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Research and optimization of bolt tightening strategy for precision machine tool guideway considering linear accuracy and assembly efficiency

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Guideway is an essential component in machine tools. The uneven deformation of the guideway during assembly can have a direct impact on the linear accuracy of machine tools. This effect is especially significant in in precision machine tools used for high-precision fields such as micro/nano manufacturing, which is more likely to lead to a decrease in the accuracy of manufactured parts. Bolt tightening is an essential step in guideway assembly, where the large-scale group bolts tightening must ensure not only the linear accuracy of the guideway but also the efficiency of the tightening process. Consequently, the establishment and optimization of bolt tightening strategies have become a significant research challenge in the field of precision machine tools. The objective of this present research is to evaluate various bolt tightening strategies, explore bolt tightening strategies which offer both strong connection performance and high linear accuracy, and optimize the bolt tightening sequence with less tightening time as the target, thereby enhancing the assembly efficiency of guideways and the machining precision of precision machine tools. First, finite element simulations modeled three different tightening strategies for the guideway, determining the straightness error and analyzing the influence of bolt preload and its uniformity on this error. Then, an experimental setup mimicking real machine tool specifications was created to validate the simulation's accuracy through practical assembly. Finally, further optimization was performed on the cross-tightening strategy, considering assembly efficiency. The findings indicate that uniform bolt preload is critical for guideway linear accuracy. The cross-tightening strategy not only ensures robust connection strength but also enhances linear motion precision. Three optimization plans based on this strategy significantly increase assembly efficiency without significantly affecting linear precision. This research offers practical application references for guideway assembly and machine tool manufacturing, contributing to the enhancement of machining precision and assembly efficiency, and providing equipment support and precision assurance for micro/nano manufacturing.

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