Automatic Laser Beam Alignment Algorithm for Angular Pulse-Echo Ultrasonic Propagation Imaging System

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In the aerospace industry, developing reliable non-destructive testing technology is crucial to ensure the structural safety of aircraft and spacecraft. Recently, the importance of non-destructive technology using laser-induced-ultrasonic has grown significantly due to its capability for fully non-contact inspection. Angular Pulse-Echo mode Ultrasonic Propagation Imaging (APE-UPI) system, a non-destructive inspection system was developed based on this technology. Among laser-induced-ultrasonic-based non-destructive testing techniques, APE-UPI is widely used due to its advantages of high inspection resolution, rapid inspection speed, and compactness, enhancing its portability for on-site applications. However, the APE-UPI system required manual alignment of excitation / sensing laser beam each time the Stand-Off-Distance (SOD) changed to ensure sufficient Signal-to-Noise Ratio (SNR) and credible inspection performance. This imposed the limitation of inspection results being influenced by the user's level of expertise and inconvenience when inspecting objects at varying SOD. In this study, an automatic beam alignment algorithm for APE-UPI system is investigated that utilizes a motorized mirror mount capable of two-axis rotation. An RGB camera was employed to detect the position of the laser beam and based on this data, the mirror mount was used to steer the excitation beam for initial alignment. Additionally, ultrasonic signal was acquired from multiple points around the initial alignment point to gather calibration data for more precise alignment.