Ballbar Applications for Machining and Non-Machining Setups in a Hexapod-Based Machining Cell

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ABSTRACT
Robotic machining is gaining popularity in modern manufacturing due to its cost and flexibility benefits. Compared to serial robots, hexapod-based industrial work cells offer greater rigidity with a smaller footprint. At ÉTS, a robotic machining cell using two Fanuc F-200iB hexapods was developed. The machining quality of the hexapod is directly influenced by its positioning performance. To ensure high-quality machining, a Renishaw telescopic ballbar with a 1000 Hz sampling rate was selected to evaluate the positioning performance of this work cell in both non-machining and machining setups.

In the non-machining setup, factors such as thermal drift, feeding speed, and testing positions for ballbar measurements were considered. The experiment showed that the circular deviation increased to approximately 53.5 µm after 12 hours at a fixed position, but stabilized within 2 hours. Therefore, a preheating process is necessary before conducting formal ballbar measurements. The circular deviation increased within the feeding speed range of 500-6000 mm/min. During no-load running, the hexapod's positioning performance varied from 33.8 µm to 99.3 µm across 30 positions. The maximum circular deviation was observed at the boundary of the maximum working envelope. In the machining setup, a customized fixture was employed to investigate how machining parameters, such as feeding speed, cutting depth, and spindle speed, affect the positioning performance of the hexapod. Through an analysis of the Taguchi experimental plan (with three factors and two levels), a significant vibration effect on circular deviation in the machining-based ballbar measurement was observed. This effect was closely related to the spindle speed. Developing an understanding of the relationship between measured vibrations and machining parameters is crucial for optimizing hexapod-based machining. To this end, an unscented Kalman filter (UKF) was developed to isolate the vibrations present in recorded ballbar results. Compared to the non-machining setup, the machining-based ballbar setup exhibited 4-20 times more vibrations, which were significantly influenced by machining parameters, particularly at high spindle speeds.

Finally, the research findings provide a quantitative assessment of the positioning performance of the hexapod-based machining cell in both non-machining and machining setups. We identified optimized machining positions and the respective contributions of each machining parameter, which are critical for achieving good robotic machining. Future work will explore the relationship between isolated vibrations and part machining quality, with the aim of developing a machining quality prediction system for hexapod-based working cells.