Real-Time Online Monitoring of Ultra-High-Speed Lasers

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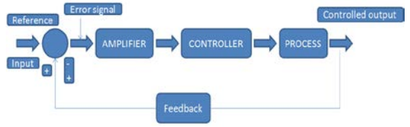
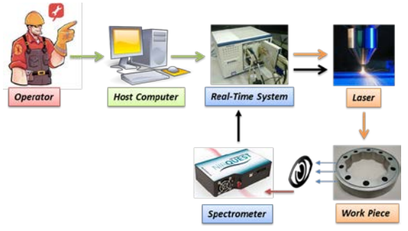
Introduction

Laser scribing is considered to be ultra-fast and accurate process and thus it would be necessary to develop accurate tuning and monitoring system for such a process. Because of nature of this process, it is very hard to monitor it in real-time. This research focuses on developing real-time monitoring of ultra-fast laser scribing processes utilizing high speed camera and spectrometer. In addition, an adaptive control strategy is developed to control and tune the laser parameters during the process. The monitoring and control algorithm is constructed on an special architecture having National Instrument PXIe as the core. The behavior of the control strategy and accuracy of the monitoring sensors is checked by scribing different steel materials.

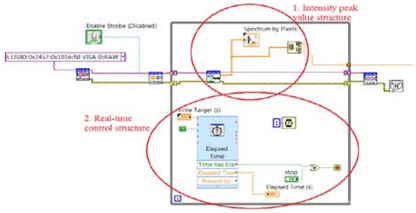
Control Strategy



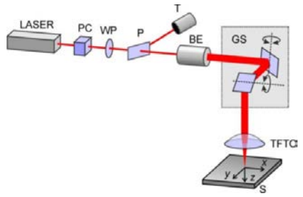
Control Algorithm

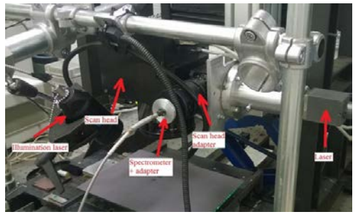


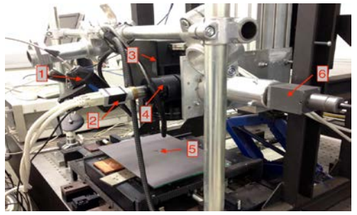
Control Algorithm



Test Setup





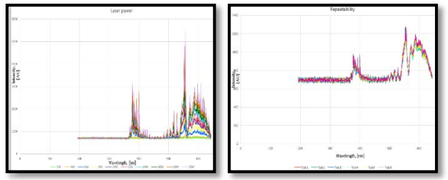


Test bed for experiments (1. Illumination laser, 2. High-speed camera, 3. Scan head, 4. Camera adapter, 5. Work piece, 6. Pulsed fiber laser).

Test Setup

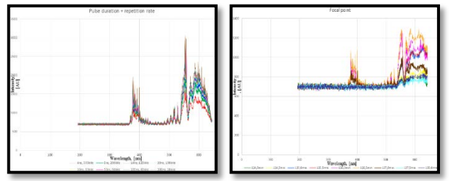
The laser used in experiments is an IPG ytterbium pulsed fiber laser with 20 W maximum average power and Scan head optics used in the laser is Scanlab's Hurryscan 14 II with an f100 tele-centric lens. The manufactured spectrometer adapter and the spectrometer from Ocean Optics and illumination laser from CaviLux. The camera was connected to laser scanner using camera adapter to follow the laser process. The material used in this test was stainless steel SS304L plate, 100x50x6mm3 in size. The composition of SS304L is C 0.03% max, Mn 2.00% max, P 0.045% max, S 0.03% max, Si 0.75% max, Cr 18.0-20.0% max, Ni 8.0-12.0% max and N 0.1% max. A NI PXIe was chosen for executing image processing and analysis. Algorithms for defect analysis, which are based on particle analysis, were developed using LabVIEW system design software.

Output of Spectrometer



Repeatability test results

Effect of the laser power

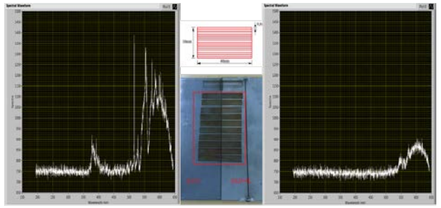


Effect of pulse length test results

Effect of focal position test results

Testing the Adaptive Control System

Experiments were performed to test real-time capability of the laser control algorithm. Experiments were started by choosing two different materials to see how the control code behaved when scribing moved from one material to another. Materials were chosen to be stainless steel SS304L and steel S355. Beam hatch shape was rectangular with dimensions of 40x10mm2 with 0.8mm horizontal hatch space.

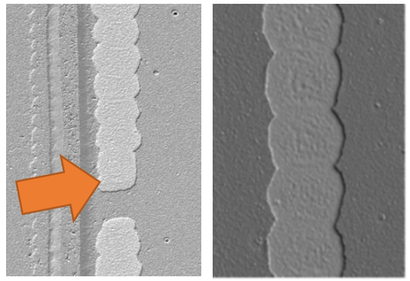


S355 SS304L

Real-Time Monitoring Utilizing High Speed Camera

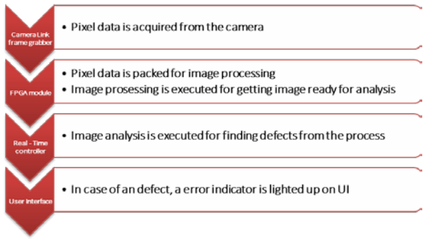
The aim of this research is to find a method for laser scribing monitoring with a high-speed camera and evaluate reliability and performance of the developed monitoring system with experiments.

Problem of Scribing Process

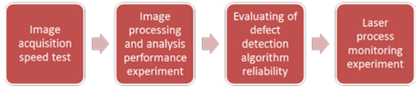


Right images illustrates a perfectly fine scribe and left image illustrates deflection during scribe

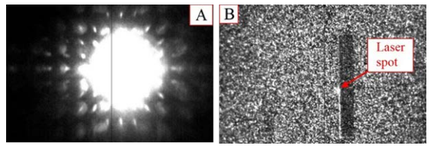
Image Processing and Analysis Procedure



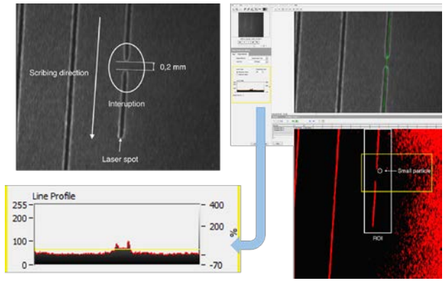
Experimental Phases

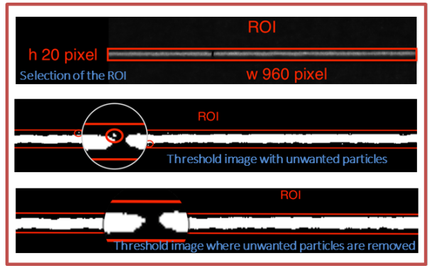


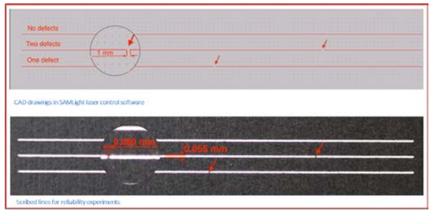
Illumination



Results of Monitoring with High Speed Camera





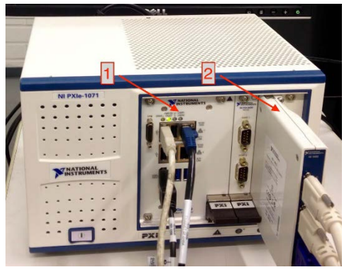


Real-Time Hardware

PXI is open PC-based platform created by National Instrument for test, measurement and control systems. PXI deployment platform is used example in applications such as manufacturing test, machine monitoring, and industrial test.

The PXI system built for the experiments consists of NI 1483 Cameral Link Adapter Module, NI PXIe 7966R FPGA Module and NI PXIe-8880 Real-Time Module.

PXI System



PXI System (1. RT-Controller, 2. Camera Link module connected to FPGA module).

Below modules were used in this project:
PXIe Real Time module, NI FlexRIO FPGA module, Camera Link Adapter Module, LabVIEW System Design Software

Computing Architecture