COMPUTER AIDED PROCESS PLANNING FOR MULTI-AXIS CNC MACHINING FIXTURE

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ABSTRACT:

This dissertation provides new methods for the general area of Computer Aided Process Planning, often referred to as CAPP. It specifically focuses on 3 challenging problems in the area of multi-axis CNC machining process using feature free polygonal CAD models.
The first research problem involves a new method for the rapid machining of Multi-Surface Parts. These types of parts typically have different requirements for each surface, for example, surface finish, accuracy, or functionality. The present paper discuss about the necessity of jigs and fixture design for multiple surfaces machining. Even though multiple axis presenting there is a need of process planning of CNC machining is required to get better results.

Keywords: *CAPP, Necessity of fixture planning, multiple surface machining.*

INTRODUCTION AND MOTIVATION

Process planning for CNC machining

In order to machine a component in a geometrically accurate and efficient manner, it is necessary to analyze the part and perform process planning for each step, setup and portion of machining code. Process planning must consider numerous attributes such as geometry, material composition (single/multiple), dimensions, tolerances, work piece geometry, clamping mechanism, available tool geometry, tool material, tool type, etc. It is also required to choose suitable machines and related parameters such as machining feed and speed. Finally, the machinist must generate an NC program for the machine such that the cutting tool follows a specific path and performs a series of cutting operations. When the machinist performs all the process planning tasks without assistance from automated systems such as computers, this planning is termed as **manual process planning** (Figure 1). Manual process planning requires considerable skill, and often consumes a large amount of time that can slow the overall production schedule and increase costs. In the past, process planning was performed manually by analyzing 2D part designs made on blue prints by experienced designers and then N C code was written. However, advances in Computer Aided Design (CAD) systems have provided an opportunity for part designers to create intricate geometric designs effectively and quickly. By the late 20th century, this led to the idea of Computer Aided Process Planning (CAPP).

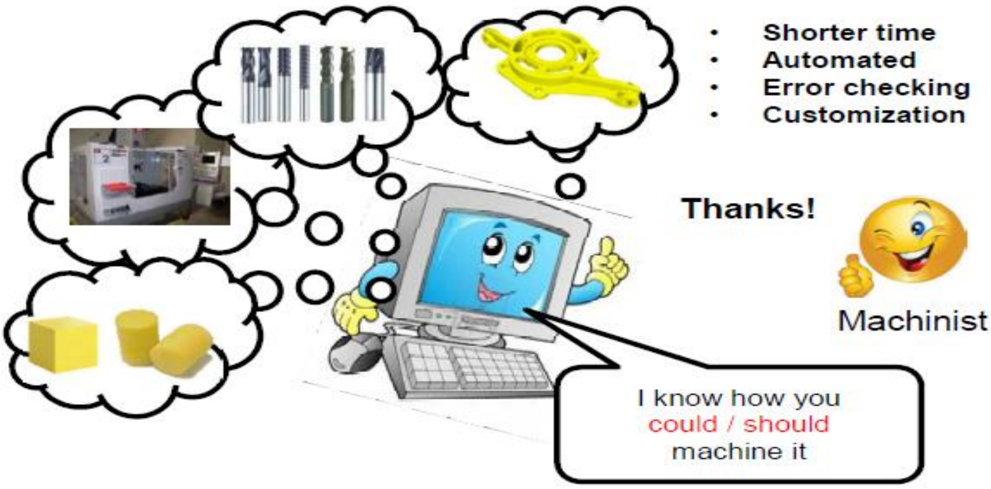

Fig. 1 shows the planning of a programmer.

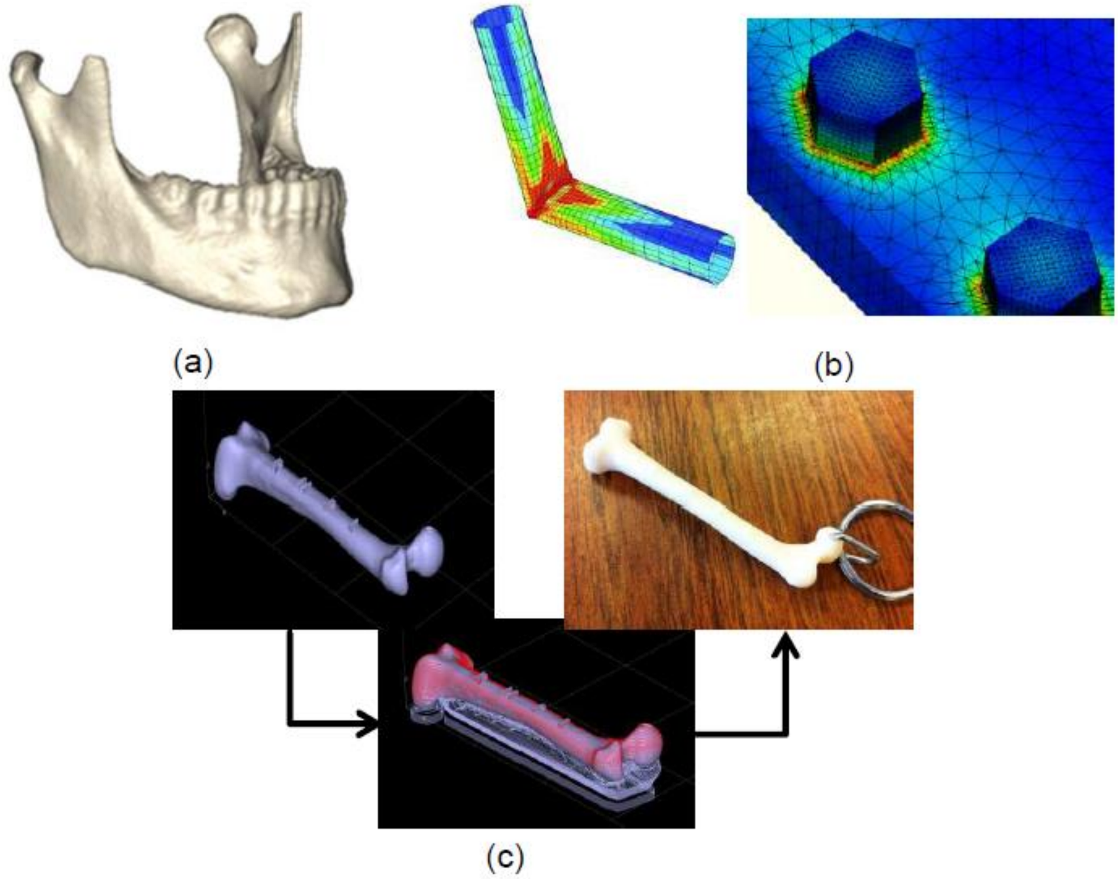

Fig .2 shows some of the complex surfaces of machining objects

Although many classifications can be used, in this work, we will categorize models as being either *feature-based* or *feature-free*. Feature based model formats are those most commonly used in the manufacturing field.

Basic Requirement of Fixture

The basic requirement of a fixture is to locate and secure the workpiece in the correct orientation and relationship so the manufacturing process can be carried out according to design specifications (Nee and Kumar 1991). A typical fixture for prismatic parts consists of three components: locators, clamps, and supporters. Locators are used to position the work piece in static equilibrium thus removing all degrees of freedom. Clamps are for holding the work piece firmly against the locators during machining for rigidity. The external cutting forces and tool direction are the major considerations. Additional support is added to reinforce the stability of the work piece. The use of these featuring elements can be determined manually or analytically. Since the work piece is subjected to the external cutting forces of machining, the three above fixture elements must make sure that the work piece is positively located, is rigid, and assures repeatability. Repeatability refers to the workpiece and subsequent workpieces can be located by the fixture in precisely the same place. This activity is considered a 'set-up' in manufacturing.

Objective

Considering the impact of Computer Aided Process Planning on manufacturing, theOverarching goal of this research is to develop new CAPP methods that would allowmulti-axis CNC machining of parts using polygonal CAD models. In order to addressthis overarching objective, this dissertation has been divided into 3 sub-objectives that will contribute to the state of the art in CAPP. The sub-objectives are as follows:

1) The first sub-objective is to develop CAPP algorithms for the rapid of machining of multi-surface Parts. The CAPP algorithms developed in this problem are demonstrated for the rapid machining of implants with preserved functionality and desired surface characteristics.

2) The second sub-objective is to develop CAPP algorithms for discrete 3-axis CNC Machining of part models using feature free polygonal CAD models.

3) The third sub-objective is to develop solutions to the problems of unique geometric situations existing on non-feature based CAD models.

Process Planning Using Various CAD Model Formats

Performing CAPP for CNC machining processes requires extensive analysis of the CAD models that are to be machined. Since the invention of Computer Aided Design, significant contributions have been made by developing various geometric formats.

These formats may have been developed for specific purposes such as Manufacturing, Engineering design, Analysis, Visualization, Reverse Engineering, Inspection etc.

Previously for the sake of manufacturing industrial parts, 2D blueprints used to be drafted by design engineers. However these 2D designs were difficult to interpret and made the overall process planning slow and costly. The development of CAD systems has made it easier for the designers to create 3D models with complicated features and surfaces satisfying complicated functionalities.

Single surface vs. Multiple Surface Parts (MSPs)

Single surface parts have same-of-a-kind property over their entire surface geometry. For example, a complete as-cast part requiring no post processing on it or a part machined from a stock with equal tolerances over the entire geometry (Figure 1.a) is a single surface part. By comparison, multiple surface parts (MSPs) may be characterized by gradual variation in characteristics throughout the surface geometry, resulting in corresponding changes in the material or mechanical properties such as surface roughness values, hardness, texture types, colour, etc. This would include part geometry that can be identified as a collection of multiple surfaces that either need fabrication or post processing using different methods.

Computer Aided Fixture Design

Over the past decade, much focus has been put on intelligent methods for computer aided fixture design to seek a technical breakthrough in embedding more design knowledge into semiautomatic or automatic CAFD systems. Table 4 shows a detailed discussion [Hui Wang et al. 2010]. Fixture design includes the identification of clamps, locators, and support points, and the selection of the corresponding fixture elements for their respective functions. There are four main stages within a fixture design process—setup planning (D1), fixture planning (D2), fixture unit design (D3) and verification (D4), as Fig. 1 illustrates [Hui Wang et al. 2010, Kang Y et al. 2003 and Boyle lain]. Setup planning determines the number of setups required to perform all the manufacturing processes, the task for each setup, e.g., the ongoing manufacturing process and work piece, orientation and position of the work piece in each setup. A setup represents the combination of processes that can be performed on the work piece by a single machine tool without having to change the position and orientation of the work piece manually. During fixture planning, the surfaces, upon which the locators and clamps must act, as well as the actual positions of the locating and clamping points on the work piece, are identified. The number and position of locating points must be such that the work piece is adequately constrained during the manufacturing process. In the third stage of fixture design, suitable units, (i.e., the locating and clamping units, together with the base plate), are generated.

Manufacturing using rapid CNC machining

The rapid CNC machining process developed at the Rapid Manufacturing & Prototyping Lab (RMPL) at Iowa State University is a fully functional rapid manufacturing process and is abbreviated as RM process throughout this paper. The RM process uses as standard 3-axis CNC milling machine with a 4th axis indexer for multiple setup orientations. This machining process includes completely automated fixture planning, tooling, and setup planning, including generation of NC code for creating a part directly from feature free CAD models.

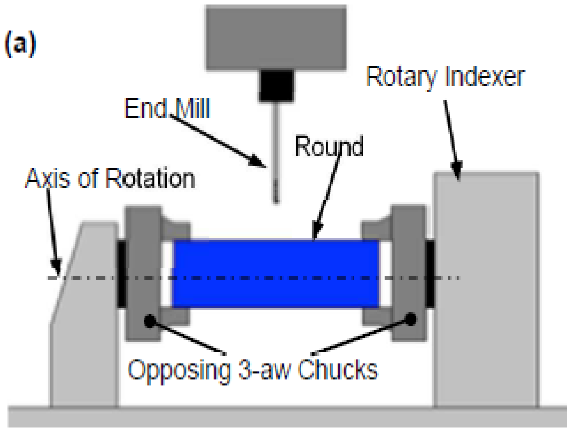

Fig shows the rotator axis of CNC 4-axis

The use of a rotation axis eliminates the need for re-clamping of the part, a common task in conventional featuring methods.

CAPP For 3-Axis Machining

The 3-axis milling configuration is a cost effective and usually preferable option; however, the lack of automated process planning systems leaves the machinist to manually determine part setups. Hence, this paper introduces algorithms that automatically determine a feasible set of orientations that could be used to machine a part. These algorithmic developments factor in **part visibility**, **tool accessibility** and **machining depths** for analyzing different candidate orientations and tool selection that could affect geometric accuracy of the machined parts as well as efficiency of machining process.

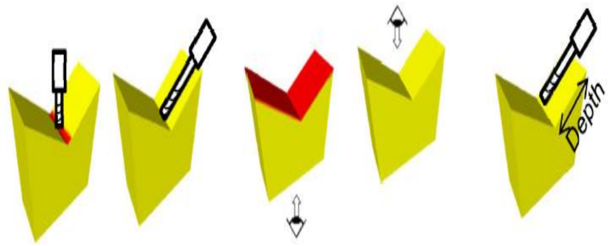

Fig shows the accuracy machining of final object

Fixture design considerations for multiple axis

Fixture Design Before designing a proper fixture, following concerns must be dealt with: "the necessity of multiple fixtures owing to workpiece geometry complexity, the number of workpieces per fixture, the determination of suitable surfaces on the workpiece for locating and clamping, and the sequence of work holding steps. The fixture configuration process would yield the following information: • Types of locators and clamps • Positions of locators and clamps • Clamping sequence and magnitudes of clamping forces The detailed designs (geometry, dimensions, and tolerances) of individual work holding elements are determined by work piece geometry, contact information (point, line, or plane contact between the locators and work piece surfaces), expected frequency of utilization (e.g., batch production versus mass manufacturing), availability of off-the-shelf standard device geometries, mode of operation (manual versus automatic), and finally conditions of manufacturing (clean-room versus machining with coolants)".

PROBLEM FORMULATION

The clamping of the work piece by using ordinary mechanical work holding devices uses single work piece for machining in each cycle. So this increase the cycle time hence decreases the productivity. Hence there was a need to design a special work holding devices. According to the specification given by the customer, about the requirement like maximum diameter of the blank, number of teeth to be cut, module, etc. The fixture is designed based on these parameters. The customer use the machine tool for batch production i.e., why the fixture is also designed in such a way that just by changing the upper half part of the fixture, the customer can switch on to other batch production with different specification and apart from this change of speed, feed by changing the gears according the requirement. The problem was to reduce the cycle time by reducing clamping and unclamping time. Since the machining should be vibration free to accurate machining, the problem has been overcome by actuating the mechanism through hydraulic cylinder. Since the machining is carried out for multiple numbers of jobs, it reduces the machining time and hence the overall manufacturing lead-time. The type of fixtures depends on the component design and type of machine used. Shaft type component require a totally different type of locating and driving arrangement compared to the disc type component with a locating bore. The type of fixture can be grouped into the following categories as: Locating mandrel and face clamping for disc types of gear blanks with controlled bore for location. Collet type of shaft type components having a controlled diameter for location and Fixture with carrier drive for shaft type components located between centres.

Complex Machining Operations

Drastically reduced cost and lead time over other methods. Especially in lower quantities or for one-off jobs Stronger, more durable parts than rapid prototyping & more representative of your finished product. Organic geometry, strength ribbing, multiple blends & radii - no problem.

CONCLUSION

Fixtures have a direct impact upon product manufacturing quality, productivity and cost, so much attention has already been paid to the research of computer aided fixture design (CAFD) and many achievements in this field have been reported. Many academic and applications papers have been published in this area. But still Fixture design needs to be tested and evaluated in real manufacturing environments and integrated with other design activities, which often are related with production resources, equipment, cost and machining processes, etc. Another important research is on the integration of various techniques directly used in computer aided fixture design. As we know, an optimal fixture solution is a hybrid result of many different considerations, such as tolerance configuration, stiffness configuration, machining process, etc. Hence attention should be paid on the establishment of a systematic way of integrating various techniques, such as Computer Aided Mass Balancing Method (CAMBM) and FEA methods for work piece-fixture system.

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