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The Modeling Realization of Virtual Assembly Precision Preanalysis Method

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Abstract

The detection of assembly precision is the key to ensure the quality and performance of assembly, and it plays a very important role in assembly production. With the increasing status of virtual assembly technology in industry, the importance of virtual assembly precision detection is increasing. This paper focuses on the content of assembly precision pre-analysis in virtual environment and designs the method of pre-analysis through simulation.

Keywords

Virtual assembly; Assembly precision monitoring; Virtual precision preanalysis; modeling.

1. Introduction

Virtual assembly technology is based on product virtual disassembling technology implementation, in the interactive virtual assembly environment, users are using all kinds of interactive devices (data glove/position tracker, mouse/keyboard, force feedback operating equipment, etc.) like in the real environment of products of spare parts for all kinds of assembly simulation of the operation, the operating system to provide real-time collision detection, in the process of assembly sequence, assembly path and constraint processing processing, and other functions, so that users can carry on the analysis for assembling of the product, to verify this product parts assembly sequence and planning, to the assembly operation personnel training, etc. After the assembly (or disassembly) is completed, the system can record all the information of the assembly process and generate the review report for subsequent analysis. Since the mid-1990s, virtual assembly technology has made great progress after more than a decade of development. Virtual assembly technology can analyze, predict and verify the assemblability, disassembly and maintainability of products, as well as the assembly precision and assembly performance in the assembly process without physical samples. It also supports the dynamic simulation, planning and optimization of the assembly process oriented to the production site, so as to effectively reduce the number of physical assembly in the process of product development, and improve the one-time success rate and assembly quality of product assembly. Due to the good application prospect of virtual assembly technology, a large number of virtual assembly research institutions have been set up in succession in the world, and related basic application technology research has been carried out. A number of virtual assembly systems have been established and successfully applied in enterprises, achieving good results.

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2. Preanalysis of Assembly Precision in Virtual Environment

Product development usually includes two processes: the design stage and the assembly stage, and the virtual assembly, as the simulation of the actual assembly process, also includes these two processes. According to the preanalysis of assembly precision in virtual environment, the design and analysis methods usually start from these two aspects.

2.1. Virtual Precision Pre-analysis in Design Stage

The virtual assembly precision pre-analysis in the product design stage is the process of obtaining the part size processing requirements, which is mainly divided into three stages: tolerance allocation, product tolerance analysis and verification, and product oriented precision correction.[1]

2.1.1. Tolerance Allocation Stage

The main task of the tolerance allocation stage is to stipulate the economic and reasonable tolerance of each component ring under the guarantee of product assembly technology. The content of tolerance allocation is known as closed ring tolerance, according to certain methods and constraints, the optimization of the distribution of the tolerance of each component ring, also known as tolerance design or tolerance synthesis. Tolerance analysis refers to the tolerance of each component ring in the known size chain and the analysis of whether the closed ring tolerance meets the predetermined accuracy requirements.

The traditional tolerance allocation has two different methods[1]: the first method is the extreme value method, which considers that the tolerance of the closed ring is the sum of the tolerance of each component ring, which inevitably leads to the relatively tight tolerance of each component ring, resulting in the unnecessary high cost. Another method is from the point of view of statistics, according to the distribution of machining size, using probability theory, to determine the tolerance. Extreme value method has been less used due to its insurmountable disadvantage, and now the tolerance allocation is basically based on the second method. Mitchell and Siddall proposed a "vector space" method for tolerance synthesis. Parkson proposed statistical tolerance allocation from the perspective of statistical tolerance, while l. anchal and s. aman et al. proposed a rule-based tolerance allocation method.

2.1.2. Product Tolerance Analysis Verification Phase

The main task of this phase is, according to the actual machining error distribution of component size, simulated by monte carlo approach size value, using virtual reality technology, simulate the tolerance design, the assembly process of the actual product, the product of tolerance design verification, analysis of the current design scheme, the fitting precision of nonconforming product distribution rule, the proportion of nonconforming product and assembly precision, etc.

2.1.3. Assembly Accuracy Correction Phase

The main tasks in this phase can be redistributed to product tolerances for different situations: in the actual processing of the product can not meet the design size tolerance requirements; Due to the adjustment or change of processing technology, the products obtained do not meet the requirements of the current tolerance design.

Product tolerance allocation, assembly precision verification and assembly precision optimization are all for the pre-analysis of virtual assembly precision in the design stage. In chapter 3, a modeling approach is presented around these two techniques.

2.2. Virtual Precision Pre-analysis in Assembly Stage

The virtual precision pre-analysis in the assembly stage is the process of simulating the actual assembly precision according to the measured dimensions of the product. It is mainly divided

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into two stages: prediction of product assembly precision and prediction of actual product precision.[2]

2.2.1. Product Assembly Precision Prediction Section

The main task of product assembly precision prediction is to simulate the actual product in virtual environment, analyze the influence of various factors on the product assembly precision in the product assembly process, and calculate the evaluation index of the assembly precision according to the different product batches.

2.2.2. Assembly Precision Optimization for Actual Products

The pre-analysis of assembly precision in the assembly stage is mainly aimed at the prediction of the assembly precision of the measured size products and the optimization of the assembly precision for the actual products. After the prediction and optimization of the product assembly precision, the results of precision prediction and precision optimization are used to guide the assembly workers in the field assembly, and the problems related to the assembly precision in the virtual assembly and the actual assembly are stored in the database together with their solutions to accumulate knowledge and experience. The above methods provide data support for the design, processing and assembly of parts in engineering practice, so as to shorten the development period, improve the average assembly precision and the success rate of a single assembly, and improve the level of assembly site management[2]. Through the unified data model and database, the system centralizes the management of the intermediate data and process information in the design, processing and assembly stages, and stores all the design experience and data in the database to realize the reuse of knowledge.

3. Assembly Precision Modeling Technology in Virtual Environment

3.1. Virtual Assembly Modeling based on Physical Attributes

Virtual assembly modeling technology based on physical attributes mainly refers to the construction of the same or similar virtual prototype physical model with the actual product, and the intuitive analysis of the impact of factors such as assembly deformation and assembly force on the product assembly quality in the virtual environment, so as to solve the physical simulation problems such as movement and force of virtual prototype under various working conditions. At present, product physical attribute modeling and assembly process simulation based on physical attribute in virtual environment are one of the bottlenecks affecting the practical application of virtual assembly technology, and also one of the key factors to solve the problem of "imitation but not true" of virtual assembly technology. At the same time, the establishment of product precision model in virtual environment is also the premise of virtual assembly with tolerance.

At present, most of the research achievements on computer-aided tolerance analysis and synthesis at home and abroad are based on commercial CAD software (such as CA TIA, UG, etc.) to develop tolerance analysis and optimization modules[3].

The research model of virtual assembly technology based on physical attributes is divided into three levels: attribute modeling, behavior modeling and engineering application. Attribute modeling layer mainly includes component physical attribute modeling and basic physical attribute calculation. The basic physical properties of parts include material, mass, center of mass, moment of inertia, velocity, acceleration, momentum, force, torque, temperature and contact surface characteristics. The calculation of the basic physical attributes includes the calculation and determination method of the basic physical attributes of the parts, including the calculation of the moment of inertia of the parts, the calculation of the center of gravity and other physical attributes, so as to lay the data foundation for the

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simulation and analysis of the physical properties of the assembly process in the whole virtual environment.

Behavior modeling layer refers to the technique of zero part behavior modeling involved in virtual assembly simulation. product

In the process of assembly, there will be contact and movement between parts, which will cause deformation and generate interaction force. Part behavior modeling is to study how the physical properties of the product during assembly affect the assembly behavior. Behavior modeling mainly includes contact modeling, steady-state analysis, collision detection, dynamic response, etc. Contact modeling is to use contact mechanics knowledge to study the contact behavior of parts. Stability analysis refers to the real-time determination of whether the assembly state can be in a stable state during the assembly process, and the analysis of the interaction between parts in a stable state; Collision detection and dynamic response include the collision detection algorithm between parts and other parts and the environment in the assembly process, and the response is based on the collision detection results. The authenticity of the simulation process is the important basis for the assembly feasibility analysis and tool space detection. The engineering application layer mainly combines virtual assembly based on physical attributes with actual engineering conditions to solve problems in practical engineering, including assembly simulation, assemblability analysis, assembly performance analysis, man-machine efficiency analysis, etc. The simulation of assembly process based on physical attributes is to calculate the assembly force and assembly characteristics of parts in real time according to the physical attributes of parts. The assembly process simulation based on physical attributes can overcome the unreality of the assembly process simulation based on geometry and simulate the actual assembly process very truly. During the assembly process, due to the consideration of the physical properties of parts (such as its own gravity and the behavior of friction and collision with other parts), the virtual assembly system will calculate and analyze according to the gravity, friction and collision conditions, and feedback the force and collision information to the operator in real time through the sensing device[3].

3.2. Tolerance Modeling

The product tolerance model in virtual environment needs small amount of data and fast calculation, and requires the coexistence of geometric information, topological information, tolerance information and product precision information. Because the product tolerance model needs to unify the model of the whole development process, detailed engineering semantic information is needed. According to the above requirements, the product tolerance mixing model can be used in the tolerance modeling. The main information includes surface information, product geometry information, precise geometry information, product precision information and engineering semantic information.

The model structure can be designed as follows: the virtual entity class derives the assembly component class and the geometric element class; The assembly component class is derived from the assembly class, assembly tool class, assembly fixture class and part class. Wherein, the assembly class is self-contained (that is, the assembly contains sub-assemblies) and contains part classes, as well as assembly dimensional tolerance information and assembly dimensional chain information of the assembly. The part class contains the information of geometric elements, dimensional tolerance and geometric tolerance. The geometric elements are derived from the cylindrical surface, plane, sphere, etc., including the surface roughness information of the geometric surface. The assembly dimension chain class contains several dimensional tolerance and shape tolerance information which exist as closed loop and component loop. The geometric precision class contains geometric precision annotation information and corresponds to one of one. Through this kind of structure, the geometric

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precision and its annotation are well managed, and the relation between geometric precision annotation and geometric precision information is realized, which provides a foundation for the management of geometric precision annotation. In the current dimension chain analysis process, the assembly dimension chain information is mainly obtained by the designer analyzing the two-dimensional drawings of the product to obtain the product assembly dimension chain. The accuracy of this method is mainly determined by the designer's design experience and level. On the other hand, the research on automatic generation algorithm of size chain mainly includes graph theory method and noise-driven method [4].

4. Conclusion

The rapid development of assembly industry in the world will inevitably promote the application of virtual assembly technology. In this context, this paper expounds the method of virtual assembly precision pre-analysis, and designs and implements these technologies by means of simulation modeling, hoping to provide new ideas for the development of virtual assembly technology.

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