Real-Time Penetration Depth Monitoring of Laser Welding Using Laser Depth Dynamic (LDD) OCT: An Experimental Study on Titanium, Steel, and Aluminium Alloys

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Laser welding has emerged as a pivotal technology in modern manufacturing industries such as automotive, medical, aerospace, and nuclear sectors, where precision, reliability, and efficiency are paramount. Its advantages—such as high processing speeds, minimal thermal distortion, and the ability to join a wide variety of materials—make it indispensable for the production of advanced components. In fields where stringent quality control is essential, the integrity of welds directly impacts safety and performance.

A critical challenge in laser welding is ensuring consistent weld quality, particularly with respect to penetration depth. In industries where failure is not an option, insufficient weld depth can result in structural weaknesses, incomplete fusion, or cracking, all of which compromise the final product's performance. Traditional methods of weld inspection, including destructive testing, are costly, time-consuming, and impractical in high-volume production environments.

This study focuses on the experiments performed with Laser Depth Dynamic (LDD) Optical Coherence Tomography (OCT) monitoring system developed by IPG Photonics, which represents a significant advancement in real-time, non-destructive weld monitoring. An experimental investigation was conducted on titanium, steel, and aluminium alloys, examining the relationship between keyhole depth and cross-sectional weld results. Key factors, such as 3D scanning of the keyhole and correct alignment of the LDD imaging beam within the keyhole, were analysed across various materials and processing power levels.

The 3D scanning of the keyhole enhances depth measurement precision and ensures optimal OCT laser imaging beam alignment within the keyhole, which is critical for achieving high-quality welds.

This presentation will present the findings of this experimental study, highlighting the performance and challenges of the LDD OCT system across different materials and power settings, and the impact of 3D keyhole scanning on weld accuracy. Furthermore, the potential for integrating this cutting-edge technology into industrial laser welding processes will be discussed.