Object-oriented design support system for machine tools

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This paper deals with an object-oriented intelligent design support system which is intended to assist in the basic design of machine tools, in particular machining centres. The machine tools design process is analysed through interviews with experienced designers, and an object-oriented model is established to represent the design process. Software modules named design objects are proposed, which are basic components for the implementation of an intelligent design support system for machine tools. A prototype of the design support system for machining centres is developed based on the design objects, and some case studies are carried out to verify the effectiveness of the methods proposed.

Keywords: Object-oriented, design support system, machine tools, design process, design object

1. Introduction

Presently, various types of machine tools are required to cope with the small-batch manufacture of a wide variety of products. It is therefore necessary to establish a design support system which can assist the designers of machine tools, in the logical and systematic design of various types of machine tools. The machine tools design process is a very complicated decision-making process which requires the know-how of experienced designers. It is, therefore, very important to develop an intelligent design support system for the machine tools which utilizes the know-how of the experienced designers effectively.

There are various intelligent CAD systems and expert systems to carry out 'routine' design of machine products in which the structures of the products are fixed and the standard methods for designing various parts are known. Brown and Chandrasekaran have developed the AIRCYL system which assists the design of various air cylinders (Brown et al., 1986). Mittal et al. (1986) have proposed the PRIDE system which designs paper-handling systems. The products dealt with in these cases are mainly the components of products, and their structural configurations are almost fixed.

This paper deals with the design of machine tools, especially machining centres, which are typical examples of complicated machine products. The machine tools have various structural configurations to cope with the wide range of machining functions. Some research on the design of machine tools has already been carried out. Systematic methods have been proposed in order to develop basic design systems for machine tools based on analysis of the shape generation process (Salje and Redeker, 1980; Iwata et al., 1990). Some structural design systems have also been developed, which deal with the design of basic structures of modular type machine tools (Shinno and Ito, 1984; Shinno and Ito, 1986). A knowledge based system has been developed to determine the types of machining centres from the functional requirements (Moriwaki and Nunobiki, 1990). However, most of the systems deal mainly with design problems in which the design parameters of the machine tools are predetermined at the beginning of the design stage.

The objective of the present research is to develop an intelligent design support system which assists the basic design of machine tools, in particular machining centres. The design process of machine tools is analysed through interviews with experienced designers, and an object-oriented model is established to represent the design process. Software modules, named design objects, are proposed, which are basic components for the implementation of an intelligent design support system for
machine tools. A prototype design support system for the machining centres is developed based on the design objects, and some case studies are carried out to verify the effectiveness of the methods proposed here.

2. Object-oriented design process model for machine tools

2.1. Analysis of design process

The machine tools design problem is recognized as an ill-structured problem, since the design parameters of the machine tools cannot be clarified without information concerning the configurations of the machine tools. The following are clarified through interviews with experienced designers, taking the machining centres as examples of machine tools to be designed:

(1) The designers first select a suitable machining centre configuration based on the requirements;

(2) Two methods are applied to select a suitable configuration: specialization of the configurations and division of the configuration into the components;

(3) When a suitable configuration is selected, the design parameters to be determined are clarified. These parameters can be determined systematically and logically based on the requirements.

The machining centres design process is represented by a series of phases, each of which consists of two steps, selection and design, as shown in Fig. 1. In the figure, the machine products are the objects to be designed. The machine products include such objects as the machines, units, components and parts, which should be designed. All the machine products are called products, hereafter. Each step may be described as follows:

STEP 1: selection of a suitable type of product

A suitable configuration of the product is selected based on the requirements of the product. When a particular configuration is selected, a set of design parameters of the product is given.

STEP 2: design of selected type of product

The product is designed by determining all the design parameters of the selected type of product based on the requirements.

Steps 1 and 2 are repeated until the geometric and technological information on the products is determined.

2.2. Design process model with design objects

Software modules named design objects are proposed here to carry out the design of individual types of products, such as machining centres and components of machining centres. The individual design objects have one-to-one correspondence with the individual types of products. The design objects are equivalent to the class objects in the object-oriented paradigm. The design objects represent the information and processes concerning the design parameters of the individual products to be designed. The products include both the machining centres and their components, such as spindle units, ATC (automatic tool changer) units and feed units. The tasks of the design objects are to determine the design parameters of the products to be designed and to select suitable design objects for the products to be activated in the next design phase.

Figure 2 shows an example of the design process model expressed by design objects. The classification schema shown here is obtained through interviews with experienced designers of conventional machining centres. In the figure, the ellipses represent the design objects, which are connected by a set of generalization-specialization links. The design object for the machining centre is first activated by a message to start the design process. The design object determines the parameters of the machining centre and generates its instance, which is represented by a box in the figure. Following this, the design object for the machining centre tries to select a design object in order to specialize the instance. In the case of Fig. 2, the design object for the vertical machining centre is selected to determine the detailed design parameters of the instance.

Thus, the selection of a suitable design object is equivalent to the selection of a specialized type of product, and the design of a selected type of product is...