

Laser Profilometry For Non-Contact Automated Countersink Diameter Measurement

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ABSTRACT

Automated countersink measurement methods which require contact with the workpiece are susceptible to a loss of accuracy due to cutting debris and lube build-up. This paper demonstrates a non-contact method for countersink diameter measurement on CFRP which eliminates the need for periodic cleaning. Holes are scanned in process using a laser profilometer. Coordinates for points along the countersink edge are processed with a unique filtering algorithm providing a highly repeatable estimate for major and minor diameter.

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INTRODUCTION

Mechanical hole-probing is susceptible to lube and debris buildup. This can manifest itself as a gradual degradation in accuracy necessitating frequent cleaning by machine operators. Manual methods like the check-bolt and height gauge are time consuming. Lube and debris must be removed from the hole prior to measurement to obtain an accurate result.

Electroimpact has integrated a laser profilometer into a machine tool for non-contact automated scanning of countersink geometry. The goal is to provide an efficient, accurate, and automatic measurement technique which solves the inherent problems associated with the current state of the art. The noise level and quantization error of the profilometer necessitates filtering and post processing specific to countersink measurement in order to provide accuracy and repeatability which meets or exceeds current technologies.

This paper is meant to be an initial document outlining the design of the system and providing experimental results for carbon fiber countersinks. Future research is planned as a follow up. This will include performance data from a production environment as well as feasibility for use on other materials such as aluminum.

HARDWARE

The hardware required to implement this measurement technique includes a profilometer head which houses the laser and detector, a stand-alone controller, and a PC application for

post-processing. The head is mounted to the headstone of the machine tool as shown in [Figure 1](#). Scan motion is then achieved using existing CNC-driven positioning.

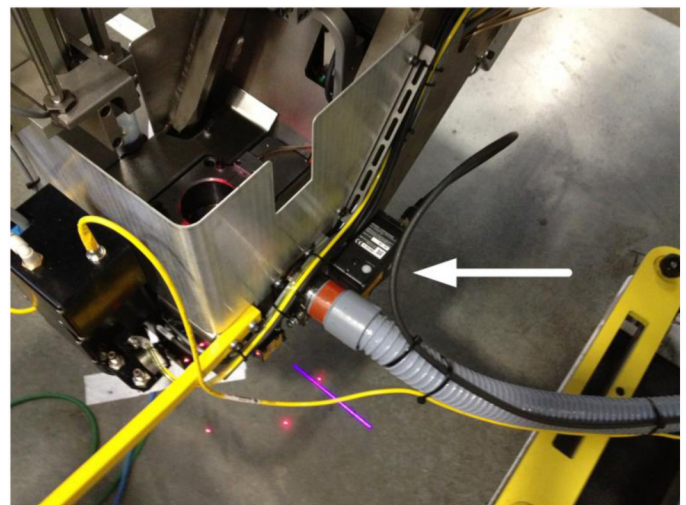


Figure 1. Mounted laser head.

The coordinate system used throughout this paper is based on the profilometer head, as shown in [Figure 2](#). The Z-axis is aligned with the laser, positive from workpiece to emitter. The X-axis is the direction of scanning, normal to the laser profile. The Y-axis is aligned with the laser profile.

The laser profilometer provides a cross-section of the countersink by determining Z position data across the profile at quantized Y positions. As an example, typical profile data for the center of a countersink is shown in [Figure 3](#).

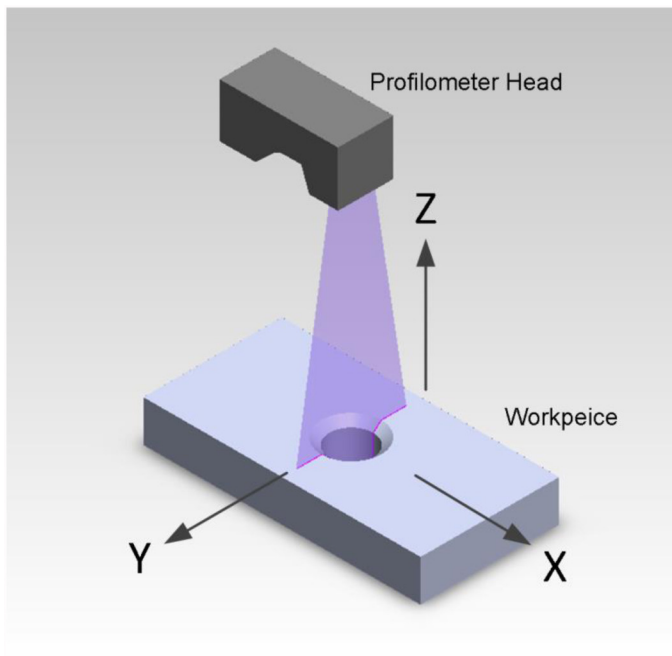


Figure 2. Coordinate system.

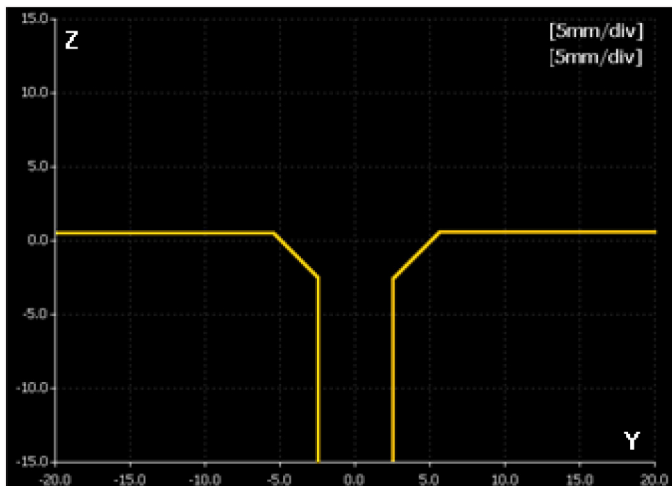


Figure 3. Countersink profile with scan position near the center of the hole.

The laser is driven across the entire countersink along the X-axis at a specified feed rate using the CNC. The Y position of the edge is sampled at a specified frequency using a stand-alone laser controller. For each sample, the X position is inferred from the feed rate and sampling frequency. The resulting data set is then fed into an ellipse fitting algorithm to provide major and minor diameter. A separate PC application runs this fitting algorithm as a post-processing step along with an outlier filtering routine. A block diagram showing the flow of data is shown in [Figure 4](#).

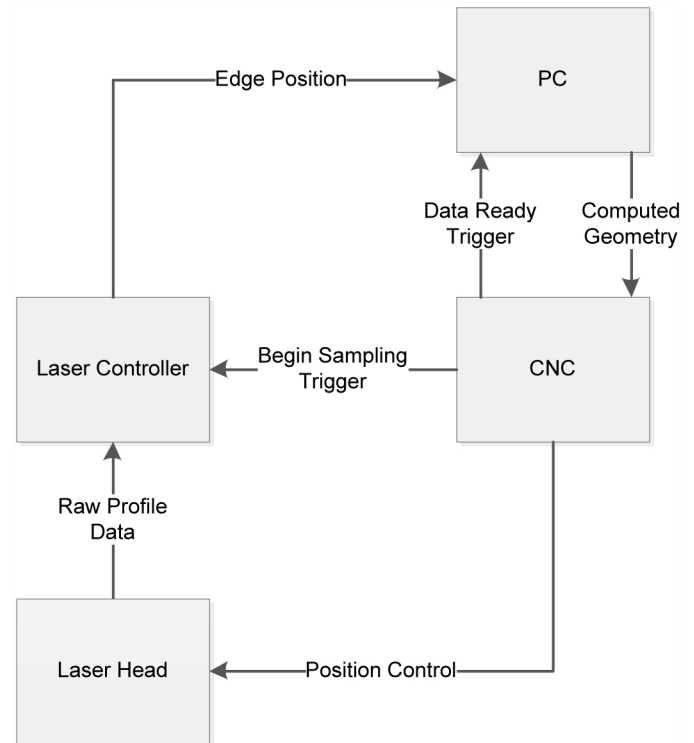


Figure 4. System diagram.

SOFTWARE

Raw Data Acquisition

It is important to note that the repeatability of the profilometer along the Z-axis is an order of magnitude better than the Y-axis. Therefore, it is advantageous to use as much Z-axis data as possible in determining edge position. To achieve this, edge location is found using the intersection between best fit lines for the inside surface of the countersink and the outside surface of the workpiece, as shown in [Figure 5](#). This method provides a precision estimate of the Y location of the two edges visible in each profile or "slice" along the scan.

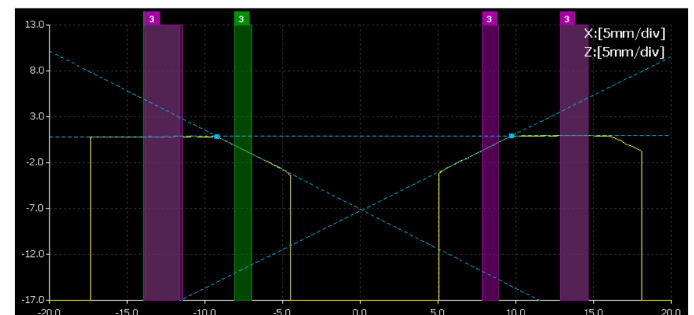


Figure 5. Edge location using the intersection of best fit lines generated within the green and purple bands.