The concept and progress of intelligent spindles: A review

Abstract
Intelligent spindles are core components of the next-generation of intelligent.smart machine tools in the Industry 4.0 Era. The purpose of this paper is to clarify the concept of intelligent spindles and provide an in-depth review of the state-of-the-art of related technologies. A new integrated concept for intelligent spindles is proposed, followed by descriptions of required characteristics, key enabling technologies and expected intelligent functions. Relevant research that may be beneficial to the development of intelligent spindles is reviewed from six thrust areas, which include monitoring and control of tool condition, chatter, spindle collision, temperature/thermal error, spindle balance, and spindle health. Finally, current limitations and challenges are discussed, and future trends of intelligent spindles are prospected from various perspectives.