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Research on Space Cam Automation Design and Manufacturing Scheme Based on CAD and CAM Systems

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Abstract: The aim of this study is to realize the fast and accurate design and manufacture of spatial CAM by introducing CAD/CAM system. By using Pro/ENGINEER software widely used in CAD/CAM system, the follower displacement curve is quickly and accurately drawn according to the curve equation of the motion specification of the spatial CAM follower, and the 3D model of the spatial CAM is created according to the curve by Pro/Feature module. Then, the contour surface quality of the spatial CAM is checked by surface analysis, and the detection results are fed back to the modeling design of the spatial CAM. After analyzing the machining theory of the spatial CAM, according to the theory and the modeling completed in the Pro/Manufacture module, the NC machining code of the spatial CAM is automatically programmed. Based on the feedback data of the surface inspection information, the design and manufacturing process of the spatial CAM are continuously optimized. Therefore, the created contour surface has high precision, excellent kinematic and dynamic characteristics. This research provides an effective method and scheme for the automatic design and manufacture of space CAM.

1. Introduction

The spatial CAM mechanism [1] is a core component of automation equipment such as automatic assembly machinery, machine tools, printing presses, internal combustion engines and textile machines, and is highly regarded for its excellent kinematic and dynamic characteristics. However, achieving accurate manufacturing of spatial cams has always been one of the challenges facing the manufacturing industry. The complexity of its lift curve often leads to the failure of traditional machining methods to meet the requirements of high precision and complex shape, which further affects the performance and stability of the mechanism [2]. In response to this problem, many researchers began to explore innovative design and manufacturing methods.

In this context, the introduction of CAD/CAM systems is seen as a revolutionary solution. With the help of commercial software such as Pro/ENGINEER, the researchers have developed interactive CAD/CAM systems that integrate design and manufacturing, providing a more efficient and controllable approach to the design and manufacturing of spatial cams. Compared with traditional methods, CAD/CAM system can draw complex curves and surfaces more accurately, and realize accurate 3D modeling of spatial CAM, thus significantly improving the accuracy and efficiency of processing.

This paper aims to deeply discuss the design and manufacture of spatial CAM automation based on CAD/CAM system. Through a comprehensive analysis of the challenges and existing technologies in the manufacturing of spatial convex wheels, we will propose a series of comprehensive solutions aimed at continuously optimizing the manufacturing quality and performance of spatial cams, contributing new ideas and methods to the development of modern manufacturing.

2. Relevant Research

The application of CAD/CAM technology in modern manufacturing industry is deepening, especially the new functions and advantages of Edgecam 2021 and Tebis 4.1. Dodok T [3] and Popov D [4] focused on Edgecam 2021 and a new CAD/CAM system, respectively. Dodok T's research covers the identification of automatic generation turning processes and the application of experimental NC strategies, while Popov D's system uses geometric function representation (FRep), which simplifies the design flow of additive manufacturing, allowing for the rapid creation of structures with desired characteristics. In addition, the Tebis 4.1 [5] system provides highly automated tooling, model design, programming, and manufacturing functions, reducing processing time and improving safety. In addition, studies by Siddanna GD [6] found that polishing CAD/CAM elastic ceramic and composite restorations creates smooth surfaces and is of clinical importance. Cioca Lii [7] used AHP and TOPSIS methods to evaluate the safety of CNC machining workshops and selected the safest CNC machining workshops. At the same time, Lee CY [8] proposed a new parameter optimization algorithm of CNC interpolator, which used the simulation model to reduce the difference between the program path and the actual trajectory of the part, so as to achieve high-precision machining. The closed-loop dynamics of CNC machine tools are described by modeling feed drive model and control algorithm, and the parameters of CNC interpolator are optimized by simulating genetic algorithm to improve machining accuracy. These research results provide an important reference for the application of CAD/CAM system and process optimization.

3. Methodology

3.1 Overview of the Proposed CAD/ CAM-based Approach

When modeling and designing spatial CAM, it is very important to ensure that the contour of the CAM is accurate. The accuracy of the contour directly depends on the motion specifications of the follower. In order to ensure the accuracy of the contour, the displacement curve of the follower must be accurately drawn. Using the graphical commands in Pro/ENGINEER software, we can accurately plot the displacement curve of the spatial CAM follower according to the curve equation of the motion specification, and generate the contour of the CAM through the variable section scan command.

When forming the CAM profile, we use the displacement curve of the follower as the reference. By combining the reference diagram and the trajectory diagram, we can precisely control the variation of the section parameters and adjust the contour shape of the CAM. In general, this relationship can be expressed as:

$$Sd\# = \mathrm{evalgraph}(\mathrm{graph.name}, x.value) \quad (1)$$

Sd# indicates the parameter to be changed, and # indicates the dimension number. 'evalgraph' is the function name, 'graph.name' represents the name of the base graph, and 'x.vue' represents the scan distance.

3.2 3D Modeling Capability for Spatial CAM

Taking a common cylindrical CAM as an example, the CAM blank is first created under the Pro/Feature module and the shape of the curve is controlled by entering the curve equation using the "slave equation" option inserted into the reference curve. The motion laws of different cams are different, so different motion curve equations are required. Pro/ENGINEER allows the input of any curve equation that meets the requirements, and can automatically draw the curve that meets the equation. Subsequently, the drawn equation curves are saved in IGES format for future use.

When drawing the reference graph, the equation curve file saved in IGES format is retrieved by using the method of data coming from file. When drawing a curve, ensure that the marked height and Angle at the beginning and end of the curve are equal to ensure the smooth transition of the contour surface and avoid the impact of the CAM mechanism. The horizontal coordinate value of the reference figure can be controlled by 360 degrees of a week, or by the circumference of a week. Once the baseline is drawn, use the variable profile scanning tool under Pro/ENGINEER to create contour features. In this process, the reference graph is loaded onto the section size to be changed, and then the dimension number in the section is converted into a number using the relationship to achieve the size adjustment. For example, by relation $sd3 = evalgraph("cam", trajpar * 360)$ control the size of scanning Angle, including trajpar function is equivalent to a variable, the range of 0 ~ 1, It changes linearly during scanning. At this point, the CAD model of the cylindrical CAM is completed.

Because of the complexity of geometric design, differential geometry and transformation tensor are often used as tools for modeling the contour of spatial indexing CAM. Taking cylindrical indexing CAM as an example, four sets of right-handed rectangular coordinate systems are established on the CAM mechanism, and the surface equations of the CAM working profile are converted to the corresponding coordinate systems by rotation transformation and translation transformation. Through the above steps, the mathematical model of the spatial indexing CAM can be obtained, and its complex geometric shape can be accurately described.

3.3 NC Machining Programming and Simulation Characteristics

In modern manufacturing, CNC machining technology [9] plays a crucial role, especially in improving product processing accuracy and production efficiency. According to the machining requirements of spatial CAM, the use of CNC machine tools for machining has become the mainstream trend. CNC machine tools can effectively solve the problem of machining accuracy and efficiency, but the programming of CNC machining is still challenging. For simple CAM contour curve, such as the combination of straight line and arc, it can be processed by manual programming. However, for spatial CAM with complex contour curve, manual programming is very tedious and error-prone.

With the continuous development of CAD/CAM technology, it has become possible to automatically generate CNC machining programs. Using CAD/CAM system, we can create contour surface modeling based on CAM motion law, and automatically generate corresponding CNC machining program. In actual machining, we can replace the corresponding shape and size of the cutter with the roller model, so that the relative motion relationship between the cutter and the CAM is consistent with the relative motion relationship between the roller and the CAM, and then the cylindrical CAM can be machined to meet the design requirements. The core steps of NC machining programming include manufacturing model, manufacturing setup, tool path generation, simulation machining and post-processing. In the manufacturing model stage, we need to assemble the solid model with the blank model, and define the working machine tools, tools, fixtures and other parameters required for machining parts. In the tool path generation stage, we verify the correctness of the program by generating the tool path and demonstrating the path. In the simulation processing stage, NC detection and overcut detection modules are used to simulate the processing scenario. To ensure the accuracy and safety of the processing process. Finally, the tool position file is converted into NC program by post processing module to realize the automation of NC machining. The application of these steps greatly improves the precision and production efficiency of spatial CAM processing, and provides a strong support for the development of manufacturing industry.

4. Case Study or Experimental Setup

In order to deeply explore the design and manufacture of spatial CAM automation based on CAD/CAM system, we conducted a series of case studies or experimental Settings to verify the effectiveness and feasibility of the system in practical applications.

First, we choose a common spatial CAM, cylindrical CAM as an example, as the research object. In the process of CAM CAD modeling, we use C language for CAM design, calculation and data processing, and combine AUTOLISP language for 3D drawing and dynamic demonstration. This comprehensive use of C language and AUTOLISP language method can give full play to the CAD software drawing advantages and high-level language scientific calculation and data analysis advantages. After the completion of CAD modeling, we carried out the experimental setting of CNC machining programming. Through the NC programming in Pro/E environment, we connected the manufacturing model with the CNC machine, and selected a four-axis CNC milling machine for processing. When determining the machining zero point of the cylindrical CAM, we place it on the intersection line between one end face of the cylindrical CAM and the outer contour surface, and ensure that the manufacturing coordinate system is consistent with the machine coordinate system. When generating the tool path and simulation machining, we need to create a cylindrical surface that is coaxial with the CAM as the tool retreat surface to ensure the tool rotates around the CAM. By considering roughing, CAM size, material and other factors, we set the spindle speed, cutter feed and other parameters, and realized the CNC machining programming of cylindrical CAM.

In the course of the experiment, we also use AUTOCAD software to calculate and simulate the CAM contour surface dynamically. AUTOCAD has powerful drawing and editing functions, and AUTOLISP language further expands the graphics processing function, so that we can realize various functions by defining functions, and operate the graphics. Through the combination of these tools, we can more intuitively observe and analyze the CAM design and machining process. Through the above case studies or experimental Settings, we will deeply explore the feasibility and advantages of the CAD/CAM system based spatial CAM automatic design and manufacturing scheme, to provide a reliable experimental basis for future research and application.

5. Conclusion

Based on CAD/CAM system, this paper explores the automatic design and manufacturing scheme of spatial CAM, and obtains a series of important results. Firstly, we successfully designed a complex, precise and changeable spatial CAM mechanism by using CAD/CAM software system such as Pro/E, and generated the corresponding NC machining program through the system. This process greatly improves the efficiency and accuracy of spatial CAM design and manufacturing, and pushes the related technology to a new height.

In the research, we deeply discuss the motion law of the spatial indexing CAM and its contour surface design, and deduce the corresponding mathematical model. By establishing CAD software system and making full use of its powerful functions, we use C language for CAM design, calculation and data processing, and AUTOLISP language for 3D drawing and dynamic demonstration. Our research team has accumulated rich experience in the Institute of Automation, Shandong University of Technology, and has successfully designed, calculated, drawn and processed cylindrical indexing CAM, globe-shaped indexing CAM, parallel indexing CAM and other mechanisms, which has laid a solid foundation for the integrated CAD/CAM application of spatial indexing CAM.

This study provides in-depth theoretical exploration and practical experience for the design and manufacture of spatial CAM automation based on CAD/CAM system, and provides useful reference and support for the development and application of related fields. In the future, we will continue to deepen the research, further improve the design and manufacturing technology of spatial CAM, and promote its wide application and promotion in the engineering field.

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