

Key Technique and Application in Error Compensation for CNC Machine Tools

Jiang Li

Guangzhou Nanyang Polytechnic College, Guangdong, China, 510925

Keywords: Key Technique and Application; Error Compensation technology; CNC Machine Tools

Abstract: The CNC Machine Tools with high efficiency, high precision and high stability is the inevitable trend of the modern manufacturing industry development. This development trend puts forward the extremely high request to the CNC machine tool error compensation technology. However, the error of CNC machine tools have a variety of reasons, these errors affect each other, which leads to the inevitable error. At the high efficiency processing, it is necessary to ensure the high stability and high precision of the machine tool, which requires the error compensation function to maintain high stability and high compensation accuracy, when the CNC machine tool is under the action of high speed and dynamic load. CNC machine tool error compensation technology is an important means to improve the machining accuracy in the manufacturing industry, which reduce the error in the production process and increase the production efficiency. This paper firstly analyses the error classification and error source percentage of CNC machine tools. And then it analyses the movement error when the CNC machine tools is working. Finally, it puts forward the key technique and application of error compensation.

1. Introduction

In the cutting process of CNC machine tools, the machining accuracy of parts mainly depends on the accuracy of cutting forming between workpiece and cutting edge position. If the CNC machine tool and fixture technology deviates from the correct position in the cutting process, it will produce machining errors. In the process of CNC machining, error is often formed by a variety of error elements. The error compensation is an important technology in the application of CNC machine tools. It has a very important effect on improving the machining precision of CNC machine tools. CNC machine tools still have errors in operation with a variety of reasons. So, the error compensation technology is specifically aimed at reducing the error and improving the accuracy of CNC machine tools. Based on the research of the technology, this paper puts forward the key technique and application in error compensation for CNC machine tools.

2. The error classification and error source percentage of CNC machine tools

2.1. The error classification of CNC machine tools

According to the source of CNC machine errors, errors can be divided into six. The error classification of CNC machine tools is shown as the table 1.

2.2. The error source percentage of CNC machine tools

Research results at home and abroad show that different kinds of error sources have different effects on the machining accuracy of CNC machine tools. The error source percentage of CNC machine tools are shown in table 2.

Table 1 the error classification of CNC machine tools

NO.	Error classification	Error definition
1	Geometric error	The geometrical error is the error caused by the original manufacturing and assembly defects of machine tools.
2	Thermal error	Thermal error is the error caused by thermal deformation when the machine temperature changes.
3	Force error/ Stiffness error	Force error is the error caused by the deformation of the machine tool when it's under a force.
4	Control error	Control error is the error caused by the control system performance of the machine tool.
5	Detection error	Detection error is the error caused by the performance and precision of the detection system.
6	Random error	Random error is the error of machine tool caused by external disturbance.

Table 2 the error source percentage of CNC machine tools

Error classification	Error classification	Percentage	Percentage
Machine tool error	The geometric error	20%-30%	45%-65%
Process error	Thermal error	25%-35%	
Detect the error	The cutting tool error	10%-15%	25%-40%
	Machine tool error	Fixture error	
Process error	Thermal error and elastic error	3%-5%	
Machine tool error	The operating error	6%-10%	10%-15%
	Installation error	2%-5%	
	Indeterminate error	8%-10%	

3. CNC machine tools moving error and rotation error

3.1. CNC machine tools moving error

Figure 1 shows the moving pair moving in the X direction. For a moving pair, there are three moving errors and three rotational error components. The moving error component includes a positioning error $\Delta x(x)$ and two straightness errors $\Delta y(x)$ and $\Delta z(x)$. In addition to the moving errors, there are three rotation errors related to the moving pair, including the rotation errors around the X, Y and Z axes respectively $\Delta\alpha(x)$, $\Delta\beta(x)$ and $\Delta\gamma(x)$. α , β and γ represent the rotation error directions around the X, Y and Z axes respectively.

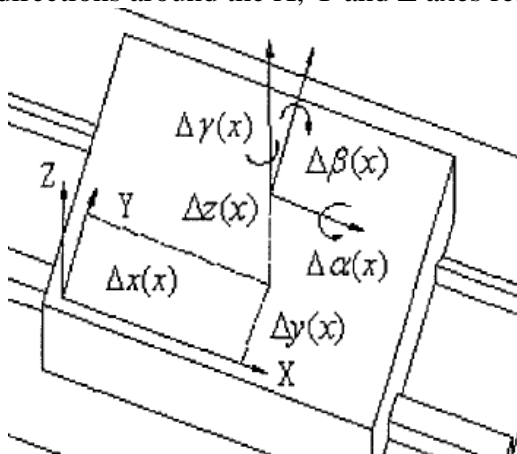


Figure 1 The moving error

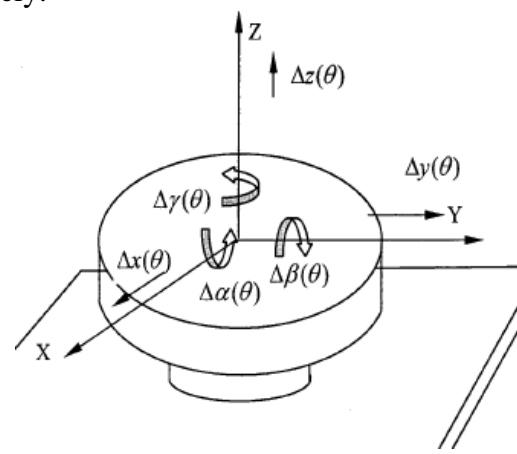


Figure 2 The rotation error

3.2. CNC machine tools rotation error

Figure 2 shows the rotation error. For a rotation pair, there are also three translation errors ($\Delta x(\theta)$, $\Delta y(\theta)$ and $\Delta z(\theta)$) and three rotation errors ($\Delta\alpha(\theta)$, $\Delta\beta(\theta)$ and $\Delta\gamma(\theta)$). α , β and γ represent the rotation error directions around the X, Y and Z axes respectively. In addition, there are also verticality errors among the coordinate axes (λ_{xy} , λ_{xz} and λ_{yz}), which constitute the geometric error source of the machine tool.

4. Key technique and application in error compensation for CNC machine tools

4.1. Real-time and non-real-time error compensation

In non - real - time error compensation, error detection and compensation are separated.

Non - real - time error compensation can only compensate system error. Real-time error compensation can compensate not only system error but also a large part of random error.

Non-real-time error compensation techniques are widely used for static errors. The thermal deformation error is always compensated by real - time error. In dynamic machining process, error value changes rapidly and compensation always has time lag. So, real-time compensation cannot compensate for all errors.

4.2. Hardware compensation and software compensation

The hardware compensation method is to change the relative position of the machining tool and the workpiece. Which can achieve the purpose of machining error compensation.

Compared with software compensation by microcomputer, this method is very clumsy. Software compensation is a special compensation method for CNC machine tools. CNC machine tools have the potential of software compensation. Software compensation is realized by modifying CNC machining code or executing compensation instruction. Software compensation overcomes the difficulty of hardware compensation and gradually replaces the hardware compensation method of error compensation. Software compensation mainly includes modify CAD model, modify CAM model and modify NC model. The figure 3 is the modify CAD model schematic diagram, and the figure 4 is the modify CAM model schematic diagram. Modification of NC data can be carried out under any processing conditions. The NC data generated is the position of the actual cutting point, which overcomes the disadvantages of modifying CAD model and CAM model.

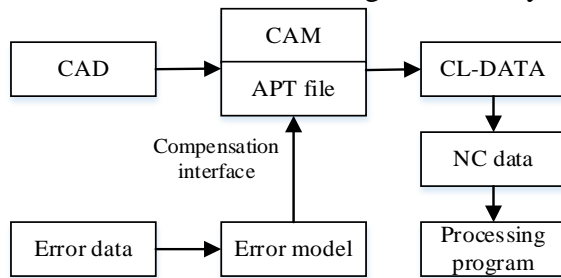


Figure 3 Modify CAD model

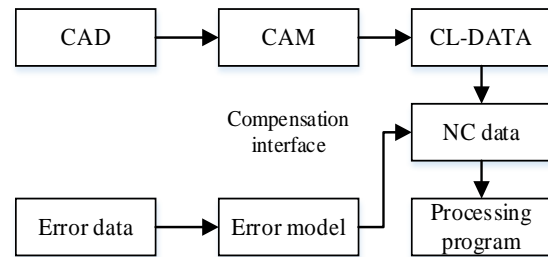


Figure 4 Modify CAM model

4.3. Static compensation and dynamic compensation

The static compensation is the compensation quantity or the compensation parameter invariant in the numerical control machine tool processing. It can only compensate according to the preset supplementary value. The static compensation method can only compensate the random error. Dynamic error compensation is a feedback compensation method. In cutting conditions, according to the machine tool, environmental conditions and changes in space location, it tracks, adjust the amount and parameters of compensation. Dynamic compensation method can achieve better compensation effect. It is the most promising error compensation method for CNC machine tools, but it needs higher technical level and higher additional cost. Figure 5 is the dynamic compensation schematic diagram.

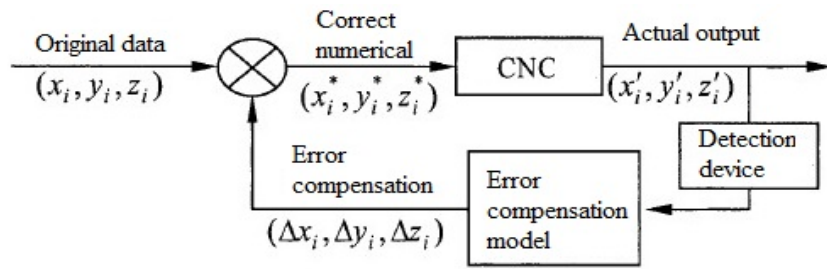


Figure 5 the dynamic compensation schematic diagram

5. Conclusions

Although China has made some achievements in numerical control machine tools, the future task of the machine tool industry is still arduous. The level and reliability of China's machine tools are slightly lower. We must find out the disadvantages to develop CNC machine tool technology. We must ensure the machine tool processing accuracy meeting market demand.

Acknowledgements

Guangzhou Nanyang Polytechnic College: Intelligent Control Technology Innovation Research Team (NY-2017CQ1TD-05)

References

- [1] Yang Zhaojun, Chen Chuanhai, Chen Fei, et al. Research progress of reliability technology of CNC machine tools [J]. Journal of mechanical engineering, 2013, 49 (20): 130-139.
- [2] Zhang Genbao, Li Dongying, Liu Jie, et al. Reliability evaluation of nc machine tools for incomplete maintenance [J]. Journal of mechanical engineering, 2013, 49 (23): 136-141.