Kinematics Simulation Modeling and Implementation of Cnc Machine Tool Based on Fuzzy Extension Analytic Hierarchy Process

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Keywords: Cnc Machine Tool, Fuzzy Analytic Hierarchy Process, Fuzzy Complementary Judgment Matrix

Abstract: the Choice of Cnc Machine Tools is a Multi-Level, Multi-Factor and Quantitative and Qualitative Indicators Coexisting. Considering the Ambiguity of Decision-Makers' Decision-Making, a Solution to Multi-Objective Decision-Making Problem Based on Fuzzy Ahp is Proposed. in Order to Quantitatively Evaluate the Remanufacturing of Electromechanical Products, an Index System and Mathematical Model for Remanufacturing Evaluation of Electromechanical Products Are Constructed. This Method Determines the Weighting Coefficients of All Levels of Evaluation Indicators and Ranks Them by Extension Analytic Hierarchy Process. Substituting Specific Values to Establish a Judgment Matrix Solves the Problem That the Subjective Judgment Ambiguity is Ignored, and the Matrix Naturally Obeys the Consistency Condition. on This Basis, the Fuzzy Comprehensive Evaluation Method is Adopted to Make a Scientific and Reasonable Evaluation of the Remanufacturability of Electromechanical Products.

1. Introduction

Cnc Machine Tools Are Highly Mechatronic Products and Are an Expensive and Sophisticated Equipment. At the Same Time, It is Also the Main Body of Parts Processing. It Affects the Productivity, Processing Quality, Production Cost and Energy Consumption of Parts, Consumption of Auxiliary Materials (Such as Cutting Fluid, Etc.), Noise, Safety and Hygiene, Recycling of Chips, and Generation of Waste Liquid. Big [1]. a Cnc Machine Tool Generally Contains Multiple Indicators, and These Indicators Are Often Contradictory and Mutually Constrained. Focusing on Different Goals, Different Choices Will Be Made. Therefore, When Selecting Cnc Machine Tools, We Must Comprehensively Consider Various Indicators, and We Must Not Blindly Pursue Advanced Nature. We Must Combine Our Own Needs and Optimize the Use of Existing Cnc Machine Tools [2]. However, Because These Indicators Have the Characteristics of Both Quantitative and Qualitative Factors, There is Uncertainty, and It is Suitable to Use Ahp to Determine the Weight of Each Indicator. Analytic Hierarchy Process (Ahp) is a Combination of Qualitative and Quantitative Analysis, Systematic and Hierarchical Analysis Method Proposed by the Famous American Operations Researcher Professor Saaty in the Mid-1970s [3]. However, the Traditional Analytic Hierarchy Process Has Obvious Shortcomings. the Judgment Matrix Has No Elasticity, That is, When Constructing the Judgment Matrix, the Ambiguity of the Evaluator's Thinking is Not Considered. Fuzzy Analytic Hierarchy Process (Ahp) is a Theoretical Method That Combines Fuzzy Theory with Analytic Hierarchy Process and Fully Considers the Fuzziness of Human Thinking [4]. in This Paper, Fuzzy Analytic Hierarchy Process (Ahp) is Applied to Each Index, and the Weight Coefficient of Each Index is Determined by Establishing a Fuzzy Hierarchical Structure Model and a Judgment Matrix.in Essence, Cnc Machine Tools Are a Numerical Control System to Control the Movement Axes of Machine Tools.

The Movement to Achieve the Relative Motion between the Workpiece and the Tool, Thus Completing the Space Mechanism of the Cutting Process. Kinematics Modeling and Solving of Cnc Machine Tools is the Basis for Machine Tool Movement. for Example, Cnc Programming Post Processing, Machining Precision Control, Feed Speed Control and Machine Geometry Error Compensation Must Use the Kinematics Model of the Machine Tool. to Realize the Virtual Machining of Cnc Machine Tools, It is Necessary to Establish a Kinematics Model of the Cnc

  DOI: 10.25236/ISMHI.2019.050

Machine Tool in the Virtual Environment, That is, to Analyze and Model the Motion and Dynamic Behavior of the Machine Components during the Machining Process. Otherwise, Virtual Machining Has No Meaning. for the Kinematics Modeling of Machine Tools, Modeling Methods Such as Trigonometric Method, Error Matrix Method, Quadratic Relation Model Method, Mechanism Modeling Method and Rigid Body Kinematics Method Have Appeared Successively. These Methods Are Often Used to Solve the Motion of Specific Cnc Machine Tools. Solving, for Different Cnc Machine Tools, Professional Technicians Are Required to Re-Establish the Geometrical Solution Model of Machine Tool Kinematics According to the Specific Structure of the Machine Tool. It Lacks Versatility and It is Difficult to Form a Fixed Product Module, Which Seriously Restricts the Widespread Promotion and Use of Error Compensation Technology. and It is Difficult to Adapt to the Continuous Development of the Machine Structure. At the Same Time, the Kinematic Geometric Modeling Method Described Above is Not Universal and Cannot Satisfy the Kinematics Modeling of Various Cnc Machine Tools. Based on This, the Paper Firstly Establishes a Virtual Three-Axis Cnc Machine Tool.

2. Overview of the Development of Kinematics Modeling Theory

Kinematics is the motion geometry, so the kinematics modeling of CNC machine tools is the motion geometry modeling. It involves the spatial relationship between the components of the CNC machine tool and the relationship and transmission of parameters between the components of the CNC system. At present, medium and low-grade CNC machine tools are still widely used in most manufacturing enterprises in China. With the development of production, the machining accuracy of these machine tools needs to be further improved. The above kinematic geometric modeling method is often used to solve the problem of solving the motion geometry of a specific CNC machine tool. For different CNC machine tools, professional technicians need to re-establish the machine tool geometry geometric solution model according to the specific structure of the machine tool. Due to lack of versatility, it is difficult to The formation of fixed product modules severely restricts the widespread promotion and use of error compensation technology. In the field of error compensation research, many scholars have begun to study the effects of thermodynamic factors and processing environment factors on machine tool processing errors. Most of these studies use finite element and thermoelastic theory analysis methods [5]. Although the above research has achieved remarkable results in the error compensation of machine-specific motion systems, such as the spindle slip system, it is still difficult to determine the boundary conditions and joint parameters for the machine tool.

2.1 Classification of Kinematic Modeling Methods

This paper mainly studies the establishment of mathematical models of kinematics and dynamics of the system, so the classification of system modeling methods is only introduced from the perspective of kinematics and dynamics modeling. For kinematics modeling techniques, modeling methods such as error matrix method, quadratic relation model method, mechanism modeling method, rigid body kinematics method and multi-body system modeling method developed in recent years have emerged. The error matrix method began in 1977, mainly using vector representation to establish the spatial error model. The quadratic relational model method emerged in 1986 is an analytical quadratic model based on rigid body kinematics and small angle error hypothesis. Because these two methods appear earlier, the modeling is complicated, the solution is cumbersome and time-consuming, and several modeling methods developed later are relatively simple and easy to solve, so these two methods have been gradually eliminated, so this is not introduced here. Two methods, the following briefly introduces the institutional modeling method, the rigid body kinematics method and the multi-body system modeling method.

2.2 Institutional Modeling Method

The institutional modeling method is a method of describing the system from the perspective of organization and mathematically modeling the characteristics of the system. In institutional science, institutions are the basic units that make up the system. The relationship between subsystems is transformed into the connection between the institutions and the institutions through the movements. The complex poles are transformed by means of dismantling, dismantling, and even dismantling the kinematic chain. It is a simple rod group to simplify the motion analysis and force analysis of the mechanism; using the theory of graph theory to transform the mechanism into a matrix symbol mark, using computer recognition methods to classify and select the mechanism; using the key map method of the mechanism structure to determine the mechanism Degree of freedom and redundancy. To study the types of mechanism structure that meet the requirements of topological structure, such as the structure type synthesis method with single open chain as the basic unit, the structure type synthesis method with loop as the unit, etc., using the topological map and its matrix representation, the two types of structure are integrated. The method can be automatically generated by a computer. Therefore, the modeling problem of the system research feature becomes the establishment of the mathematical relationship between the mechanical feature position or the institutional variable [6]. The homogeneous coordinate matrix method uses the homogeneous coordinate representation of points to provide a matrix operation formula for converting point sets between coordinate systems.

2.3 Rigid Body Kinematics Modeling Method

The basic object of rigid body kinematics modeling is mainly rigid body systems, so this modeling method has certain limitations. The rigid body system is a continuous system composed of rigid bodies. The so-called rigid body refers to an object that does not deform under the action of force. The characteristic is that the distance between any two points inside remains unchanged. The rigid body is an idealized system model, and the actual object will produce different degrees of deformation under the action of force. However, the deformation of many objects is very small, and it has no major effect on the balance of the research object. It can be omitted, which can greatly simplify the problem [4]. The rigid body motion modeling method is to use the mature rigid body kinematics knowledge, mainly the D'Alembert-Lagrangian principle, to mathematically model the rigid body system. The model formula established by the rigid body kinematics modeling method is simple and tidy, and the concept is clear, but relatively speaking, the redundant information in the model is more and the calculation is more complicated, so its utilization is relatively less.

2.4 Multibody System Modeling

A multibody system is a complete abstract and efficient description of a general complex mechanical system. It is the optimal model for analyzing and studying complex mechanical systems. A complex mechanical system in which a plurality of rigid or flexible bodies are connected in some form can be extracted into a multi-body system by abstraction. Multi-body system theory includes multi-body system kinematics theory and multi-body system dynamics theory. The core of multi-body system theory is the description of the relationship between multi-body system topology and the description of kinematics or dynamics. The theoretical basis of multi-body system error motion analysis is multi-body system kinematics theory. The basic principle is to describe the relationship between multi-body system topological structures by low-order array method, and to establish generalized coordinate system on multi-body system topology.

2.5 Cnc Machine Tool Dynamics Modeling Theory

The structural dynamics modeling of CNC machine tools is the basis for dynamic analysis and dynamic design of CNC machine tools. Only by establishing a dynamic model that can accurately represent the dynamic characteristics of the actual machine tool structure and facilitate analysis and calculation, it is possible to carry out detailed analysis and calculation of the dynamic performance of the CNC machine tool to achieve the intended goals of dynamic analysis and dynamic design. At present, the most common models in the dynamic modeling of machine tools are: concentrated parameter model, distributed mass model and finite element model. The lumped parameter model replaces the mass of the structure with a concentrated mass dispersed at a finite number of appropriate points. The elasticity of the structure is replaced by some equivalent elastic beams without mass. The damping of the structure is assumed to be hysteretic structural damping, and the joint is simplified. It is a concentrated equivalent elastic element and damping element. However, this method is relatively rough and it is impossible to approximate the dynamic characteristics of the structure. Therefore, a distributed mass model has been proposed to consider the component as a uniform mass distribution.

3. Fuzzy Analytic Hierarchy Process

The key to the analytic hierarchy process is to establish a judgment matrix. Whether the established judgment matrix is scientific and reasonable directly affects the effect of the analytic hierarchy process [6]. The following describes how to establish a fuzzy complementary judgment matrix, a fuzzy mutual complement judgment matrix weight calculation method and a fuzzy complementary judgment matrix consistency judgment method.

3.1 Hierarchical Single Sorting Weight

According to the relative important values between the various factors given by the judgment matrix, the weight of each index in its judgment matrix is calculated. The specific calculation step is [3]:

(1)Multiply matrix elements by rows

$$Mi = \prod_{j=1}^{n} a_{ij}, i = 1, 2, \cdots, n \tag{1}$$

(2)Calculate the weight value

$$Wi = \frac{Mi}{\sum_{j=1}^{n} Mj}, i = 1, 2, \cdots, n \tag{2}$$

The weights of B1, B2, and B3 can be calculated by the judgment matrix A, that is, the weights of the quality attributes, economic attributes, and environmental attributes in the criterion layer can be determined for the motion attributes of the target layer CNC machine tool, and then the calculated weight vectors are respectively filled in table, the weight vectors of the three criterion factors for the target layer are obtained. Similarly, the weight vectors of the judgment matrices B1, B2, and B3 are calculated, and the results are filled in the table.

3.2 Consistency Test of Judgment Matrix

In order to scientifically reflect the relative importance of each indicator, after obtaining the weight vector of the judgment matrix, it is necessary to test the consistency of its validity. The specific test steps are as follows [4]:

(1) Multiply the judgment matrix by its corresponding weight vector.

(2) Calculate the largest eigenvalue of the judgment matrix.

(3) Calculate the consistency index CI and the selected average random consistency indicator RI, see the corresponding values given in Table 1.

$$\text{Where } CI = \frac{\lambda \max * n}{n-1} \tag{3}$$

(4) Calculate the consistency indicator ratio:

$$CR = \frac{CI}{RI} \tag{4}$$

(5) According to the CR value, determine whether the judgment matrix passes the consistency test:

Table 1 Conformance Test Evaluation Form

CR	Result
CR=0	Completely satisfactory consistency
CR<0·1	With satisfactory consistency,
CR>0·1	Need to re-evaluate relative importance until CR<0.1 is satisfied

By calculation, the CR values of the judgment matrices A, B1, B2, and B3 are all less than 0.1, which have satisfactory consistency. It is concluded that they are all effective matrices, and the values of λmax, CI, and CR are filled in Table 2.

3.3 Hierarchical Total Ordering

According to the various indicators in the optimal numerical control machine tool equipment selection model hierarchy diagram, please consult the two experts who have been engaged in the development, application and research of CNC machine tools for the quality attributes and economic attributes according to the principles of scales from 0.1 to 0.9. The environmental attributes and the human-machine attributes are compared and judged (Table 2), and the weighted fuzzy complementary judgment matrix is obtained. Based on the calculation results of single-level sorting at each level, the weights of the three criterion indicators and factor indicators relative to the total target can be obtained. The calculation results are filled in Table 2, and the index system of CNC machine tool equipment selection is constructed.

Table 2 the Index System of Cnc Machine Tool Equipment .

Index layer	Sub-layer	Sub-index weight	Index weight	index weight of the total weight
Economic attributes	0.29	Equipment cost	0.41	0.10
		Production costs	0.28	0.07
		Maintenance costs	0.32	0.08
Environmental attributes	0.21	Noise pollution	0.45	0.09
		Man-machine property	0.55	0.11
Quality attribute	0.28	Dimensional accuracy	0.35	0.10
		Shape accuracy	0.35	0.10
		Roughness	0.30	0.08
Man-machine attribute	0.22	Comfort	0.30	0.08
		Safety	0.33	0.08
		Maintainability	0.37	0.08

4. Conclusion

This paper proposes a method to evaluate the exercise ability of CNC machine tools by using the combination of analytic hierarchy process and fuzzy comprehensive evaluation. Based on this method, it can overcome the deficiencies of the traditional analytic hierarchy process in solving the fuzzy problem of expert experience judgment and the consistency of judgment matrix, effectively avoiding a lot of trial calculation work in traditional analysis method, and can reasonably calculate the degree of motion of CNC machine tools. Introducing the extension theory, constructing the extension judgment matrix by using the interval number instead of the point value, so that the evaluation result is more reasonable. The practical application shows that the method is practical, reliable, convenient and reasonable. From the environment, energy, resources, economy, man-machine and technical indicators and more than 10 sub-indicators, the numerical control machine tool degree evaluation index system and the hierarchical relationship were established. The weighting judgment matrix of the same level evaluation index is constructed by the expert scoring method, and the weights of each level evaluation index are calculated. At the same time, the membership degree of the index is calculated. The fuzzy comprehensive evaluation method is used to comprehensively evaluate each evaluation index. Finally, the evaluation indexes of each index are respectively evaluated.The method is simple and clear, easy to implement by computer programming, and has great practicability.

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