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基于声波多域特征提取和深度学习的铝合金脉冲激光焊接熔透定量评估

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摘要：焊缝熔透状态是定量评价激光焊质量最重要的指标之一，准确识别焊缝熔透状态是动态激光焊过程监测和控制的关键瓶颈。针对薄壁件铝合金脉冲激光焊接，文中通过构建深度学习模型提出了基于声波多域特征提取的焊缝熔透定量评估新方法。首先，搭建了视觉-声发射多信息实时同步传感系统平台，获取反映匙孔动态行为的视觉图像和声波信号，并对声波信号进行了分帧和去噪预处理；其次，提取了各帧声波信号的时域、频域特征信息，并使用平滑伪魏格纳维利分布 (SPWVD, Smoothed Pseudo Wigner-Ville Distribution)提取了各帧信号的时频域图像，相应的，引入灰度共生矩阵（GLCM, Gray Level Co-occurrence Matrix）提取出了各帧时频图像的纹理特征；最终，以声发射信号时域、频域、时频域多域特征为原始输入，构建基于 CNN-LSTM 神经网络 (Convolutional Neural Network-Long short-term Memory) 的焊缝熔透状态分类模型. 结果表明：声波多域特征与匙孔动态行为和焊缝熔透状态具有高度相关性；基于多域特征提取的 CNN-LSTM 分类模型有着高达 95%以上的分类准确率. 所提出定量评估新方法为铝合金薄壁件脉冲激光焊接熔透的的在线智能诊断与自适应控制提供了基础.

关键词：脉冲激光焊接；声发射信号；特征提取；深度学习；熔透分类

Quantitative evaluation of penetration condition in pulsed laser welding of aluminium alloys based on acoustic multi-domain features extraction and deep learning

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Abstract：The welding penetration state is one of the most important indicators for quantitative evaluation of laser welding quality, and accurate identification of the welding penetration state is a key bottleneck for dynamic laser welding process monitoring and control. For pulsed laser welding of thin-walled aluminium alloys, a new method for quantitative assessment of welding penetration based on acoustic multi-domain features extraction is proposed in the paper by constructing a deep learning model. Firstly, a visual-acoustic emission multi-information real-time synchronous sensing system platform is built to obtain visual images and acoustic signals reflecting the dynamic behaviour of the keyhole, and the

acoustic signals are pre-framed and denoised; secondly, the time domain and frequency domain features of each frame of acoustic signals were extracted, and the time-frequency domain images of each frame were extracted using the Smoothed Pseudo Wigner-Ville Distribution (SPWVD), and accordingly, the Gray Level Co-occurrence Matrix (GLCM) was introduced to extract the texture features of each frame of time-frequency images. Finally, a CNN-LSTM Neural Network(Convolutional Neural Network-Long short-term Memory) based weld penetration state classification model was constructed using time-domain, frequency-domain and time-frequency-domain features of the acoustic emission signal as the original input. The results show that acoustic multi-domain features are highly correlated with the dynamic behaviour of the keyhole and the weld penetration state; the CNN-LSTM classification model based on multi-domain feature extraction has a classification accuracy of over 95%. The new quantitative evaluation method proposed provides a basis for online intelligent diagnosis and adaptive control of the melt-through of pulsed laser welding of thin-walled aluminum alloy parts.

Keywords: Pulsed Laser Welding; Acoustic Emission Signal; Feature Extraction; Deep Learning; Penetration Classification

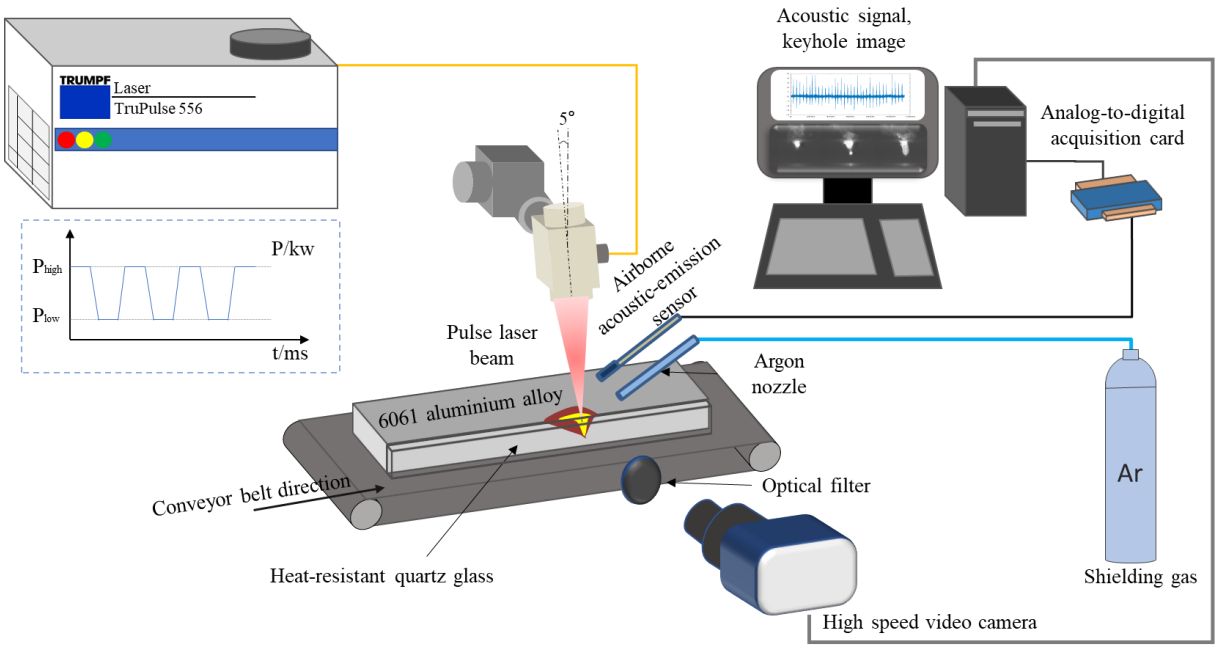

Figure 1. Schematic of the experimental setup

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