Research on CNC Contour Error Compensation Approach Based on Straightway Approximate Nodes

Guoyong Zhao, Zhiyong Li, and Hongjing An

Department of Mechanical Engineering, Shandong University of Technology Zibo 255049, Shandong Province, China
Zgy709@126.com

Abstract. In the CNC machining on complex parts, how to compute contour error with high precision and distribute contour error correction quantity on each sampling period, is much significant to improve matching degree among each axis. Consequently, a CNC contour error compensation control approach with stable calculation error, high computing precision and satisfied real-time characteristic, is researched in detail in the paper. Firstly, compute the contour error according to the actual cutter position dots and the straightway approximate nodes; Secondly, add the obtained contour error to the following error of current sampling period, and send the results to CNC position controller to calculate position controlled quantity; Finally, the contour error compensation contrast experimentations are done on the three-axis linked CNC test table, and the experimental results show that the developed approach can reduce contour error effectively.

Keywords: Approximate nodes, CNC system, Contour error compensation, Complex parts.

1 Introduction

In general, multi-axis CNC machine tool is adopted to process complex parts, after approximating complex cutter position track instruction curve with straightway. To multi-axis CNC machine tool, the profile precision is the important factor to determine its machining accuracy [1]. Because CNC machine tools have complicated servo drive equipments, and the CNC system parameters may change in practical machining, the multi-axis actual dynamic performances don’t match well, which reduces the profile precision [2-3]. In contrast to the advanced single-axis servo controller, the cross-coupled-controller is more effective to enhance profile precision, which computes the contour error and compensates each axis servo motor on each sampling period [4-6].

Some research results in point have been achieved recently. For instance, Myung-Hoon LEE puts forward a multi-axis contour controller based on a contouring error vector using parametric curve interpolation [7]. Peng Chao-Chung introduces a new contour index (CI) aimed to arc and line profile, which can be looked as an equivalent contouring error [8]. Aimed to profile curve in plane and space, Gen Lirong and
Wang Baoren look the distance of actual position to the line which links the dots of the current and the last sampling period as the current contouring error respectively, entitled “two-dot line approximation method” [9-10]. However, because of inertia and frictional force, the hysteresis phenomena exist in truly CNC machine tool each axis movement, which is difficult to be foreseen accurately. As a result, the above-mentioned approaches are unstable sometimes. What’s more, the calculation error is uneasy to control if the hysteresis time is much longer than a sampling period.

Consequently, a CNC contour error compensation control approach with stable calculation error, high computing precision and satisfied real-time characteristic is developed in the paper. Above all, compute the contour error according to the actual cutter position dots and the straightway approximate nodes; Secondly, add the obtained contour error to the following error of current sampling period, and send the results to CNC PID position controller to calculate position controlled quantity in order to compensate contour error; Finally, the contour error compensation control contrast experimentations are done on the three-axis linked CNC test table.

2 Contouring Error Computing Model

The key idea of the developed contour error computing model is as followed: After approximating complex parts cutter position track instruction curve with straightway according to equi-error method, calculate the current actual cutter position coordinates owing to the position measure feedback from each axis and table on each CNC line interpolation sampling period; Compute the minimum distance from current actual cutter position to cutter position track instruction curve according to the actual cutter position dots and the approximate nodes, in other words, to calculate the contour error.

As shown in Fig.1, suppose to approximate part cutter track instruction curve L under the precision requirement with straightway AB, BC…, and define the actual cutter position as dot R on certain sampling period. Above all, obtain the three approximate nodes A, B, C nearest to actual cutter position R on the cutter position instruction curve L, and then calculate the distance $|RM|$, $|RN|$ from actual cutter position R to straightway AB, BC. It is noticed that the calculation is complicated if transform the distance from dot to line, to the maximum distance from dot to plane pencil through the line. Consequently, the vector method with the space analytic geometry and vector algebra theory is adopted to compute the distance $|RM|$, $|RN|$ from dot R to straightway AB, BC:

$$|RM| = \frac{|AB \times AR|}{|AB|}$$

$$|RN| = \frac{|BC \times BR|}{|BC|}$$

The coordinates of both approximate nodes A, B, C and actual cutter position R are known, so the calculations of Equation (1) and (2) are simple. After obtaining $|RM|$ and $|RN|$, the contour error $\varepsilon$ is calculated according to two kinds of conditions.