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OPTICAL EMISSION MONITORING FOR DEFOCUSING LASER PERCUSSION DRILLING

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Abstract:

This paper presents a novel method for controlling the laser-drilling process for a hole by monitoring induced plasma emission. The variation of light brightness from laser-induced plasma is used as an indicator to control laser percussion drilling. Through on-line plasma emission acquisition and analysis, we obtain the positive association between the increased depth and the optical signal output. A coaxial photodiode is used to estimate the brightness levels of laser-induced plasma. The above constitute an inexpensive and practical on-line feedback system that can be easily implemented in the laser systems. All of the processing work is performed in air under standard atmospheric conditions without gas assist. The acquired signal for drilling could also be used as an input to a focus point process control scheme. Moreover, the technology demonstrates the feasibility to develop an automated laser micromachining system. Experimental results show that drilling efficiency was increased 47% by applying the proposed defocusing laser percussion drilling.

Keywords: Laser micromachining, laser-induced plasma, process monitoring, plasma emission, defocusing laser micromachining.

1. INTRODUCTION

Optimizing the focusing conditions for laser percussion drilling could improve productivity and drilling quality. The position of the focal spot relative to the workpiece surface determines whether the laser beam is converging or diverging. Drilling causes change in focal position, which reduces laser power density and affects drilled-hole quality. An incorrect workpiece standoff or focal position that is due to the defocusing of the laser beam by the increasing depth can be a major cause of process deterioration [1]. As laser percussion drilling become more automated, process monitoring need to be applied to focusing conditions, rather than relying on experience-based control rules.

Previous research has addressed the problems in automatic monitoring of material processing using a laser. Kaebernick *et al*. [2] used a photodiode-based adaptive control system for improving the laser cutting surface quality by controlling the striation frequency.

Fox *et a1*. [1] developed a focus control system for closed-loop control of laser cutting and drilling, which uses the chromatic aberrations of the effector optics. However, the accuracy of the measurement will be reduced when laser drilling with high peak power pulses.

Stournaras *et al*. [3] used optical signals acquired by off-axial photodiodes that were positioned above the processing zone for real-time monitoring of the diameter and depth of the drilled hole. However, the proposed configuration indicated a weak coefficient of confidence of the output optical signal with machining depth.

Chang and Tu [4] proposed a closed-loop control for ablation depth in femtosecond pulse laser micro-machining by monitoring the brightness of the derived light. The ablation process was recorded by a CCD camera and analyzed frame by frame to obtain the brightness level of the plasma. However, this closed-loop method was not applicable for drilling a deep hole in which the plasma may be blocked by the sidewall of the hole.

Ho *et al*. [5] showed that the cumulative size of the laser-induced plasma correlates with the depth of the hole. However, because of the radial arrangement of the camera, some of the detected plasma signal emitted from a deep hole was blocked by the sidewall of the hole. Therefore, this system is a poor candidate to provide real-time control for laser drilling.

Diego *et al*. [6] attempted to detect the working focus position during laser scribing by monitoring the intensity of plasma emission. A linear correlation between plasma emission intensity and ablated mass per pulse was established.

Our previous work [7] showed that the intensity of the light emitted from the plasma plume correlates with the depth of the drilled hole. In the present work, we used a photodiode to detect the emitted light, and the focus position was adjusted accordingly. This increased quality while reducing process time.

2. ANALYSIS AND EXPERIMENTS

A high-speed, silicon photodiode (Hamamatsu, S1223) with an active area of 3.6 × 3.6 mm^2 was employed coaxially to measure the light emission of the plasma that appeared near the workpiece surface. It had a maximum sensitivity of 960 nm and a response time of 50 ns, which makes it reliable for signal detection. The intensity of the light emitted from the plasma plume formation passed back up through the nozzle, the focusing lens through a focused lens, a neutral density filters (transmittance 10%), and two 532 nm notch filters onto the photodiode. To distinguish between the ionization phenomena for the air and workpiece caused by the laser-induced plasma and to suppress the strong intensity of the light emitted from the plasma plume to saturate the photodiode, a wavelength filter and neutral density filter are placed in front of the photodiode. An amplifier with a peak detector circuit indicated when light