SYNCHRONIZATION OF PRODUCT DESIGN AND DEVELOPMENT FOR INCREMENTAL SHEET FORMING TECHNOLOGY (ISF)

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(Manuscript Received on October 21th, 2010, Manuscript Revised January 21st, 2011)

ABSTRACT: *Incremental Sheet Forming Technology (ISF) has been attracted many interests of researchers in recent years. The researchers have focused on many engineering aspects of ISF and found out feasible applications for many sectors of industry and domestic fields. However, to be able to apply more successfully in industry, it is necessary to build a completely digital integration for ISF process from product design to development stage. In this paper, authors propose an approach to rationalize End-to-End process for this technology which CAD-CAPP-CAM-CNC is integrated into unique environment (CATIA) by using a data exchange format (STEP). This integrated system increases the geometric accuracy of data exchange and reduce significantly the time for product design and development.*

Keywords: *ISF, incremental sheet forming,…*

1. INTRODUCTION

In small and medium production, die/mold manufacturing and design has a high rate of total product cost. Die/mold companies always seek a solution to decrease the product development time and cost which can amortize each production unit. In recent years, Incremental Sheet Forming (ISF) is an innovative approach to produce a product from sheet materials without using die/mold [1]. The die-less nature in ISF provides a competitive alternative for economically and effectively manufacturing low-medium production patch. The main advantages of ISF are dieless, short product design and development cycle and low cost which can overcome the disadvantages of such conventional approaches as deep drawing, hydro-forming stamping, etc... Thus, ISF technology offers significantly the potential application areas for aerospace industries, customized products in biomedical applications and prototyping in the automotive industry.

In recent years, there are many researches in this technology with an expectation to carry out successfully to many sectors of the practical industrial applications. The researchers focused on various aspects of ISF technology such as forming process parameters [2], ISF machine design [3], tool design [5], deforming mechanics [6], FEM analyses [4] … which contributed into acceleration of industrial applications. Nowadays, this technology has been applied successfully into many sectors such as cortical implant, prototypes in automotive industry, and domestic applications [1]. However, ISF approach is still using up the existing technologies of conventional processes. Most those applications have not yet synchronized the

End-to-End process of product design and development. To reduce the time and cost for product design and development and to emerge potential advantages by using ISF technology, is to need a completely digital integration of End-to-End process through design, planning and manufacturing stage.

This paper proposes an integrated process for ISF technology which can carry out to practical industrial applications. The integrated system uses only a data exchange format so-called STEP (Exchange of Product Model Data). This exchange format overcame the main disadvantages of IGES format, nowadays, used normally in CAD/CAM software. The data exchange between softwares usually triggers off geometric inaccuracy which is referenced in researches [7, 8]. This paper presents automatically integrating system from design, planning, FEM analyses, manufacturing and CNC connection on CATIA software. Visual Basic Application (VBA) programming language is used for integrated program which overcame about inaccuracy in data exchange and incorrespondency among software and reduce the time and cost of product design and development.

2. PRODUCT DESIGN AND DEVELOPMENT USING ISF TECHNOLOGY

In comparison with conventional sheet forming technology, the ISF technology reduces significantly product design and development time. The time for conventional process can last to a month and the quality of product does depend much on the manufacturing quality of die/mold. This technology is only to suit to large production patch which the die/mold cost can be amortized by the large number of fabricated product. ISF is dieless approach which allows a manufacturing company to be able to produces a product in a day with lowest cost. It is to suite for prototype and low and medium production patch.

The product design and development process using ISF technology is presented on Figure 1. It includes four main stages: design, planning, manufacturing, and product finishing. Firstly, customer requirements is modeled by using normal CAD system such as CATIA, Pro Engineer, AutoCAD, ..etc. The model designed with all wall angles are always less than a limited forming angle of formed material, for example, less than 67° for DC04. In additional, aspects of geometric symmetry, filleted and chamfered angle are also calculated to satisfy manufacturing conditions in ISF technology.

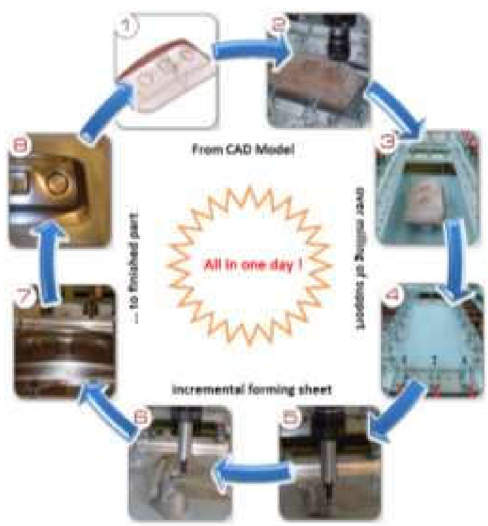


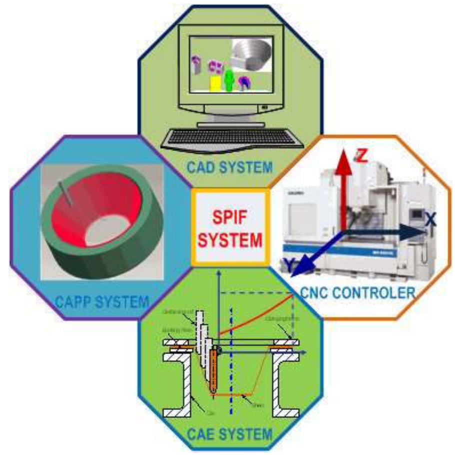
Figure 1. Process of product design for ISF technology

Secondly, the CAD model is imported into CAM software to establish manufacturing planning and generate toolpath. In recent time, most CAM systems are only available to generate spiral and zigzag toolpath. These toolpaths leave the failure trace on product surface where forming tool goes down with peak force. A spiral toolpath is converted into a helical toolpath which trigger off an equal force in three directions through machining process. In this stage, dividing into machining layer is necessary because machining principle of ISF technology is to deform material layers through step by step. It depends on experience of planning engineer, forming material, and tool radius to optimize the formability.

Next stage, material sheet is clamed firmly on CNC machine table and uses CNC program generated in previous stage. The sheet is positioned and covered a thin layer of lubrication to decrease the friction between the forming tool and sheet surface in deforming process. Finally, product is released a clamped device and cut needless parts for finishing product.

3.BASIC ELEMENTS OF ISF SYSTEM

The basic elements of ISF system include: CAD system, CAM system, CAE system, and CNC controller as shown on Figure 2. CAD system creates 3D model of product in IGES format after that is used to generate toolpath and CNC code in CAM system. CNC data is transferred to CNC controller through RS 232 serial port. The material sheet is clamped firmly on CNC machine table and is ready to turn on CNC program from CNC controller. However, analyzing deformative behavior or predicting mechanical failures and fracture occurred the deformation process by using CAE software is an important step in ISF system. This step is usually performed by using analysis model in FEM software.



CNC: Computer numerical controlled

CAD: Computer aided Design

CAM: Computer Aided Manufacture

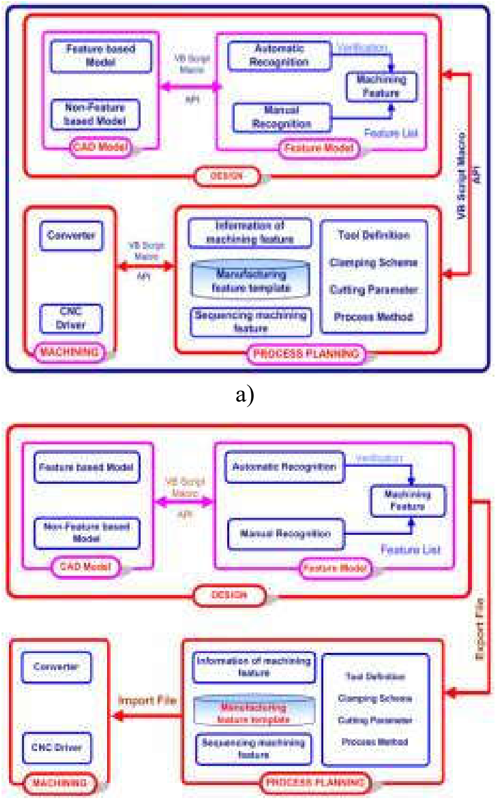
CAPP: Computer Aided Process Planning

CAE: Computer Aided Engineering

Figure 2. Basic elements of ISF technology

4.INTEGRATED SYSTEM IN CATIA ENVIRONMENT

The basic elements of ISF technology are integrated to a completely digital integration for the process from product design to development stage and CNC operation. In this study, the authors proposed two integration models for this process along with their advantages and disadvantages (Figure 3).



a)

b)

Figure 3. Digital integration models of ISF technology

In the model 1 (Figure 3a), elements are integrated relatively simple by using API function and VB macro to create the connection between them. This model is chosen in this research. Its disadvantages are the relatively low processing speed in selecting current modules; moreover the Visual Basic language operates slower than other high-level programming languages. In design stage, user can builds directly the product model in CATIA environment or imports other models from other CAD softwares under two models such as feature based model and non-feature based model. The feature based model can be interpreted directly by CATIA. However, an interpretive module is made to convert non-feature based model (or IGES format files) into feature based model in STEP format. Those features are recognized by using one of the approaches: automatic and manual approach. From here, the list of features is extracted and presented in html format file to serve for establishing design documentation and planning process.

In planning process, a module written in VBA which can support for user to plan process steps from information received feature list. This is very difficult task to make an automatic module which can performed automatic step in this stage. It is necessary to verify again by user because the module can only support partly in this task. The next task of planning process is to generate the toolpath and CNC code. This work is performed by a module which can convert automatically CL file into CNC code under two types: STEP AP 238 and G-Code. The new aspect in this study is able to generate 3D helical toolpath and simulate the tool movement which is suit for SPIF process to avoid mechanical failure in manufacturing stage. This cannot do with normal commercial CAM system in this recent time. Those CAM systems are only able to generate simple toolpaths.

The last stage, CNC code is transferred to CNC controller through a module which can interpret both STEP AP 238 and G-Code. It is connected together by RS-323B serial port which allow the technician be able to monitor the machining process from control room. This module is upgraded almost drivers of recently commercial CNC system. All of four stages (i.e. Design, Planning, Manufacturing and CNC control) are interlinked internally and controlled by VB script macro.

Another approach shown in the model 2 (Figure 3b), basic systems are not directly connected each to other, but using a temporary data file. This model is quicker in operating than the first one however its use is too complicated, as the result this option is not chosen.

Using synchronous data for all systems is the most important factor in integrating process. STEP is largely used as a data exchange format in CAD/CAM systems to increase geometric accuracy and high compatibility. Figure 4 illustrates a complete process of data exchange, in which STEP AP 203 is used for definition of geometric objects. The program decodes geometric data entered into systems that can recognize geometric features by two following ways: manual and automatic approach. The geometric features will be stored in the planning stage, in which format STEP AP 224 is used for data storage. The final step is to transfer data to CNC controller through RS 232B serial port, in this period format STEP AP 328 is used. Nowadays, STEP AP 328 can be read by most of CNC controller, but some older controllers using G-code format can lead to the difficulty in use of these systems. Authors have built a suitable data format converter from STEP AP 328 into G-code for the certain integration.

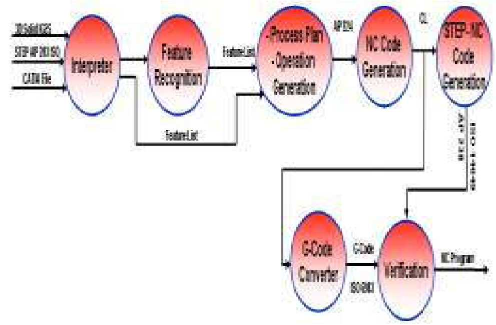


Figure 4. Data exchange scheme of integrated system

5.MAIN WINDOW DEVELOPMENT AND CONCLUSION

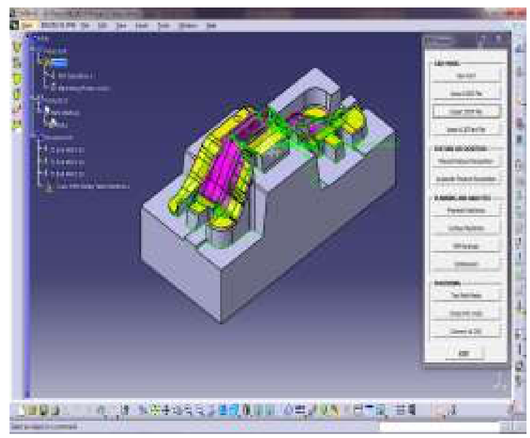


Figure 5. Main interface of integrated system in CATIA V5

All modules are integrated into unique environment CATIA by using Visual Basic language; user can order functions of the integrated systems from a button on the CATIA menu. Main table appears on the left of the window that consists all important functions for modeling, process planning, generating toolpath and connecting with CNC controller.

This is a completely digital integration for ISF process from product design to development stage. This integrated system allows limiting geometric errors and increasing the compatibility in data exchange, thus reducing significantly the time for product design and development. Engineers could have sufficiency of tools for product design and development in a unique environment. As the result, this system can bring highly economic and industrial effect, especially for making prototype, testing production and manufacture.

ĐỒNG BỘ HÓA QUÁ TRÌNH THIẾT KẾ VÀ PHÁT TRIỂN SẢN PHẨM CHO PHƯƠNG PHÁP TẠO HÌNH SẢN PHẨM KHÔNG DÙNG KHUÔN (ISF)

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TÓM TẮT: *Kỹ thuật gia công gia tăng không dùng khuôn cho vật liệu tấm (ISF) đã thu hút nhiều sự quan tâm của các nhà nghiên cứu trong vài năm gần đây. Các nghiên cứu đã tập trung hầu hết các khía cạnh kỹ thuật của ISF và được áp dụng thành công trong nhiều lĩnh vực của công nghiệp và đời sống. Tuy nhiên, để xây dựng một công nghệ hoàn hảo cho phương pháp này thì đòi hỏi một hệ thống tích hợp toàn bộ quá trình từ thiết kế sản phẩm đến hoàn thiện sản phẩm. Trong bài báo này, các tác giả đưa ra một phương án tích hợp một hệ thống đầy đủ cho việc thiết kế và phát triển sản phẩm bằng phương pháp ISF. Hệ thống tích hợp giai đoạn thiết kế CAD, lập quy trình công nghệ, lập quy trình gia công và điều khiển máy CNC trong một chuẩn dữ liệu duy nhất (STEP) và trên môi trường CATIA. Hệ thống tích hợp này cho phép giảm sai số hình học trong quá trình chuyển đổi dữ liệu và rút ngắn đáng kể thời gian phát triển sản phẩm.*

Từ khóa: *ISF, incremental sheet forming,…*

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