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Adaptive Control of CNC Machine Tool Cutting Process Based on Artificial Brain-Computer Interface Technology

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Abstract:In this paper, an intelligent adaptive CNC system is developed based on the artificial brain-computer interface to realize the intelligent adaptive control of the cutting process of CNC machine tools and improve the cutting efficiency. The test results of intelligent adaptive control of the CNC milling process with the fuzzy controller show that the intelligent adaptive CNC system has good performance, can improve the intelligent level and adaptive ability of the CNC machine tool in the cutting process, and improve its cutting efficiency Through MATLAB/SIMULINK, the machine tool cutting process models under three conditions of closed-loop, open-loop and model reference adaptive control were simulated respectively, and the cutting performance was improved by 7.1%.

Keywords: Adaptive Control, CNC Machine, Cutting Process, Brain-Computer Interface

1. INTRODUCTION

The usual CNC machine tools have a low ability to recognize and deal with unpredictable, fuzzy and uncertain situations in the cutting process. In order to avoid or reduce the abnormalities that may occur due to the inability to deal with these situations, more conservative cutting is generally used in actual machining. Parameter, which is not conducive to give full play to the processing potential of CNC machine tools and improve cutting efficiency. Therefore, it is necessary to enhance the ability of CNC machine tools to recognize and deal with these situations, and to improve its adaptability and intelligence level in the cutting process. For this reason, adaptive control technology can be applied to the control of the cutting process, so that the CNC machine tool has the ability to adaptively adjust the cutting parameters in real time according to the processing conditions, so as to ensure the stable and normal operation of the system and a certain processing quality. Give full play to its processing potential, improve cutting efficiency, and protect cutting tools [1-6].

In the process of CNC machine tools, there are many unstable factors, mainly because it is a dynamic process, for example, the type and wear of the tool will have an important impact on the efficiency and quality of the machining, in order to ensure the cutting process The quality of work requires a comprehensive grasp of these elements to ensure the overall benefits of the enterprise. In order to ensure the efficiency of cutting work, the adaptive control method came into being. The use of this method in the actual work process can guarantee the quality of related processing work and effectively realize the optimal allocation of resources in the industry. As one of the important methods to improve the processing accuracy, efficiency and automation of CNC machine tools, adaptive control technology can self-identify, adjust, and modify according to the data input and output of the controlled object, and finally realize the optimization of the processing process [7-14].

So far, most of the research on the adaptive control technology of CNC machine tool processing by Chinese experts and scholars has adopted technical methods. Fan Hao, Li Hang and Wang Guofeng based on the theoretical cutting point of the workpiece and the theoretical cutting point of the tool in 2013. The coordinate relationship in the basic coordinate system of the machine tool is the same, and the comprehensive error mathematical model of the CNC machine tool processing process including geometric error and cutting force error is derived; adaptive control technology is one of the important methods to improve the machining accuracy, efficiency and automation of CNC machine tools , According to the data input and output of the control object, self-identification, adjustment, correction, and finally the optimization of the processing process. So far, most of the research on the adaptive control technology of CNC machine tool processing by Chinese experts and scholars has adopted technical methods. Fan Hao, Li Hang and Wang Guofeng based on the theoretical cutting point of the workpiece and the theoretical cutting point of the tool in 2013. The coordinate relationship in the basic coordinate system of the machine tool is the same, and the comprehensive error mathematical model of the CNC machine tool processing process including the geometric error and the cutting force error is derived; Guo Xiaojun, Wang Qupeng, etc., respectively, in 2008 and 2014, respectively, the networked monitoring technology of CNC machine tool processing Do research on monitoring and fault diagnosis technology [15-21].

Relatively speaking, there are relatively few researches on the adaptive control technology of CNC machine tools in China combined with patent analysis. To this end, this article uses patent analysis methods to analyze the application status, key technical directions, and core patents of China's CNC machine tool processing adaptive control technology from multiple perspectives. Guo Xiaojun, Wang Qupeng and others did research on the networked monitoring technology and monitoring and fault diagnosis technology of CNC machine tool processing in 2008 and 2014 respectively. Relatively speaking, there are relatively few researches on the adaptive control technology of CNC machine tools in China combined with patent analysis. To this end, this article uses patent analysis methods to analyze the application status, key technical directions, and core patents of China's CNC machine tool processing adaptive control technology from multiple perspectives. Using Thomson Reuters' Thomson Innovation database as the data source, on the basis of fully researching the subject industry background and technical field, the key technologies in the field are classified, and the intelligent error displacement compensation technology, intelligent vibration suppression technology, and intelligent drive are used [22-24].

2. THE PROPOSED METHODOLOGY

2.1 The Artificial Brain-Computer Interface

The system is flexibly configured and used, and provides a standard style software interface. In order to further understand the development direction of the self-adaptive control technology in the machining process of CNC machine tools in recent years, the author made a comparative analysis of the number of domestic and foreign patent applications in this field from 2005 to 2015. On the whole, intelligent operation, intelligent error displacement compensation technology , The intelligent maintenance monitoring function has always been the key research and development direction in the past ten years. In order to realize the true adaptive predictive control of CNC machining, indirect measurement and control of cutting force, a set of adaptive predictive control software must be written, and modularized, and added to the process layer software of the Huazhong I-type CNC system software.

This, combined with the limited manufacturing precision of the machine tool itself, makes direct measurement techniques of little engineering value. Based on the above reasons, using the principle of the mapping relationship between the motor current and the cutting force and the adaptive predictive control technology, a different indirect measurement method is proposed. The key technologies of adaptive control of CNC machine tool processing process are divided into intelligent error displacement compensation technology, intelligent vibration suppression technology, intelligent drive technology, intelligent tool monitoring technology, intelligent anti-interference function, automatic programming, intelligent maintenance monitoring Function. Since 2005, the number of patent applications in China in the field of adaptive control of CNC machine tools has generally increased. The number of applications in 2005 was 15, which decreased slightly in 2006. Since then, the number has increased year by year, reaching 163 applications in 2013. In the CNC milling process, when the cutting force changes, the current state signal is also constantly changing, and the signal has a lag, and there is no rule to follow. In order to solve this problem, the indirect measurement and control of cutting force is made practical. Jiangsu, Shanghai, Zhejiang, Liaoning, Shaanxi and other provinces are areas with relatively developed machine tool industries.

From the perspective of patent applications in various provinces across the country, patent applications in the field of adaptive control technology for CNC machine tool processing are all over the country, and the province with the largest number of applications is Jiangsu Province. Generally speaking, the above technical fields are the main application directions of my country's adaptive control technology patents. According to the analysis of the units with the largest number of domestic patents, indicating or measuring devices and compensation control devices are generally the focus areas in their patent applications. Huazhong CNC system is based on industrial PC as the basic hardware support environment and DOS operating system as the software support environment, realizing an open CNC system software platform, providing a convenient secondary development environment, which can be used for different CNC systems.

2.2 The CNC Machine Cutting Process

For example, in the MRAC feedback loop, in the actual cutting process, after being affected by multiple influencing factors, the state parameters of the machine and equipment will change accordingly. At this time, the sensor can play an important role as a bridge and can perform real-time monitoring of these parameters. Monitor and adjust the parameters when necessary, and then the MRAC control unit can complete the evaluation work in time, and compare the information and data. After the conclusion is drawn, the signal is sent to the CNC to ensure the best of the entire machine and equipment. change. The machining process of mechanical cutting is a complex dynamic process with highly nonlinear, time-varying, serious random interference and uncertainty. It is difficult to effectively control it with traditional adaptive control technology based on the precise mathematical model of the controlled process.

The intelligent control reflects the high degree of self-adaptation, self-organization and self-learning ability of people in control activities. It can deal with uncertain and inaccurate knowledge without relying on the mathematical model of the controlled process, and can obtain the complex controlled process. Satisfactory control effect, so intelligent control can be applied to the process control of machine cutting. The specific structure of the machine tool cutting MRAC model is also more complicated, which can be divided into feedforward device, feedback device and adjustment mechanism. The specific content of these different components is also different. Here, the feedforward device and the feedback device are mainly explained. There are certain differences between these two devices and other devices in the model, because these two devices are proportional links. Considering a variety of factors, this mathematical control model has more specific content, which is a huge challenge for industry workers.

In the process of machine tool processing, the cutting performance will not only have a great impact on the quality of the parts, but also easily damage the tools. The cutting process of the machine tool, tool, and workpiece system is an unstable process. It is often disturbed by many uncertain factors from the outside world, which causes the state parameters in the cutting process to change at any time. If it is not adjusted in time, the cutting performance will be greatly reduced. Through MRAC adjustment, the parameters of cutting performance can be kept in a stable state all the time.

2.3 The Adaptive Control of CNC Machine Tool Cutting Process

The structural block diagram of the intelligent adaptive CNC system developed on the basis of the Huazhong I CNC system mainly includes two parts: a CNC unit and an intelligent adaptive control unit. The main tasks undertaken by the CNC unit are servo control, CNC machining, and in the cutting process. In real time, it exchanges information with the intelligent adaptive control unit, adjusts cutting parameters, etc.; the main task of the intelligent adaptive control unit is to detect the processing status, optimize the cutting parameters in real time according to the processing status, and exchange information with the CNC unit. In order to give full play to the guiding role of the processing concept, it is very important to realize the transformation of the processing concept.

The transformation of the processing concept needs to grasp multiple influencing factors. The following main tasks need to be promoted: First, it must be combined with the actual development of the enterprise itself. Including operating costs and infrastructure construction, etc.; secondly, it is necessary to combine the actual needs of the development of the industry to achieve the transformation of processing concepts in a targeted manner; finally, it is to conform to the

development trend of the times and help the development of the enterprise. Now take the cutting force constant at the set value during the machining process to illustrate that MRAC can adjust the cutting force in time to keep it at the desired cutting force when the external factors (for example, the change of the back-engagement amount) interfere with the cutting force. According to the experiment, the parameters in the machining model are known Ks =1 500N/mm 2 , n=600r/min, Kn =0.95mm/(V· s), ξ=0.68, p=1, m=1, ωn = 22rad/s,The amount of back-cutting is changed according to a sine curve from 1 to 3mm, and the expected value of cutting force is set to 1 000N. Substituting the above parameters into the mathematical control model of Fig. 3, the simulation diagram shown in Fig. 4 can be obtained by using MATLAB/SIMULINK tools. The system has two forms: Insert the self-developed 8098 single-chip intelligent adaptive control card into the numerical control unit, the numerical control unit exchanges information with the intelligent adaptive control unit through the dual-port RAM memory of the card; insert the control card into another PC to form an intelligent adaptive control unit.

3. CONCLUSIONS

The method and approach proposed in this paper to realize the intelligent adaptive control of the cutting process of CNC machine tools is simple, effective and feasible. The 8098 single-chip intelligent adaptive control card developed by the 8098 single-chip microcomputer provides a simple structure for the realization of intelligent adaptive control of the cutting process. Reasonable and reliable technical means, the performance and cutting efficiency comparison test results of the CNC milling process with the parameter adaptive fuzzy controller show that the established intelligent adaptive CNC system has good performance, greatly improved cutting efficiency, and can effectively Prevent the occurrence of tool breakage and protect the tool. In actual production, it will have greater use value and prospects for popularization and application.

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