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INTEGRATION OF STAND ALONE FACILITIES FOR AUTOMATED DESIGN AND MANUFACTURING: A CASE STUDY

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Abstract The project deals with the automation of the product development process. The objective is to establish a paper free working model of this process. To meet this end, the endeavor involves the integration of various components and stages in a product development cycle. The Coordinate Measuring Machine (CMM), CAD/CAM software, and a CNC machine with other related paraphernalia are identified as main components in a typical product design and manufacturing cycle. The aim is to link all these individual components into an integrated and efficient working system. Two phases are involved in the process. The first phase deals with the establishment of smooth and error free flow of information and operations between the different stages of product development. The second phase involves testing of the workability, flexibility, and effectiveness of the system with a real life design problem.

Keywords: Automation, Computer Aided Design (CAD), Computer Aided Manufacturing (CAM),Computer Numerical Control (CNC)

1. INTRODUCTION

Conventional product design and manufacturing methods involve stages that are distinct and at the same time repetitive in nature. An important feature of this process is the transfer of relevant information between various stages. The conventional method of product design and manufacturing has the following serious drawbacks:

- Repetition of task among different stages.
- Difficulty in ensuring smooth and fast transfer of data between stages.
- High possibility of vital information being misconstrued or even lost during data transference.

With the advent of computer technology, ways have been developed to integrate these ‘distinct’ stages of product design and manufacturing operations so that the flow of work between stages is smooth, efficient, and reliable. With automation, the complete cycle starting from conceptual design to final production is done fully with the aid of computers. Paperwork, such as hand drafted design drawing, production drawing, or handmade calculations are eliminated.

Fig. 1, shows the fundamental product development cycle. Each stage requires a need of data feedback to check whether or not the output corresponds to the design requirements. Forward transfer of information is then required as a response to this prompt. Normally, this feedback and forward data sharing is done many times in the cycle through a fixed hierarchy, thus it is important to ensure that data is transferred in both directions in an effective, efficient, and reliable manner.

The project deals with a specific type of product design and manufacturing cycle. Rather than beginning with a conceptual design, reverse engineering is done on an existing product model. The steps involved in such a process are shown in Fig. 2. Each of the four stages of product development are linked to each other. Data sharing is enabled for each stage. A significant advantage of this setup is the unhindered data flow between different stages.

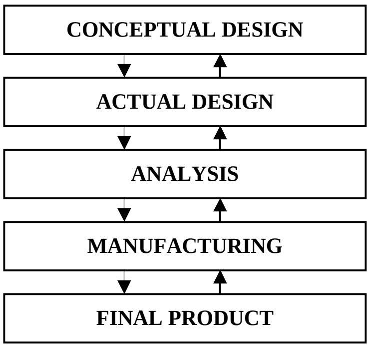

Fig. 1 The Fundamental Product Development Cycle

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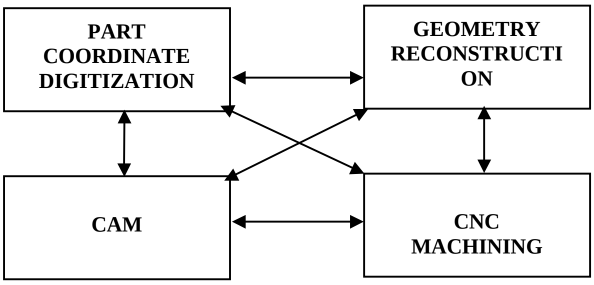


Fig. 2 The Product Design and Manufacturing Stages

2. DATA INTERFACING

To enable data sharing between these four stages, appropriate data interfacing between the different systems must be prepared. The term refers to the conversion and storage of data in a neutral format that is recognizable by the different systems involved.

The two types of data interface namely are:

- Graphical Data Interface (GDI)
- Machine Control Data Interface (MCDI)

Fig. 3 illustrates their positions with respect to the product cycle.

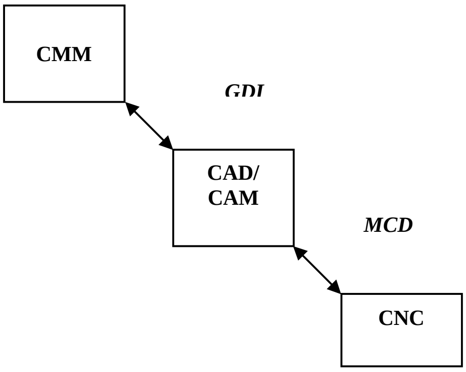


Fig. 3 Data Interface Between the Stages

2.1 Graphical Data Interface (GDI)

GDI involves the transfer of geometrical design drawing data from one CAD system to another or from a CAD system to a CAM system. There are requirements that this type of standardized interface must fulfill. Some of the requirements are:

- The interface must be capable of handling all of the manufacturing data.
- There should be no information loss when data is transferred between heterogeneous systems.
- The system should be adaptable to other standards.
- The system should be able to achieve production data.

2.2 Machine Control DataInterfac (MCDI)

In CAM, the toolpaths are firstly produced in generic format. This means that the CAM system compiles and processes this information to produce the machine-independent list of cutter movements and ancillary machine control information known as cutter location data (CLDATA) file. A program called post-processor (so-called because it takes place after the processing stage) then converts this data into the form suitable for the machine tool. This form is known as the MCDI. Different machine tools have different variations of MCDI files and meanings of G (preparatory) and M (miscellaneous) codes. Post-processors are developed to suit specific machine tool/controller combinations.

3. PART COORDINATE DIGITIZATION

Part digitization is done using various forms of coordinate measuring machines (CMM). Though the main application of CMM is in quality control and inspection of finished products, the present trends have seen a new application of the CMM in the field of reverse engineering, i.e. the process of duplicating existing component or subassembly, without the aid of drawings or documentation. The main objective of such application is to develop the technical data required for commercial reproduction of an existing product through reverse engineering.

3.1 CMM Measuring System

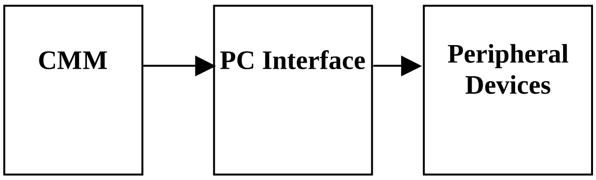


Fig. 4 Peripheral Devices

Figure 4 shows the basic organization of the CMM measuring system. The CMM itself consists of the machine and a counter (for manual CMM) or a CNC controller (for CNC-CMM setup). The sensor and the probe system differs for manual CMM and CNC-CMM. In this project, a manual touch sensor and probe system was used.

3.2 Steps in Digitizing

Digitizing using the CMM consists of four main steps. These steps are listed as presented:

1. Probe Calibration
   Here, the touch sensor probe's effective diameter is identified, taking into account the deflection of the probes and the probing force.
2. Component Positioning
   This step involves appropriately placing the component within the measuring space and selections of appropriate clamps and fixtures.
3. Part Coordinate System Setup
   In this step, type of coordinate system for measurement, its origin, reference axes and plane are selected.

3. Digitizing : The part-digitizing step itself needs to be carefully executed. Proper digitizing techniques would give sufficient, unambiguous, and non-redundant data.

4. COMPUTER AIDED DESIGN (CAD)

Once the design component has been sufficiently digitized, using the CMM, the data is then ready to be relayed to the CAD system. The data must be converted into a neutral format that is readable by the selected CAD system. Current CMM systems are provided with the necessary software for this purpose. In most cases, CAD systems are also equipped with their own translators.

There are basically three types of CAD representations. These are wire-frame, surface, and solid modeling. To manufacture 3-dimensional components, CAM systems can only work on surface or solid models.

5. COMPUTER AIDED MANUFACTURING (CAM) AND NUMERICAL CONTROL SYSTEMS

The basis of CAM lies in the idea of encoding machining instructions in numerical form and using them to control the movements of automated tools in the machining operations. By integrating CAD and CAM, these instructions are derived directly from the CAD data itself. A significant advantage is that all those involved in the manufacturing process, i.e. part programmers, group technologists, and machinists, can play an integral role at every stage of development.

The most efficient CAM system in the market is one that is packaged with in-house CAD software. This alleviates the problem of data transfer between these two stages. However, integrated CAD/CAM software limitations exist mainly because they are not dedicated to a sole function. For example, a CAD/CAM software may not have complete drawing tools and features that come with specialized CAD software.

However, today’s market is abundant with highly sophisticated CAD/CAM systems that offset this problem. Furthermore, CAD designs have a manufacturing limitation in terms of complexity. Complex designs sometimes may not be manufactured by a CNC system. The design tools packaged in a CAD/CAM system usually takes this issues into consideration.

The following fundamental steps have been taken in applying CAM to generate machining instructions for the CNC.

- Selecting of the Tool Plane

The tool plane defines the inclination of the tool with respect to the existing coordinate system.

- Setting up the Workpiece/Stock

Based on the geometry imported from CAD, the next step is the proper stock size/raw material selection. At this stage the coordinate system of the workpiece is also set up. This information is required to locate the workpiece with respect to the tool.

- Programming the Toolpaths

This is the most important in the product manufacturing cycle. Previously, the part programmer had to base his selection of toolpaths on the basis of expertise and experience. Now the CAM system assists him by providing a set of optimum system defined toolpaths.

- Specifying the Machining Parameters

CAM also provides the feature of defining the stock material. Based on its database of materials, CAM is able to suggest appropriate depth of cut, feed for the tool and also the spindle speed.

- Simulating the Machining Operations

CAM provides the programmer with the invaluable tool of simulation of the machining operation before going into the actual machining operation. The time taken for machining can be estimated and errors in toolpath programming may be identified. This saves both time and unwanted expenditure.

- Post-processing

The final stage involves generation of the coded instructions for the CNC operation. CAM system generates these codes automatically by the system post-processor at the end of the preceding steps.

The final post-processed part program may be copied onto a floppy disk or transmitted directly to the CNC machine through RS 232 cable.

6. CASE STUDY

Telephone model S3000 of SAPURA TELEDATA SDN. BHD., a leading Malaysian Manufacturing Company, was chosen as a prototype. The main objective of the work was to integrate the various stand-alone facilities to perform the following tasks:

- To digitize the part shape,
- To perform further modification of the part shape using the CAD,
- To generate the shape of the cavity and core mould of the handset-top casing and finally
- To come up with the part program using the CAM software for machinining of the cavity and core moulds for the identified part.

The handset-top casing of the model was firstly digitized using a Mitutoyo CMM model BH-V507. The CMM was supplied with dedicated software to aid in digitized data handling. GEOPAK was utilized to set-up the coordinate system for digitizing. SCANPAK was a utility in aiding the digitizing process. The TRANSPAK program translated the digitized data into a format readable by CAD systems. The format was selected from a database list kept by SCANPAK. From the menu, AutoCAD DXF 2D was chosen for 2-dimensional digitized points while AutoCAD DXF 3D was chosen for the 3-dimensional points. After conversion, the data was stored in a diskette.

Only half of the handset-top casing was digitized since it was symmetrical. This reduced the number of digitizing points, thus saving time and also computer memory space. Certain features such as 3D fillets were digitized in 2D projections for identification by the CAD system. The digitized shape of the Handset-top surfaces is shown in Figure 5.

The digitized data points had to be manipulated to correct any errors induced at the digitizing stage or due to data conversion and transfer (Figure 6, Figure 7).

MasterCAM Design was used to reconstruct the digitized data into surfaces and lines to represent the handset-top casing.

The core and cavity were constructed simply by subtracting the model from a rectangular block. MasterCAM Mill was used to graphically create the machining instructions. Figure 8 shows the reconstructed handset outer surface used to form the cavity mould-parting surface. Based on given tools, the optimum cutting paths and methods were selected.

MasterCAM was successfully utilized in achieving three objectives:

1. Generating the toolpaths for each stage of machining.
2. Simulating the machining process to check for any errors and to evaluate optimum cutting methods.
3. Generating the G-codes for the machine tool.

Figure 9 shows the simulated surface generated by MasterCAM Mill indicating the surface finish to be attained at the curved surfaces of the cavity.

The total simulated time for machining was 8 hours, 40 minutes, and 41 seconds. This estimate did not include set-up time.

The post-processing and machine control language used to generate the G-Code was Acramatic A2100 CNC. This post processor is machine specific, depending on the make and/or machine language of the CNC. In this case, the CNC machine was a Vickers 3-axes VMC.

The G-Code instructions were transferred to the CNC machine via the RS-232 serial communication port. This is a significant advantage over diskettes in that larger NC part program file sizes can be uploaded to the machine.

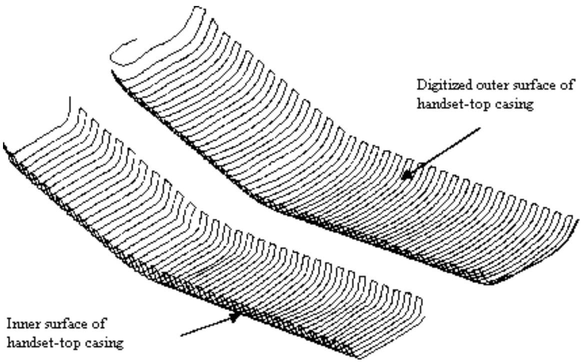


Fig. 5 Digitization of the Handset-top Surfaces

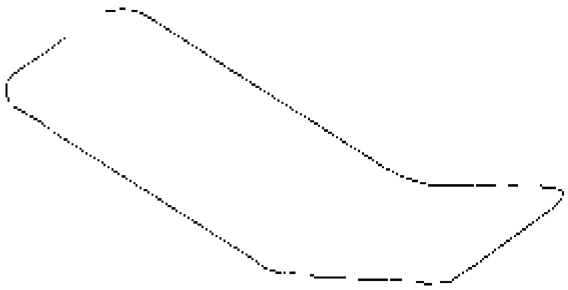
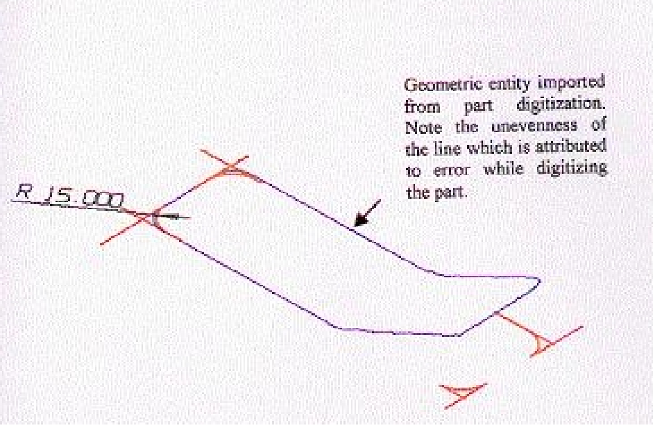


Fig. 6 Digitization of the Outline Perimeter of the Outer Surface



Geometric entity imported from part digitization. Note the unevenness of the line which is attributed to error while digitizing the part.

Fig.7 Reconstructed Outline Perimeter of the Outer Surface

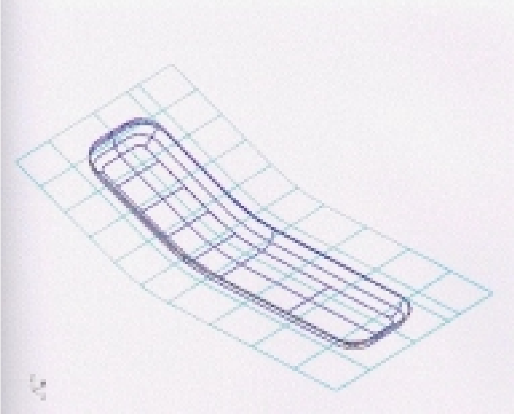


Fig.8. Reconsctructed Handset Outer Surface Used to Form the Cavity Mould Parting Surface

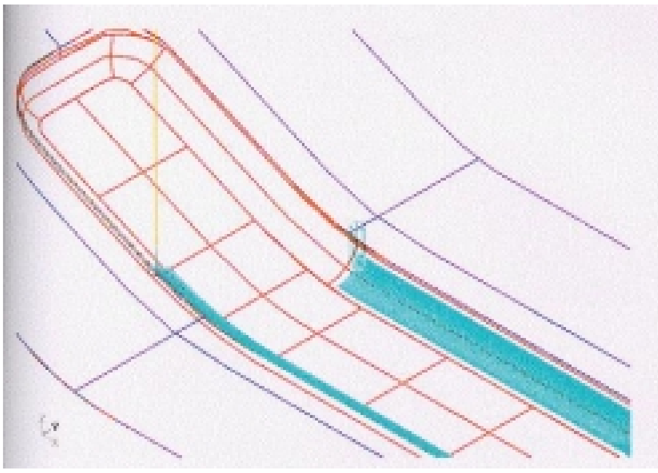


Fig.9 MasterCAM Mill Simulation Showing Surface Finish Cutting of Curved Cavity Face

7. CONCLUSION

The project was successful in achieving the following:

- A semi-automated product design and manufacturing process was set up and tested.
- The “stand-alone” machines and systems (CMM, CAD/CAM software, and the VMC) were successfully integrated into one efficient system through interfacing.
- The cavity and core for the handset-top casing model was successfully digitized, and its basic core and cavity moulds were designed and manufactured.

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