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Stretchable Eddy current Sensors Array Probe for Geometry Complex Surface Inspection

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ABSTRACT

With the rapid development of mechanical fabrication techniques, increasingly complex components are being designed and manufactured. Among these, turbine blades hold significant importance in gas turbine engines, as they facilitate the conversion of heat energy into mechanical energy. However, prolonged exposure to high temperatures and pressures accelerates the aging process of turbine blades, increasing the risk of defects such as erosion, cracking, and tearing. These defects can compromise the integrity of the turbine system, making regular inspection of the blades imperative for safe operation. Eddy current testing (ECT) is a widely used nondestructive testing technique for inspecting metal components. Flexible ECT sensor array probes, fabricated using flexible printed circuit boards (FPCBs), are particularly suitable for inspecting curved surfaces. It should be noted that turbine blade surfaces are geometrically complex. The curvatures at different regions of the blade are inconsistent, which is designed to meet aerodynamic requirements. However, a bended FPCB maintains consistent curvature along its bending axis, this poses a challenge when inspecting turbine blade surfaces. The FPCB surface cannot conform to the varying curvatures of the turbine blade, leading to increased lift-off distance between the EC sensor and the inspected surface. Consequently, the strength of the EC response signal decreases, reducing the detectability of damage.
To address the challenge of inspecting geometrically complex surfaces such as turbine blades, a stretchable EC sensor array probe has been proposed. This array probe consists of two rows of copper wire coil-based EC sensors, designed and fabricated. The sensors are encased and interconnected by silicone rubber material with a hardness of 15 shore A. The softness of the material allows the probe to stretch. Unlike existing flexible EC sensor arrays, which typically utilize non-stretchable polyimide as the substrate material, the proposed probe addresses the issue of lift-off caused by inconsistent curvature by employing a deformable substrate material. During inspection, applying force to the probe enables it to conform to the contours of the surface being inspected. This action ensures that the probe adheres closely to the surface, minimizing the lift-off distance between the EC sensors and the inspected surface. As a result, the stretchable probe enhances the detectability of defects on geometrically complex surfaces like turbine blades.

Keywords: Eddy current testing, sensors array, stretchable probe, complex surface inspection

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