Optik 126 (2015) 3616–3623

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Development of a simple laser-based 2D contouring accuracy compensation system for the laser cutting machine

Hsueh-Liang Huang*, Wen-Yuh Jywe, Ming-Chen Cho

Department of Automation Engineering, National Formosa University, No. 64, Wunhua Road, Huwei Township, Yunlin County 632, Taiwan

ARTICLE INFO

Article history:
Received 16 September 2014
Accepted 30 August 2015

Keywords:
Position sensor detector
Laser diode
Contouring accuracy
Laser cutting machine

ABSTRACT

The effect of dynamical contouring error is a critical to the production yield of the laser cutting machine. Dynamical contouring error is defined as the difference between the actual processing path and the commanded path, as implemented by following the command curves of the feeding and driving system associated with the machine tools. Contouring error is the result of various factors, such as the external loads, friction, moment of inertia, feed rate, speed control, and servo control. This study proposes a 2D compensation system to improve the contouring accuracy of the laser cutting machine. An optical method was adopted, in which a stable frequency laser diode and a high precision position sensor detector (PSD) were adopted to perform noncontact measurement. Experimental results demonstrate that the accuracy of the position sensor detector (PSD) in the 2D contouring accuracy compensation system was ±1.5 μm over a calculated range of ±3 mm, representing an improvement accuracy of over 80% at a high feed rate.

1. Introduction

Elimination of dynamical contouring error is important in improving the laser cutting machine performance for users and manufacturers. Current trends require a dynamical contouring measuring system and error compensation method that can simultaneously on-line monitor the manufacturing process of the laser cutting machine. The commercial instruments, such as laser interferometers, double ball bars (DBBs), and plane encoders, are widely be used to inspect the performance of machine tools.

Laser interferometer has been adopted for the inspection of geometric error. The measurement range and resolution can be as high as 1 m and 1 nm [1], respectively; however, this approach is restricted by its difficult set-up, high costs, inability to measure dynamic performance, and other shortcomings. For these reasons, the double ball bar (DBB) and plane encoder were adopted for circle contouring or contouring tests in the inspection of dynamic performance.

When the DBB was first proposed by Bryan [2,3], it has become the most popular equipment for testing the dynamic performance of machine tools, due to its easy set-up, low cost, wide applicability, and ease of operation. Nonetheless, DBBs can only be applied to the circle contouring test and are unsuitable for high-speed contouring. The LBB system was proposed by Ziegert et al. [4] in 1994. This approach uses a laser interferometer to overcome the limitations in the measurement range associated with DBBs. However, this approach is not without drawbacks such as an inability to perform effectively in the small-range circle contouring test and high costs. Srinivasa et al. [5] also applied the LBB system to the problem of spindle thermo drift.

The plane encoder is a diffraction grating type encoder used to measure the two dimensional position of an optical head through the use of a grid plate, in which the grids are aligned orthogonally to one another [6]. The cross-grid encoder is capable of measuring contouring error two-dimensionally to provide an arbitrary reference trajectory. This approach is widely used in the accuracy calibration of robot manipulators [7] and machine tools [8]. Various two-dimensional position encoders have been proposed in the literature (e.g., [9–11]). Because the 2D contouring error of a machine tool is generally much smaller than the distance traveled, the error is often magnified in the graphical display to a scale relative to the reference trajectory. Clearly, the magnified trajectory cannot be continuous at any unsmooth corners. Commercial software ACCOMEN 2.8 [12] was developed by Dr. Johannes Heidenhain for use with the KGM series for data acquisition and the visual display of measured profiles.

To modify parameters of the controller is one of the methods for reducing the dynamical contouring error. Thus, many researches based on algorithm design also have been proposed for improving the dynamical contouring error [13–17]. These methods usually

* Corresponding author. Tel.: +886 5 6315400; fax: +886 5 6315401.
E-mail address: ajiff38@gmail.com (H.-L. Huang).

http://dx.doi.org/10.1016/j.ijleo.2015.08.244
0030-4026/

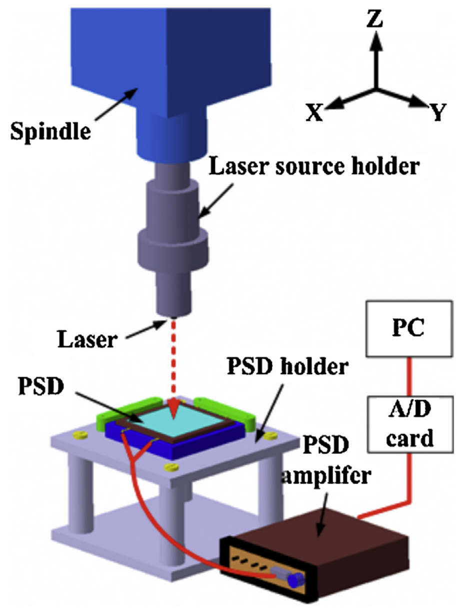

Fig. 1. Sketch of simple laser-based 2D compensation system.

used to compute the magnified trajectory of the dynamical contouring error profiles, such that the magnified trajectory becomes continuous even when the reference trajectory is unsmooth.

Compared with the previous literatures about the traditional method for measuring the dynamical contouring error, a laser-based 2D contouring error compensation system, proposed in this study, exhibits four main advantages: (a) reduced uncertainty; (b) friction can be ignored; (c) magnetism is not a factor, and (d) the signals used in the proposed system can be used to obtain other parameters associated with machine tools as well as to measure contouring accuracy.

2. Principles of measurement and instrument configuration

2.1. Overall system layout

The proposed system includes a laser light source ($\lambda = 635$ nm, power = 5 mw) [18], position sensor detector (PSD) [19], signal processor [20], A/D card [21] and PC, as shown in Fig. 1. A Li battery is built into the aluminum fixture to provide the power source for the laser. The weight of the fixture is less than 200 g and the length is less than 10 cm with a diameter of 4 cm. The laser is affixed to the front end. Adjustment screws are provided to introduce a degree of eccentricity and wobble during testing. Table 1 shows the experimental apparatus. As shown in Fig. 2, the user interface was developed using Visual C++, in which the NC code of the CNC controller was modified according to the contouring error measurement results. The standard operating procedure (SOP) of the laser-based 2D compensation system is shown in Fig. 3.

Table 1
Experimental Apparatus.

PSD	UDT SC-10D
PSD amplifier	On-Tark OT-301
PC	Intel Pentium4 2.0G 256 MB RAM 40G HD
A/D card	NI USB-6210
CNC machine tool	YCM FV56T vertical milling machine
Controller	FANUC MXP-200i
Parameter (smooth function)	Turn on

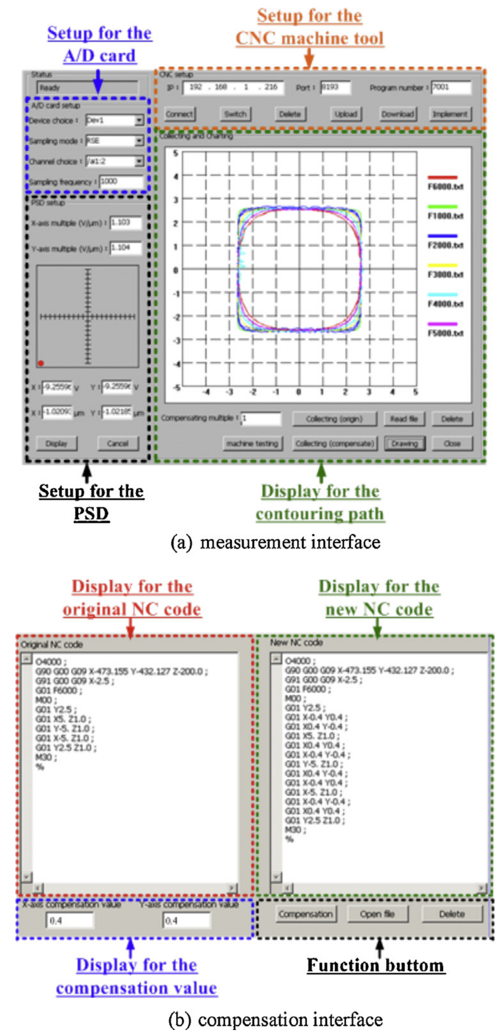

Fig. 2. Sketch of the interface for the laser-based 2D compensation system.

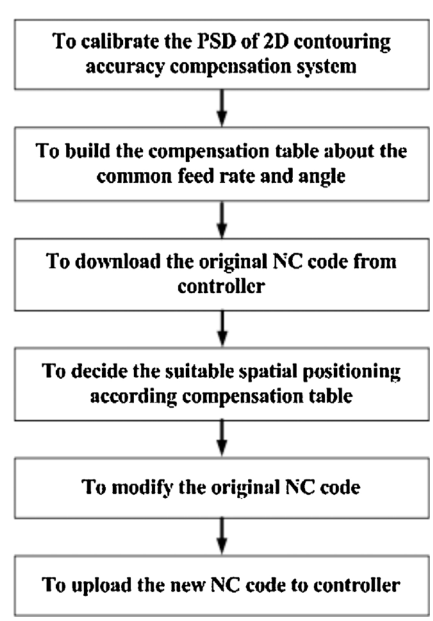

Fig. 3. Sketch of the SOP for the laser-based 2D compensation system.