A Method of Computer-aided Design for Machine Center

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Abstract. This paper studies the conceptual design of MC (machining center), and the main findings are as follows: The RW (representative workpiece) is the data source of designing an MC. The mechanical matrix of an MC can be figured out by the requirement arising from NC manufacturing of the RW, in which the layout of an MC matrix is constructed with the FPCNMT (functional parts consisting of an NC machine tool). In any CAD system, the design jobs of an MC’s layout involve three different fields. The first work deals with the preconstruction of the feature-model repository of FPCNMT, and the methods of building the repository are introduced by the author. The second design issue focuses on the construction of the mechanical matrix of an MC, in which the writer presents assembling the matrix by calling the FPCNMT based on the PP of a RW. The last job involves correctness and optimum of the layout design of the MC.

Keywords. FPCNMT, RW, Data source of designing MC, designing MC based on RW.

1. Introduction
Every kind of CNC machine tool consists of all sorts of functional module (functional parts/assembly) such as spindle, linear guideway, ball screw, CNC turret/saddle tool magazine, CNC manipulator/turntable (rotational worktable), servo system, measure plus feedback system, and safety protection devices. These functional parts are selected to be integrated in the machine frame (machine bed and column) to form an MC (machining center) to satisfy the specific production requirement [1-3]. An available developing method is proposed by the author: The FMR (feature-model repository) of all sorts of functional parts consisting of an NC machine tool (FPCNMT) can be created in a CAD (computer-aided design) package firstly [4-5]; The layout of an MC (machining center) can be created by calling of the FPCNMT from the repository based on the production job of a RW (representative workpiece) secondly; Lastly the NVMS (NC verification manufacturing system) is created following the NMS (NC manufacturing system) in CAD, and the validity of the designed MC can be confirmed by the Post-NC verification.

2. Create the FMR of FPCNMT in CAD Package

2.1. A Survey of FPCNMT
The performance parameters and interface structure-dimensions of FPCNMT are the important issues when the layout of a CNC machine tool is considered. These parameters and dimensions should be the primary/retrieval variables during the creation of an FMR of FPCNMT. The inner detailed formation of a FPCNMT is reasonably calculated.
This paper focuses on the mechanical functional parts performing all kinds of motions in an MC. These mechanical functional parts are selected to execute the primary and feeding motions based on the NC manufacturing requirement arising from the PP of a RW [6-7].

As shown in figure 1-2, these are a series of linear guideways. The interfacing dimensions are as follows: dimension of assembly (H, H₁ and N), dimension of block (W, B, ...), and dimension of roll (Wᵣ, Hᵣ, ...). The performance parameters are as follows: allowable static moments—Mᵢ (Pitching), Mᵧ (Yawing), and MR (Rolling).

As shown in figure 3-4, these are a series of ball screws. The interfacing dimensions are as follows: screw size-OD (outside diameter), lead, ball dia., and dimension of flange-A\T\W. The performance parameters are as follows: basic rate load-dynamic and static axial load.
Figure 5. Motor spindle.

Figure 6. The connection dimensions.

Figure 7. The feature-type repository of a guideway-pair.

Figure 8. The feature-type repository of a motor-spindle.

Figure 5 shows the series of motor spindles, and the interfacing dimensions are shown in figure 6. The performance parameters include rated torque/power/speeds.

Taking the guide way, ball screw and motor spindle as examples, the methods of creating the FMR of FPCNMT in CAD package are presented in the next section 2.2.

2.2. The Method for Creating the FMR of FPCNMT

There are three kinds of methods used to create the FMR of FPCNMT: a) the feature-mode of a FPCNMT is created as single component very similar to the FMR of bearing in CAD package, in which each element in a FPCNMT is just the local geometric-feature of that FPCNMT. At this point the FMR of FPCNMT can be created with the technology of ‘Typical Part (TP)’, and the details will be discussed in section 2.2.1. b) The FMR is created according the physical constitution of FPCNMT. Here, the technology of ‘Typical Assembly (TA)’ will be applied to establish the FMR of FPCNMT, and this technique will be expatiated in section 2.2.2. c) The FMR of FPCNMT is created with hybrid way, in which the methods of a) and b) are synthesized to setup the FMR. Section 2.2.3 will involve such means.

2.2.1. The FMR is Created as Single Component. At this point, the inner construction of a FPCNMT is neglected, and the three-dimensional structure/size and the interfacing dimensions of a FPCNMT are the focuses. The FMR created with this way have the precise geometric and topologic features in appearance while the non-geometric features such as materials, element and assembly information do not need to be added in.

The FPCNMT with full-scale configuration can be viewed as the ‘Typical Part (TP)’, and the
spreadsheet can be used to driven the feature model of the TP and to further create the FMR [6, 8]. The interfacing-dimensions or the structure-dimensions can be used as the retrieval parameters of the FMR when calling the FPCNMT. Some examples of FMR are shown in figure 7-8.

2.2.2. The FMR be Created According the Physical Construction of a FPCNMT. From the perspective of the constitutions of parts, a FPCNMT consists of a large numbers of standard elements (the bolt, the nut, etc.) and a small amount of dedicated components (the envelope), in which, the features of a FPCNMT are the arithmetic sum (accumulation/stacking) of the geometric and non-geometric feature of each element; from the interrelation point of view, the features of a FPCNMT involve all kinds of relations among different levels of elements such as, the type of assembly constrain, configurative characteristics of elements (the numbers of elements, appearing or disappearing of elements), hierarchical relation, the type of kinematic-pair, etc.

![Figure 9. The driven spreadsheet for the NC worktable.](image)

![Figure 10. The feature-model of an NC worktable.](image)

![Figure 11. The combined feature-model of a motor-spindle.](image)

The stacking of the geometric and non-geometric feature of each element will directly compose the total features of a FPCNMT. The relations among different levels of elements can be introduced with a spreadsheet to drive the FPCNMT, in which the FPCNMT will become a ‘Serial Assembly’ that is the base of FMR. The correlation among the elements of FPCNMT is named and is further designated to a cell in the spreadsheet, in which the interrelationship among elements of a FPCNMT can be driven by cell-data/formula such as the feature variables, the equations, suppress/non-suppress (option from a dropdown list), appear/disappear (option from a dropdown list), numbers of elements, etc. Some FPCNMTs driven by a spreadsheet are shown in figure 9-10.

2.2.3. The FMR of FPCNMT be Created with Hybrid Way. The components that are relatively stationary within a FPCNMT can be treated as one element to be feature-modeled; the components that have relatively movement within a FPCNMT should be feature-modeled individually by their actual engineering information (geometric and non-geometric features). An example of FMR is shown in figure 11.

3. The Configuration Design of an MC Based on a RW

3.1. Introduction to RW

From 2-axis NC lathe to multi-axis MC, the job-scope of an NC machine tool is of great different. As the high-end manufacturing equipment, its main function involves in the cutting of all types of
workpieces. Among all kinds of workpieces to be fabricated, there must be a kind of workpiece that possesses the shared characteristics and collective needs to be processed. The integrated processes of the workpiece can be satisfied by one manufacturing equipment in one setup. This kind of workpiece is defined as the ‘representative workpiece (RW)’ by the writer.

The NC machine tool meeting the process demand of the RW can transact most of the production problem occurred during fabricating some types of components. In order to satisfy specific production task and to keep enough flexibility, the initial design of an MC should begin with the RW, namely, the original data source of designing MC comes from the RW tooling with an appropriate fixture [8].

3.2. The Configuration Method of MC Based on RW

The special process considerations of a RW are the bases of choosing the dedicated type of FPCNMT. The process tasks are mainly performed by an MC, in which the subsystems such as the CNC, the servo, the mechanical matrix, etc. run according to the PP of a RW. The dedicated operations are finished by the motional parts of an MC. The movements in machining consist of primary motion and feed motion. There are two kinds of parts for executing the primary motion: the common spindle (passive spindle) with gear transmission (or plus some time-belt driving subsystem) and the advanced motor-spindle (active spindle) what is just one of the FPCNMTs. The parts for carrying out the feed motion can achieve each kind of axis-movement including the translational motion and rotational motion: the executor of a translational motion consists of such FPCNMT as motor (step-motor or servo-motor, and linear-motor), ball-screw pair, linear guide-way, etc., the actuator for a rotational motion consists of such FPCNMT as turning worktable, moment motor, and so on. The initial configuration of an MC can be created after the selection of these basic FPCNMTs.

4. Verification to the MC based on NVMS

The relative moving connections among the subassemblies are extremely complex and cannot be manually calculated in advance. The verification technology of NC manufacturing can be applied to transact this problem.

In NC manufacturing verification, an NVMS should be setup firstly. An NVMS consists of the NC machine tool (including its attached CNC), the fixture, the cutting tool, and the workpiece (RW). The processing job of an NC operation is fulfilled in the NVMS. The designer can operate each element of an MC under the NVMS; the whole NC operation of the RW can be completely observed. As the executor of NC processing, the MC and its configuration can be diagnosed and improved [9-11].

5. Conclusion

The modularized FPCNMTs compose each functional-subassembly of a complicated MC. During the design of an MC, the FMR of the FPCNMT should be created in CAD package firstly in order to be called in by the designer. The writer summarized out three kinds of methods for building the FMR of FPCNMT in CAD software.

The RW can be used as a data-source of design for an MC. During the computer-aided MC design, the RW is set as the top-node on the feature-model tree within a CAD package, in which the derived feature-mode of an MC matrix is of flexible and can follow the changing of the RW.

The comprehensive simulation to the NC manufacturing PP of the RW can be executed in the NVMS. The design defect can be found quickly and efficiently. The conceptual design to the MC can be modified and updated with the help of bidirectional feedback between the CAD and the Post-NC verification.

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