Development of Laser Ultrasonic Testing Technology for Diagnosis of Reusable Rocket CFRP Composite Combustion Chamber

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The next-generation space industry is increasingly emphasizing the use of reusable launch vehicles (RLVs), driven by the private sector and cost-effective operation. However, RLVs face extreme conditions during their missions, including high temperatures, high-pressure combustion environments, random acoustic vibrations, and potential shocks. These conditions can lead to structural deformations and internal defects. Therefore, the development of key technologies for assessing the structural integrity of launch vehicle's primary structure is essential to ensure rapid RLV refurbishment and mission reliability. This research aims to develop an inspection technology and a system capable of diagnosing the structural integrity of hybrid rocket solid fuel composite combustion chamber exposed to the combustion test. The non-destructive testing (NDT) employed in the system is automated laser ultrasonic testing (LUT), a fully non-contact NDT method. The LUT mode utilized in the system is the pulse-echo (PE) mode, which involves irradiating a pulsed laser beam and a laser Doppler vibrometer (LDV) beam at the same point to generate and measure ultrasonic signals. This inspection technique is well-suited for detecting thickness-direction defects, making it suitable for detecting delamination that may occur within composite structures. The control unit of the system consists of a rotational motor for controlling the rotation angle of the combustion chamber and a large-scale linear rail for precise positioning of the LUT system. The inspection areas were selected based on finite element analysis (FEA) results, considering the loading conditions experienced by the launch vehicle in its operational condition. The diagnostic system for RLV developed in this study represents a core technology for achieving flexibility in launch frequency and cost reduction in the space industry.