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Finite Element Analysis in the Development of an Ultra-high Speed Micro-milling Center

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Abstract: High-speed micro-milling is a versatile micromachining technology used to develop miniaturized components with highly finished surfaces. However, cutting vibration remains a significant challenge due to the high spindle speed. This paper describes the development and analysis of two different configurations of an ultra-high-speed micro-milling machine tool. The machine comprises an ultra-high-speed spindle capable of reaching a maximum rotational speed of 140,000 rpm and ultra-precision linear stages, all housed within a developed rigid machine structure. In configuration A, the spindle is attached to the linear stage assembly. In contrast, in configuration B, the spindle is mounted on the upper block of the machine structure. The primary objective is to reduce cutting vibration in the micro-milling machine. Finite Element (FE) analysis was conducted on both configurations to evaluate their static stiffness, natural frequencies, and dynamic stability. The analysis results indicate that configuration A exhibits higher stiffness, rigidity, and damping capability compared to configuration B under both static and dynamic conditions. Consequently, configuration A was selected as the preferred design for ultra-high-speed micro-milling operations. This study provides valuable insights into the design and optimization of ultra-high-speed micro-milling machines, highlighting the importance of machine configuration in enhancing performance and reducing vibrations. The findings underscore the effectiveness of configuration A in achieving superior static and dynamic characteristics, making it a suitable choice for high-precision micromachining applications.

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