called up to a great concern to the environment. Most industries still cannot cope up with the sustainable development.

As the mold and die manufacturing uses heavy metals, electrolytes, and chemical and so on, toxic and hazardous wastes become the factor. Including, sometimes, low-level radioactive wastes, which are deposited on land often are carried far from their sources by air, groundwater, and surface water runoff into streams, lakes, and rivers where they can accumulate in the sediments beneath the waters.

One of the most important factors contributed by the mold and die industries to the global warming is they are the back-bones of the auto industries, the major automakers of the world and are still promoting the consumption of fossil fuels, which is a very bad impact to the environment. The global warming is extremely hard hitting the global society; especially those living in the low land areas are now facing the fact of becoming the environmental refugees as the sea level is rising every year.

Regarding these factors, the companies should consider deeply the impacts and plan for the cleanup, control and sustainable management on the economy as well as their industries.

IV. THE PROPOSED SYSTEM

Referring back to the previous chapter, automation and CIM systems used by Kyocera Chemical (Thailand) Limited (KCTL) is such a model for the mold and die manufacturing industries especially for the mold and die makers for the auto parts. Recalling back the main systems and equipments of Kyocera Chemical (Thailand) Limited (KCTL) are Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM), Computer Numerical Control (CNC) machines, Electric Discharge Machines (EDMs) and Milling machines. Although the company is trying to implement most of the CIM systems for its mold and die manufacturing, it still needs to extend its implementation to improve the manufacturing processes in some major areas.

4.1 Areas to be adjusted, upgraded and modified

The areas, of the main systems and equipments of KCTL. to be adjusted, upgraded and modified are as follow:

1. CAD/CAM software and hardware,
2. Communication and Networking systems,
3. CNC machines,
4. EDMs,
5. Finishing section, and
6. Factory safety standards, Machine cooling and ventilation systems.

4.1.1 CAD/CAM software and hardware

Since KCTL is still using Cimatron IT old version for CAD/CAM, in which the design engineers and CAM operators stress on the issue like the standard parts are not complete in the design catalogue giving programmers difficulties in writing the programs. Thus, the company is in need of upgrading CAD/CAM software and hardware. So, what shall be the next upgrade? "In considering the option of upgrade, the following factors should be considered *(http://www.moldmakingtechnology.corn):*

1. The hardware and software tools should be kept up-to-date through a software maintenance contract and regular hardware updates, thereby assuring compatibility of all of the equipment involved.
2. The designers must be provided with comprehensive and ongoing training on the software products they use in order to maximize the benefits that the company will receive from its equipment and people.
3. The design engineer must develop a clear understanding and compassion for the methods, process and needs of the manufacturing engineers.
4. The CAD/CAM system that a company chooses must perform the job it is advertised to perform. This should include a demonstration on your own parts because the most powerful systems with the best features are useless if they won't run your machine properly. Most buyers, unless they have experienced problems with previous systems, tend to overlook this very important point. This can be costly and time-consuming a moldmaker - so let the buyer beware. *(http://www.moldmakingtechnologv.com)"*

Therefore, the next upgrade should be CimatronE, which is a successor and a better version for the operators as well as for the machines. Cimatron is a publicly owned company with a worldwide presence. The company is one of the largest global providers of CAD/CAM software with a comprehensive solutions approach to the toolmaking market. On the basis of revenues received, ClMdata ranks Cimatron in the top 10 among the CAM software vendors worldwide. It is also in the top **10** in Europe and Asia. The following are the CimatronE Version 8.0 product review.

"(http://www.cimatron.com) CimatronE Version 8 is being announced at IMTS 2006. Some of its key elements are:

- Introduction of the new progressive die design application
- Increased capability and productivity for mold design of huge and complex molds
- Introduction of CimatronE concept for molds
- Introduction of a machining preview capability
- Dramatic improvements in plate machining, including automated drilling Introduction of EDM setup and programming
- Major improvements in core/cavity machining
- Increased emphasis on 5-axis machining, including the application of 5-axis machining to production machining

With Version 8, Cimatron is focusing on enhancing their mold design and complex machining capabilities, such as 5-axis machining; at the same time they are entering new markets such as design of progressive dies and the 5-axis segment of the production machining marketplace. Some of the expanded or new capabilities in CimatronE Version 8 are briefly discussed below.

Progressive Die Design is a new product being introduced in CimatronE Version 8. Cimatron is currently one of the few CAM software vendors to offer such a capability. Progressive dies are commonly employed to produce sheet metal components in industries such as automotive, consumer products, computers, and electronics. A progressive die sequentially transforms a flat strip of metal into a completed part by employing a series of stations that cut, form, and coin the material into the desired shape.

In Progressive Die Design, a user analyzes the part, builds the strip layout, creates the die tool, and documents the process. Cimatron Progressive Die Design is a single integrated solution that provides a broad and flexible tool set from quoting to production. It includes a combination of automation and hands-on control to offer speed, consistency, flexibility, and the ability to reduce trial-and-error iterations. It is intelligent, parametric, and associative. Software is provided for finite element analysis, strip design, die set design, detailed tool design, tool validation, machining, and support of shop floor operations. The system allows users to work in the method they prefer, and an "Intelligent Toolbox" makes the relevant tools available for each task at the appropriate time.

Integral finite element analysis is used for the standard blank calculation and thinning analysis, as well as in surfacing operations which are used for unbending, unfolding, and compensation for spring back. Cimatron offers a hybrid solid and surface-based system. A rich surfacing package is provided. CimatronE allows users to work directly in 3D or in a 2D environment within its 3D assembly. This capability, which is especially apparent during nesting and strip design, enables users accustomed to working in a 2D environment, to continue to do so while also enjoying the benefit of 3D robustness. Users can also start designing directly in 3D.

Mr. Jay Weiner, IT Manager at CAM Tool & Die Ltd. stated, "The new Cimatron Progressive Die product is very flexible and powerful. By starting in 3D, we expect substantial productivity improvements. The surfacing package is second to none. There are no limitations on what can be done.¯

Support for Large and Complex Molds: Cimatron is able to effectively support the design of large and complex molds. In Version 8, the increase in capacity and performance ranges from 35% to 50%. As one specific example, a leading automotive provider utilized CimatronE to create a bumper mold that was 3.2 meters long, had 1,200 parts, and 36,000 faces. The mold design software is associative, so that as a screw is changed, the corresponding hole is automatically updated. In addition, quick modification tools allow users to make immediate local changes. With these tools, the system can perform any complex change within seconds, even in a mature assembly holding thousands of components. An additional new feature, particularly useful for large mold shops, is concurrent mold design. This feature allows several users to simultaneously work on the same mold assembly with each portion of the mold owned by a different user.

Other features include analysis of opening direction and draft angles for parts with ambiguous opening directions to determine the desired parting line, and automatic grouping of holes according to their shape, dimensions, and position on the plate, including automatic numbering. CIMdata views CimatronE among the high-end software products being employed for mold design.

CimatronE Concept: Concept is a new product in Version 8 permitting users to quickly establish concepts, create designs, perform analysis, and collaborate with other members of design and manufacturing teams up and down a supply chain. It can be applied to estimating, quoting, and design review, and can be used by product managers, team leaders, designers, and manufacturing engineers. Native data can be accepted from all major CAD systems. Some of the specific applications of E concept include:

- Determining the feasibility of producing a part
- Establishing mass properties of a part
- Evaluating the splitting of core, cavity, and slides
- Performing a draft analysis to establish undercuts or reverse draft conditions

- Verifying engineering changes and comparison of models by use of Quick Compare software
- Viewing completed mold designs, including how a mold opens and a complex component fits into a mold

NC Preview: NC Preview is a new decision support capability in CimatronE Version 8. It provides a preview of a cut by showing the outcome of a toolpath without actual calculation of the toolpath. For a given set of parameters and toolpath strategy, the remaining stock or extra material at any point on a part after each cut is displayed. Potential collisions are considered. With NC Preview, users can quickly verify results and eliminate errors early in the process. This level of preview is unique to Cimatron.

Automated Drilling of Holes: In Version 8. Cimatron introduced a new automated capability for drilling of holes. Full user control is provided. With feature recognition, any type of hole geometry is recognized and similar holes are detected and grouped by type of hole. The drilling can be optimized to minimize the number of tool changes and tool movement. The software learns over time, as processes can be captured and reused in similar situations.

EDM Setup and Programming: CimatronE EDM is a new solution in Version 8 that provides a comprehensive set of programming tools to automate and optimize the end-to-end electrode design and manufacturing process. It minimizes the tedious task of EDM die sinker programming and greatly reduces the programming time. Multiple cavities and electrodes are supported. It builds upon the strong capability provided in CimatronE Quick Electrode for electrode extraction and design. Mr. Jim Dent and David Koning of LS Mold commented, "The Cimatron modeling package is first-rate. It particularly shines in electrode creation. Further, customer support from Cimatron is outstanding."

Core/Cavity Machining: A large number of new features are included in CimatronE Version 8 to support core and cavity machining. These include:

- Strong algorithms to support a 3D stepover machining strategy for high surface quality

  Motion Editor that has knowledge of the remaining stock and can be employed to modify the toolpath and boost the NC programming cycle
- Use of different offsets to machine different areas of an electrode
- An automated capability to prevent waterfalls in a mold and part and to provide high surface quality Providing support for a conic tool and shank for high-speed machining and cleanup
- Collision checking considering the tool, holder, and shank during toolpath computations, as compared to checking at a later time

Increased Emphasis on 5-axis Machining: Cimatron has long been one of the leading CAM centric vendors supporting 5-axis positioning and continuous 5-axis machining for moldmakers. This capability is now becoming more important as moldmakers are increasing their use of 5-axis machines as they become easier to operate and the price of the machines has decreased. Five-axis machining reduces the number of setups, permits use of shorter tools, and can reduce the number of electrodes required.

In Version 8, Cimatron has expanded the scope of 5-axis machining from toolmaking to the high end of production machining. They have defined a series of new application solutions to support 5- axis machining of production components. This includes 14 bundled and broad-based standard application solutions for machining of complex production components including pumps, turbine blades, speed boat propellers, screws, impellers, and molds for plastic plates. In all cases, a collision check is performed on the tool and holder. By employing standard application solutions, a user can increase programming consistency, quality, and productivity.

Marketing and Sales: From a geographical perspective and unlike most CAM-oriented vendors, Cimatron has formed wholly-owned subsidiaries in major geographies to serve local markets. Their sales channels span more than 30 countries in North and South America, Europe, and Asia. Cimatron is now placing increased emphasis on the emerging manufacturing segments of the world including China, India, and South Korea. They also plan to add focus to their North American operations. They attach major importance to consulting and product support.

Summary Comment: CimatronE Version 8 is a substantial and significant release that will greatly enhance and broaden the Cimatron CAD/CAM offering. It introduces totally new applications, new product features, and also provides substantial improvement to existing functions within CimatronE. With this expanded scope of applications, product enhancements, and focus on the more rapidly growing areas of CAM technology and market, Cimatron expects to increase their rate of revenue growth and profitability. ClMdata is favorably impressed by the evolution in the Cimatron product and market strategy, and the sizeable content of Version 8. It is expected that the product will be well received in the worldwide market. *(http://ww14:.cimatron.com)"*

4.1.2 Communication and Networking systems

The communication and networking systems of KCTL are also in need of upgrading as the systems in use are one of the weak points of the company. The CAD/CAM room has a server with only 80GB capacity and operates only on LAN. The manufacturing management department and other department have no LAN system. KCTL is still using 56K dial up connection. The communication medium in the company is Thai language. The communication between the management and the staffs has to depend on the interpreter because the management team is made up of Japanese staffs (who cannot speak Thai) and the other employees are mostly Thai nationals (who cannot speak Japanese).

In reinforcing the communication and networking weakness, the company should upgrade its LAN system with Internet sharing throughout other depaitments with good firewall software so as to protect the design and product data (which are also the product of the KCTL). Internal phone lines and the company's LAN should be always upgraded and maintained so as to facilitate the communications between customers and suppliers (local and international) and the company's manufacturing facilities as well as to its main headquarter in Japan.

4.1.3 CNC machines

The KCTL is facing some disadvantages (like in reducing manufacturing lead time) in competing some of the upcoming competitors because the company is still using old CNC machines, from which the workpiece has to go on with EDM machines (the most painful part of mold and die makers, as well as the most energy consuming. part of the mold and die manufacturing process). Thus, the company should consider investing in new 5-axis CNC machines replacing the old ones with low efficiency in the near future.

4.1.4 EDMs

Electric Discharge Machines (EDMs), the most painful part and time consuming phase of mold and die manufacturing. Since KCTL is still using the old EDMs, after the EDM section the workpiece still has to forward to the surface polishing section, where the manual labor is the working force and consumes the manufacturing lead time at this section. The company should consider investing energy efficient and user friendly EDMs because one of the latest versions of EDMs, like smart EDMs, is CAD/CAM build into the EDM making the user easier and time efficient.

4.1.5 Finishing section

The finishing section of KCTL is still using the manual labor. The section sometimes consumes at least a week for a workpiece. This section should be studied and researched carefully as the manufacturing lead time could be reduced from this section. If precise smartEDM machines are used, this section's delay time will be reduced or totally eliminated.

4.1.6 Factory safety standards

Although the company is running with ISO standards, there still needs improvements in some manufacturing areas. As KCTL factory is using overhead crane yards, machines, oil-coolants, EDM electrolyte, and heavy metal blocks, there have some weak points at the factory. For the overhead crane yards, safety shoes and gloves are provided to the workers, but the safety helmets are not provided, instead some soft cotton caps are only provided. The company should consider the safety standard for this section.

Although the heat inside the factory is fair enough for the machining environment, the odor inside the factory is bad as the ventilation systems are not properly installed. Thus, the company should consider installing the air purifiers and good exhaust system for the machines inside the factory.

V. PROJECT IMPLEMENTATION

5.1 Overview of the project implementation

Project implementation is the well planned and systematic extension of the existing system to the new proposed system. Firstly, group meetings, evaluations, research and analysis must be done so as to make sure that the new proposed system is an essential system for the company as well as to meet the company's goals and objectives after installation other than that of following the competitors' profiles. The following are the basic steps in implementing a new proposed system:

1. Meeting for purchasing a new system (software or hardware)
2. New system installation and on-site training
3. Testing the new system
4. Operating the new system

5.1.1 Meeting for purchasing a new system (software or hardware)

Most of the systems and machines are upgraded and replaced with new systems only when the approval of the managing director of the company is granted. Also the meeting for the new installation or replacing other systems are mostly done between the CAD/CAM manager and manufacturing general manager.

Firstly, the managing director of KCTL, CAD/CAM general manager and the CAD/CAM team must call a meeting, where the CAD/CAM team presents the facts and reasons of the installation and upgrading the new version of CAD/CAM software and hardware.

Secondly, only after the approval of the managing director is granted, the request is then forwarded together with the facts and reasons from the meeting minutes to the Japanese headquarter for the budget approval.

Finally, only the approval from the headquarter is granted, the purchase team will then order the new system (software or hardware).

5.1.2 New system installation and on-site training

After the new system is purchased, most of the supplier companies provide on-site installation and on-site training for the new system purchased. Before the arrival of the new system, the factory layout team has to make sure there is a place for the new system to be installed. The location must then be properly measured, prepared and cleaned up for the new system to be placed.

For example; CAD/CAM software system installation, the CAD/CAM team has to undergo training at least one month. The company's customization may sometimes take up to 1 year to c3mplete. But, to get skills and experiences on the new system, it may take at least 3 years. Thus, most of the companies conduct surveys or research before implementing a new system.

Other hardware and new machine installations are less time consuming compared to that of software installation. For example, new CNC machine installation and on-site training will take only about a week and to get the skills on the machine will take less than 1 year.

5.1.3 Testing the new system

After installation and on-site trainings are done, the new system (software or hardware) has to be put on trial runs. In this period, the performance data recording and analysis must be conducted so as to check the new system's results whether they meet the performances as it is advertised. Only after the trial runs show the constant results as expected, the new system is put onto the final operation level.

5.1.4 Operating the new system

At this level the new system has passed the probation period and it is ready to operate for any assigned tasks. From this stage onwards, the performances will be recorded so as to produce the evaluation and review annually on the system for the future implementation plans.

VI. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Implementing CIM systems in the mold and die manufacturing industries requires a number of departments and decision makers. As a model, Kyocera Chemical (Thailand) Limited (KCTL) is one of the companies implementing CIM systems and ideas in manufacturing mold and die especially for auto parts. Since the mother company of KCTL has been contributing to its customers with 50 years history in making mold and die around the world, KCTL is always seeking for production expansion and technology development. Having the feedback 80% customer satisfaction, the company is still researching its manufacturing systems to improve the product delivery, product quality and product price.

The project covers literature reviews on different scopes of CIM systems, on-site survey and analysis of the existing CIM system in mold and die manufacturing industry, system requirements, the most recent technologies and trends for mold and die manufacturing industries, advantages and disadvantages of implementing CIM systems, and delivery of the proposed system to cope with the future needs of the company.

In doing the literature reviews, which are the most valuable supporting pillars of this project, I found out the evolution of CIM systems have started since the very early years of 1950s with a very wide scope of interests covering most of the fields in manufacturing industries. Nowadays, the current CIM systems are astonishingly migrating with a huge impact on the global industries starting form the agricultural industry to aerospace industry.

On-site survey and analysis of the existing CIM system in the mold and die manufacturing industry gave me a chance to experience the real world functioning patterns of the CIM systems in mold and die manufacturing industry. The survey and analysis, however, were done in a very short period of time, the findings were very useful for the mold and die manufacturing industries.

As the nature of the CIM systems is always integrating itself, the manufacturing firms also have the impact of the system's integration. As the global market is opening up its competition world wide, the manufacturing industries have to change their business strategies in every aspect. Thus, the existing system of the company surveyed had come up with some extension for its existing system so as to reinforce the company's goals and objectives.

To come up with good systems and ideas so as to improve the gaps of requirements, I had to find out the current trends, technologies and systems for mold and die industries. Surprisingly, many websites (many thanks to the freedom of Internet) have provided me, regardless of the different topics they cover, invaluable information for my project as well as for my general knowledge. So also the past trip I made to the BITEC, which provided me the way to find out the information regarding the industrial automation system softwares, hardware and their services.

As the purpose of this project is to implement CIM systems in mold and die manufacturing industries, especially implementing CAD/CAM systems, the conclusions are divided into six sections which explain the integrative effects of CIM. They are as follows:

1. Designing section
2. CAM section
3. Machining section
4. Finishing section
5. Shop floor section

6. Manufacturing management section

6.1.1 Designing section

The designing section is the initial part of the manufacturing process, which is very important for a company's benefits. Most companies, usually, cannot give full load of their CAD design section as it is associated with the skill and experience of the CAD/CAM team operators. The more the operator's skill and experience levels increase, the more the benefits of the company increase. In another way, implementing more advanced and user friendly CAD/CAM tools provide the increment in the already existing skilled and experienced operators, which will absolutely boost the maximum benefits to the company. As the design data is also the company's product, the more designs that the CAD/CAM team makes, the more product that the company produces. In a way more profits towards the company.

6.1.2 CAM section

Also the advanced CAM tools are provided with user friendly interface, reliable data translation form other CAD systems, shape diagnosis, modeling, easy previewing, complete standard part catalogue, easy CNC and EDM setup and programming and support 5-axis machining. Thus, providing the company with the following benefits:

I. Shortening the delivery dates (reducing the manufacturing lead time)

2. Saving costs

3. Creating quality products.

6.1.3 Machining section

As of the use of 5-axis CNC machines instead of the old 3-axis machines, it is very clear that the finishing workpiece of the 5-axis machine only has to go through only one more face. Most NC programs usually contain errors, so also the CAM systems and post-processors can both produce errors. Thus, using precise CAD/CAM tool for NC programming is crucial to avoid costly mistakes at the machining section.

6.1.4 Finishing section

In replacing the old inefficient EDM machines with the new smart EDM machines, the finishing workpiece will need only a very few touching at the finishing section so as to avoid the rejection from the quality control section. The promising facts of installing the smart EDM machines are:

1. Quick delivery
2. Best quality
3. Reduce manual labor delay.

6.1.5 Shop floor section

Considering the safety and healthy environment for the employees not only upgrade the company's standard, it also gives back the employees trust on the company. In thinking about the safety standards and environmental standards, the company is heading towards the stance of doing a sustainable industry, which is a most important part of doing manufacturing in the world. In placing the safety standards and environmental care programs, the company will absolutely free from the unwanted long term compensation schemes regarding damaging the safety of workers and the environment.

6.1.6 Manufacturing management section

In upgrading the LAN system with Internet sharing throughout other departments and internal phone lines maintained, the manufacturing management section will benefit the reduction in cost of every individual personal computer upgrade as LAN system needs only one server HDD with high capacity and that server will be shared by the whole factory. With good firewall software, the separate server containing the design data (which are also the product of the company) will be protected. The undisturbed LAN system and internal phone lines facilitate the smooth communications between customers and suppliers (local and international) and the company's manufacturing management team as well as to its main headquarter in Japan. The advantages of installing LAN systems are:

I. Reduce software upgrading costs

2. Reduce stationary costs

3. Faster communications throughout all departments

4. Save energy cost

5. Easy access for the customers and suppliers

6. Continuous communication with the main company.

6.2 Recommendations

As the implementation of CIM systems in the mold and die manufacturing industries is vital for every mold and die manufacturing industry, not only KCTL must consider the implementation, but also the other mold and die manufacturing industries must consider the implementation of CIM systems. Taking as a model, KCTL's implementation of the CIM systems in its mold and die manufacturing is a good example to follow. But to face the global market trends and upcoming global competitions, the company needs to consider the proposed systems to be extended.

CAD/CAM is one of the most expensive softwares and is also taking a crucial part in making mold and dies. For example, "the heart pump, one of the innovations in medical industries, researchers and engineers used CATIA from Dassult Systemes and IBM to design prototypes of an auxiliary heart pump that could prolong the lives of thousands of heart transplant candidates awaiting a donor heart. With a diameter of only 22mm, the size of a fingertip, the pump is the smallest of its kind." Which is why companies servicing the medical industry rely on CAD/CAM systems, analysis and rapid prototyping tools to develop medical devices quickly and effectively.

The reasons of using advanced CAD/CAM tools are:

1. To reduce the manufacturing lead time
2. To improve quality
3. To reduce cost
4. To make the quick delivery
5. To achieve goals.

CNC machines and EDM machines are also playing one of the most important parts of manufacturing mold and die. Since CNC machines mostly take the rough cutting of the workpiece, the finishing workpiece from the CNC machine should be nearly done quality. But most of the 3-axis CNC machines cannot go through details and some places are left behind for the EDM machine for polishing. The most painful part of mold and die manufacturing industries is the EDM processing, where the workpiece is carefully finalized.

By using advanced CAD/CAM tool, the machine simulation can be done so as to avoid the costly machine crash on CNC machines, as well as the replacement of 3-axis CNC machine with 5-axis machine shortens the EDM process. The use of smart EDM also provide precision on the finishing part of the workpiece as well as a shorter EDM processing time. Thus, every mold and die manufacturing industries must consider the chain effects of not implementing the good CIM systems.

By implementing the communication and networking systems in the company, the company will have potential benefits regarding the reduction in software upgrade cost, stationary costs, energy consumption, difficulties in communications between departments, and response delay. In another way, the company will have positive results in keeping in touch with the potential customers and suppliers, so also continuous communication with the mother company is also and advantage.

Finally, the recommendations on the workers safety and environmental concerns are made so as to improve the image of the company as well as for the long term proceedings. As the company is working with heavy machinery and overhead cranes, the company should consider more safety standards in improving the shop floor safety. The ventilation systems and air purifiers are recommended to install so as to provide a long term relationship with the employees as well as for the sake of company's image.

BIBLIOGRAPHY

1. Mike11 P. Groover. Automation, Production Systems, and Computer-Integrated Manufacturing, 2nd Edition, 2001, Prentice Hall International, Inc.

2. James A. Rehg. Computer-Integrated Manufacturing, 1994, Prentice Hall Career & Technology, by Prentice Hall, Inc.

3; John. W. Satzinger, Robert B. Jackson, Stephen D. Burd. Systems Analysis & Design In A Changing World, 3rd Edition, 2004, Thomson Learning, Inc.

4. Jeffery L. Whitten, Lonnie D. Bentley, Kevin C. Dittman. Systems Analysis And Design Methods, 5th Edition, 2001, McGraw Hill.

5. Kenneth E. Kendall, Julie E. Kendall.Systems. Analysis and Design, 6th Edition, 2004, Prentice Hall International, Inc.

6. http://www.cimatron.com

7. http://www.moldmakingtechnology.com/ articles/

8. http:// www.healthypeople.gov