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Fiber bragg grating sensing technology and its application in thermal errors monitoring of CNC machine tools - Yuegang Tan - Wuhan University of Technology

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For an extended time, Fiber Bragg Grating (FBG) based sensors were intensively studied for application in engineering structure, like bridges, dams, etc. Recently, thanks to the benefits of small volume, light weight, anti-electromagnetic interference, anti-oil corrosion, and multiple measuring points in one glass fiber, FBG-based sensors have attracted many interests and been widely investigated by researchers and engineers in industrial filed. Our research focuses on dynamical monitoring and diagnoses of mechanical systems supported distributed fiber Bragg grating sensors. The FBG-based sensors we developed for mechanical equipment (large turbine, aero engine, large crane, heavy-duty CNC (computer numerical control) machine tools, etc.) involves the measurement of temperature, strain, force, pressure, and accelerator. Thermal error monitoring technology is that the key technological support to unravel the thermal error problem of industrial quality CNC machine tools. FBG temperature sensors were utilized to detect the temperature field of main heat sources and therefore the structure in heavy duty CNC machine tools to review the thermal characteristics of main heat sources and to determine the thermal error prediction model. Meanwhile, supported the advantage of multiple strain measuring points in one glass fiber, FBG-based strain sensors were studied and wont to measure the thermal deformation of structural components (gantry beam, column and base) of the heavy-duty CNC machine tools using the integral relationship between the strain and deformation.

The history of the study of the machine thermal error is on the brink of a century long. There's still no solution to the thermal error problem with modern high precision CNC machine tools. Most research about the machine thermal error has focused on establishing the connection between the temperature field and thermal error of machine tools, but no solutions have presented themselves well in industry application. Since there are no new technological breakthroughs within the experimental studies on the thermal error, traditional electrical testing and laser measurement technology are commonly used. The research objects in thermal error testing are usually small and medium-sized CNC machine tools. There’s relatively less research on heavy-duty CNC machine tools.

Heavy-duty CNC machine tools are pivotal pieces of kit in many advanced manufacturing industries, like aerospace, energy, petrochemicals, rail transport, shipbuilding, and ocean engineering. They're widely utilized in the machining of huge parts and high-end equipment, like steam turbines, large nuclear pumps, marine propellers, and enormous aircraft wings. Improving the machining precision of industrial quality CNC machine tools is of great significance to comprehensively improving the efficiency of turbine units, extending the lifetime of the atomic power shaft system, reducing the noise of submarine propulsion, reducing the resistance of flight and so on.

Thermal error monitoring technology is that the key technological support to unravel the thermal error problem of industrial quality CNC (computer numerical control) machine tools. Currently, there are many review literatures introducing the thermal error research of CNC machine tools, but those mainly specialize in the thermal issues in small and medium-sized CNC machine tools and rarely introduce thermal error monitoring technologies. This paper gives a summary of the research on the thermal error of CNC machine s and emphasizes the study of thermal error of the heavy-duty CNC machine tool in three areas. These areas are the causes of thermal error of industrial quality CNC machine and therefore the issues with the temperature monitoring technology and thermal deformation monitoring technology. A replacement optical measurement technology called the “fiber bragg grating (FBG) distributed sensing technology” for heavy-duty CNC machine tools is introduced intimately. This technology forms an intelligent sensing and monitoring system for heavy-duty CNC machine tools. This paper fills within the blank of this type of review articles to guide the event of this industry field and exposes new areas of research on the heavy-duty CNC machine thermal error.

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