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Modeling of the Dynamic Characteristics of a Spindle with Experimental Validation

Authors : Jhe-Hao Huang, Kun-Da Wu, Wei-Cheng Shih, Jui-Pin Hung

Abstract : This study presented the investigation on the dynamic characteristics of a spindle tool system by experimental and finite element modeling approaches. As well known facts, the machining stability is greatly determined by the dynamic characteristics of the spindle tool system. Therefore, understanding the factors affecting dynamic behavior of a spindle tooling system is a prerequisite in dominating the final machining performance of machine tool system. To this purpose, a physical spindle unit was employed to assess the dynamic characteristics by vibration tests. Then, a three-dimensional finite element model of a high-speed spindle system integrated with tool holder was created to simulate the dynamic behaviors. For modeling the angular contact bearings, a series of spring elements were introduced between the inner and outer rings. The spring constant can be represented by the contact stiffness of the rolling bearing based on Hertz theory. The interface characteristic between spindle nose and tool holder taper can be quantified from the comparison of the measurements and predictions. According to the results obtained from experiments and finite element predictions, the vibration behavior of the spindle is dominated by the bending deformation of the spindle shaft in different modes, which is further determined by the stiffness of the bearings in spindle housing. Also, the spindle unit with tool holder shows a different dynamic behavior from that of spindle without tool holder. This indicates the interface property between tool holder and spindle nose plays an dominance on the dynamic characteristics the spindle tool system. Overall, the dynamic behaviors the spindle with and without tool holder can be successfully investigated through the finite element model proposed in this study. The prediction accuracy is determined by the modeling of the rolling interface of ball bearings in spindles and the interface characteristics between tool holder and spindle nose. Besides, identifications of the interface characteristics of a ball bearing and spindle tool holder are important for the refinement of the spindle tooling system to achieve the optimum machining performance.

Keywords : contact stiffness, dynamic characteristics, spindle, tool holder interface
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