Automatic Numeric Control Programming System for Locators

ZHU Bin
School of Electromechanical Automobile Engineering
Yantai University
Yantai, P.R.C
zbtnyt@sina.com

CHAI Yong-sheng
School of Electromechanical Automobile Engineering
Yantai University
Yantai, P.R.C
chaiysh@163.com

***Abstract*—Locators are important parts for clamping and locating auto-bodies in the jigs of an automobile welding line. Their diverse shapes and number lead to the complexity of the toolpath planning for them. Thus the efficiency of the numeric control(NC) for them is important to the productivity of automobile welding lines. An automatic NC programming system for locators has been developed. Manufacturing features are automatically extracted from the design features of locators and the assembly relationships between them and other parts. Toolpaths are generated automatically using knowledge-based approach. NC code files transmission, task assignment and the monitor of machine states in workshop are achieved through the distributed numeric control(DNC) system. The key technologies of the system are studied in detail. This system has been put into the enterprise's production.**

***Keywords*—locator, numeric control programming, feature recognition, knowledge-based approach, distributed numeric control**

I. INTRODUCTION

The manufacturing of auto-bodies is a systematic engineering in the automobile manufacturing, in which the design of automobile welding lines plays a critical role. With the development of computer aided design(CAD), the virtual design and assembly technique have been used to design an automobile welding line so as to improve correctness and efficiency[1]. Locators, clamping and locating auto-body panels in an automobile welding line, belong to the category of variant parts, and their manufacturing precision affects the quality of auto-bodies directly.

The variant design of a part is in part the adjustment of its design structures and/or the modification of some of its design parameters based on its master part model, which do not breach the basic principles and geometric structure features[2]. The characteristics of variant design bring a large number of parts with similar types and different dimensions. It will take lots of time and human resources to program such parts using the interactive numeric control(NC) programming means, which fails to meet the requirement of high efficiency and low cost, so it is significant for enterprises to study a rapid NC programming system for variant parts. Reference [3] develops a rapid NC programming system by means of tabular layouts of article characteristics and similarity-based master models of products, but it is limited and unfitted for some special parts.

This research was supported by Yantai science and technology bureau under Grant 04138 and Yantai university foundation for young scholars.

This paper combines feature recognition, knowledge-based approach and distributed numeric control(DNC) technologies to develop an automatic NC programming system for locators to replace current manual NC programming means. This paper first analyzes some key technologies, and then presents the system structure. Finally an example is given to show the procedure of the operation of the system.

II. AUTOMATIC RECOGNITION OF MACHINING FEATURES

Recognition of machining features provides a bridge between CAD and computer aided manufacturing(CAM) of machined parts. The literature on feature recognition is relatively large, but there are four attractive distinct approaches: graph pattern matching, convex hull decomposition, cell-based decomposition, hint-based reasoning[4]. In a locator part, machining features include the machined faces named clamping faces and the datum face which is used to set up the NC programming coordinate system. In order to realize the automatic NC programming, the machining features must be recognized automatically, however it can not be achieved by means of the topological relationships among geometric elements in a locator using the previous approaches. In this paper, the clamping face features are extracted through the traversal of the design features and the datum face feature is recognized from the assembly relationships among the parts in a jig.

In the design of a locator, using a panel to trim the locator work piece makes the shape of the trimmed face identical to that of the panel. But concerning cost, locators are manufactured in a wire electrical discharge machine, so the shape of a clamping face is only approximately identical to the real shape of the panel. The real shape can be created using the geometric approach. The recognition of clamping faces includes following practices:

1) Traverse the assembly tree of a jig and find the locator.
2) Traverse the design feature tree of the locator to extract the trim feature.
3) Find the trimmed face from the trim feature.
4) Create the clamping face from the trimmed face, as shown in Fig.1.
5) Assign an attribute to the clamping face.

In a fig assembly, a mate constraint is formed between a locator and a washer, and it is the coplanar face in the locator that is the datum face. The recognition of a datum face includes following practices:

1) Traverse the assembly tree of a jig and find the locator.
2) Traverse all of the assembly relationships of the locator and other parts to find the mate constraint.
3) Get the coplanar face in the locator.
4) Assign an attribute to the face.

The NC programming system has been integrated with the bill of material software system, in which each part has its own attribute by which the locator can be recognized. In addition, because the design and the NC programming of a locator is respectively in different computers, an attribute is assigned to the machining feature so that it will not be lost in the following NC programming procedure.

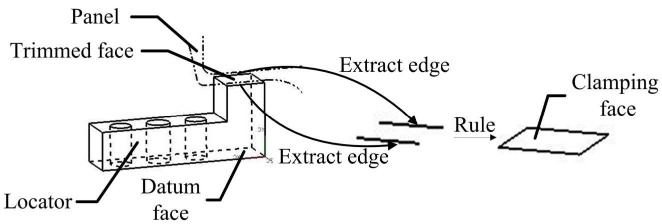

Figure 1. Formation of the clamping face.

III. AUTOMATIC GENERATION OF TOOLPATHS BASED ON KNOWLEDGE

Toolpaths differ from each other greatly due to the different shapes of locators. Besides the toolpath for a clamping face, there are other toolpaths which do not really remove materials and just guide the tool properly to move to or leave the clamping face, and generally are parallel to *X* axis or *Y* axis, as shown in Fig.2. The style and number of this kind of toolpaths depend on designers, and planning for them accounts for a large portion in the entire programming procedure, so the automatic generation of toolpaths is critical to the automatic NC programming for locators.

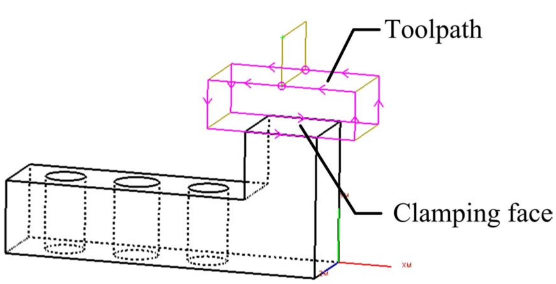

Figure 2. Toolpaths for the locator.

In this paper the knowledge-based approach is used to generate toolpaths automatically, which can greatly improve the scalability and flexibility of the system. A sample rule for the generation of the toolpath between two adjacent clamping faces with a normal vector approximately parallel to *Y* axis is shown as follows:

IF the angle between V_{f1} and V_{f2} less than α
AND the angle between V_{f1} and Y axis less than α
THEN $T = \{ T_{f1\_e\_l}, T_y, T_x, T_y, T_{f2\_e\_r} \}$

where *f1* and *f2* are the two adjacent faces, V_{f1} and V_{f2} are the normal vector to *f1* and the normal vector to *f2* respectively, α is the upper limit of the angle between V_{f1} and V_{f2}, T represents the toolpath, $T_{f1\_e\_l}$ and $T_{f2\_e\_r}$ extend *f1* to left and *f2* to right respectively, T_x and T_y create a plane parallel to *X* axis and *Y* axis respectively.

The system provides basic actions to generate the corresponding basic toolpaths. For example, T_x generates a toolpath parallel to *X* axis and T_y generates a toolpath parallel to *Y* axis. Complex and needed toolpaths can be achieved using the combination of such basic actions. Currently, the knowledge base includes the following rules:

- Rules for the generation of toolpaths between lead in point and cut beginning point.
- Rules for the generation of toolpaths between lead out point and cut ending point.
- Rules for the generation of toolpaths between two adjacent clamping faces.
- Rules for the generation of toolpaths for clamping faces
- Rules for the extension of clamping faces.

The knowledge base is developed with the knowledge fusion(KF) language within the UG user environment, which is an interpretative object-oriented engineering language, with which engineering rules and object models in the UG system can be combined together to create needed geometric solids, so that changing rules can drive the change of the solids automatically[5].

IV. DISTRIBUTED NUMERIC CONTROL SYSTEM

Transmitting manufacturing files to machines is critical to a mass-customization oriented system, which is realized by means of DNC. “Manufacturing islands”, NC machines, are connected to enterprise’s information system using computer network communication technologies to unify the management of manufacturing information and equipments. Various kinds of DNC modes have been presented[6][7]. In this study, a practical and cost-efficient DNC mode based on client/server structure has been implemented in terms of the characteristics of the NC programming for locators and the condition of the enterprise, as shown in Fig.3.

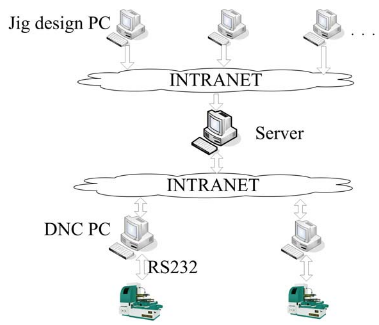

Figure 3. Distributed numeric control mode.

All of PCs and the server are connected through the intranet. The design of a jig and the NC programming for locators in the jig are carried out respectively in different computers.

The server runs the automatic NC programming system. After the server accepts a locator part file, it will automatically generate a corresponding NC code file for it and then inquire the NC machine in the idle state, which the file will be sent to.

A DNC PC controls and monitors a machine through a RS232 interface. The main functions of DNC PCs can be described by the following:

- Monitor the working state of machines and report it to the server.
- Transmit NC code files to machines.

V. SYSTEM STRUCTURE

An automatic NC programming system for locators, as shown in Fig.4., has been implemented based on the previous description, in which the function of feature recognition is developed using UG application programming interfaces, embedded in the UG system and runs in the PCs for designing jigs, and other modules of the system as an independent software platform operate in the server. All of data are managed using the oracle database system.

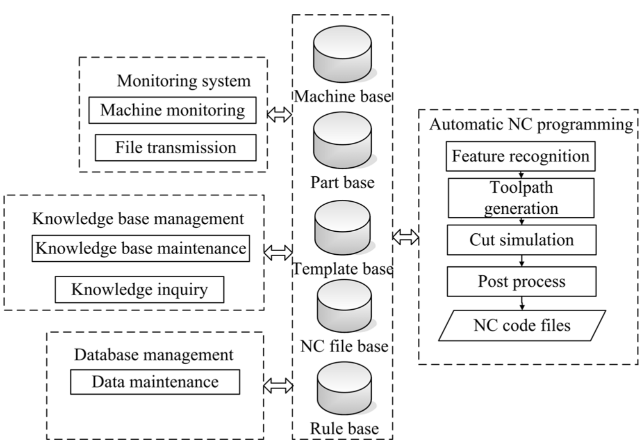

Figure 4. System structure.

The system can be divided into four modules: database management module, knowledge base management module, automatic NC programming module, monitoring module. Their main functions are shown in Fig.4. All of process parameters, including wire diameter, upper plane, lower plane, plunge speed, cut increment, etc., are saved in the template base. Proper process parameters will be selected to generate NC codes according to the geometric data of locators and their toolpaths.

VI. EXAMPLE

Fig.5 shows the automatically generated toolpath of a locator with two clamping faces. The basic sequence of the manufacturing can be described by the following:

1) A designer designs the jig, the clamping faces and the datum face of the locator are recognized using the software embedded in UG for feature recognition and then the locator part file is transmitted to the server.

2) The software system in the server automatically carries out the NC programming for the locator and generates the corresponding NC code file and then transmits it to the DNC PC connected to an idle machine.

3) The DNC PC transmits the file to the machine to manufacture the locator.

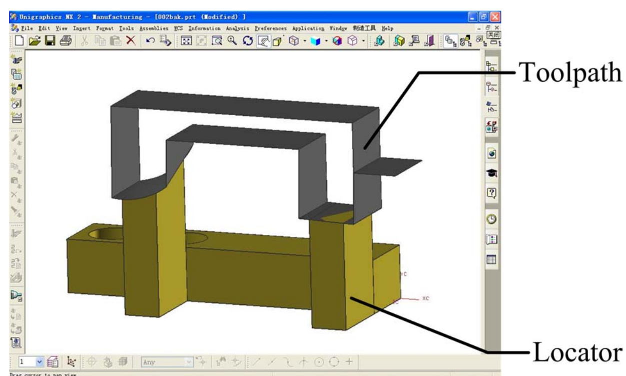

Figure 5. Sample toolpaths generated automatically.

VII. CONCLUSION

An automatic NC programming system for locators in an automobile welding line has been implemented based on the feature recognition and knowledge-based approach. Together with the DNC system, it can dramatically reduce the manufacturing cycle of locators. In addition, the mode of this manufacturing system has also been applied to another kind of important parts, bases, in an automobile welding line and works well.

ACKNOWLEDGMENT

The authors wish to thank Wooshin Ltd. for many helpful suggestions. This research was supported by Yantai science and technology bureau under Grant 04138 and Yantai university foundation for young scholars.

REFERENCES

[1] XIONG Xiao-ping, LI Chun-zhi, JIN Quan-dong. “The design of body welding Line based on the virtual manufacturing & assembling environment,” New Technology & New Process, pp. 2-4, March 2004.

[2] QI Guo-ning, SCHTTNER J, GU Xin-jian, et al. “A mc-oriented producted product modeling method,” Computer Integrated Manufacturing Systems, vol. 8, pp. 13-16, January 2002.

[3] FANG Shu-ling, WU Sheng-yong, LI Qiang. “Rapid NC programming system for variant parts,” Computer Integrated Manufacturing Systems, vol. 12, pp. 13-16, October 2002.

[4] JunHyun Han, “Survey of feature research,” Technical Reports, IRIS-96-346, Institute for Robotics and Intelligent Systems, University of Southern California, 1996.

[5] ZHAO Bo. “Machinery product design based on KBE,” Machine Design, vol. 21, pp. 7-9, June 2004.

[6] ZHANG Xu-mei, LIU Fei, DAN Bin. “The study on the workshop operating mode based on integrated DNC technology,” China Mechanical Engineering, vol. 10, pp. 321-323, March 1999.

[7] XU Xiang-bin, ZHOU Xin-jian, FANG Shui-liang. “Computer aided manufacturing system oriented to mass customization,” Computer Integrated Manufacturing Systems, vol. 13, pp. 704-710, April 2007.