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Laser Micro Machining System Communication Protocol Design

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Abstract: This study introduced a serial communication method between PC and lower computer. PC was used to process the image in self-developed laser micro machining system. The data information was setting value of machining track after image processing. Data information, different command flag, start text (STX) and end text (ETX) composed command frame. We detailed the frame structure in different machining method. Use checksum to check the transmission content. Resend data according to feedback frame improving the reliability of communication.

Key words: Laser micro-machining, communication protocols, frame data feedback

INTRODUCTION

Laser micro machining has a very wide range of applications in many fields because of its high machining precision, high performance price, high degree of automation, processing conditions easy to satisfy and widely processing object (Zhang *et al*., 2012a; Tao *et al*., 2011).

Laser micro machining was as follows: PC processed a source picture according to the required of lower computer and send the image information to it. Lower computer controlled light source or platform to move to complete the machining process. To the laser micro machining, the study emphasis was divided into three aspects.

The one hand was research on computer graphics processing. It was impossible to get color graphic on the work-piece through laser processing. Generally, PC transferred a picture to gray image or binary image. The binary image could only describe the outline of a picture. Transferred a binary image to a vector diagram could avoid saw-tooth after enlarged (Zhang and Song, 2010). To the gray image, special method could show laying on the work-piece (Wang *et al*., 2006; Cai *et al*., 2008). Literature (Wang and Li, 2010a) derived Non-Uniform Rational B-Spline (NURBS) expression of an explicit rational polynomial. Based on which investigated the corresponding laser marking algorithm. The study applied NURBS images to laser marking system and helped to implement the laser marking of complex NURBS images. NURBS method had been applied in Chen and Li (2012) study. Chen and Li (2012) proposed the approximation principle based on the time division and the tool path curve that approximated by a group of chord lines. Literature (He *et al*., 2013) analyzed approached machining errors of five-coordinate numerical control machining curved surface to improve the machining accuracy and productivity. The other hand was the research on lower computer design and control (Fu *et al*., 2012; Wu *et al*., 2009). Last were the whole control system and the efficiency. Zhao *et al*. (2010) used one PC to control multiple lower computers through USB to improve the work efficiency. Zhang *et al*. (2012b) developed a vector image processing software using Delphi. Through the special control card, the software control lower computer to complete machining process. Wang and Li (2010b) designed laser marking system driver program deep into underlying OS. The method improved performance and efficiency through simplifying the operation of laser marking machining.

Processed image information need download to lower computer. The method was not mentioned in above studies. This study detailed communication protocol between PC and lower controller by taking self-developed laser micro machining system for example.

Laser micro machining and motion control system composition: In the laser micro machining system, the tiny spot shines on the surface of work piece for processing. The spot ablate the required figure on the surface of work-piece through the relative motion between spot and work-piece. It is very difficult to ensure the light source quality when it is moving. In contrast, control work-piece to move is very easy to meet the machining precision. In the self-developed laser micro-processing system, laser is fixed and work-piece can move follow the X-Y platform.

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Laser micro machining system composition: Embedding MS Visio drawings causes problems while transforming the document into PDF format. It is better to export them to GIF (graphics, screenshots) or JPEG (photos) format.

Laser micro machining system composition is shown in Fig. 1. After expanded beam processing, the light source Focused tiny spot through Short focal length lens. The spot shines on the work piece for processing. The work piece fixed on the X-Y platform moves followed with platform. The work piece is imaged in the CCD camera. CCD camera connects with image acquisition card in the PC. PC collects image and generates BMP file of work piece. The controller is the core of the motion control system. The motion control system drives stepping motor and stepping drives X-Y platform to move.

Motion control system composition: Motion control system composition is shown in Fig. 2. Motion control system is a closed-loop control system. The core of the system is the controller (contain nonvolatile memory, communication interface RS232, grating ruler counter parts, stepping motor control unit) based on AT89C52 MCU. The working principle of motion control system is as follows. Controller downloads movement locus (target value) from PC through communication interface RS232. The target value is as a movement of a given input. Grating ruler as displacement sensor is installed in X-Y platform. Grating ruler can translate displacement of platform to pulse quantity and input in controller as the feedback signal of displacement. The difference of given input and feedback signal is deviation value. The controller calculates output though control algorithm.

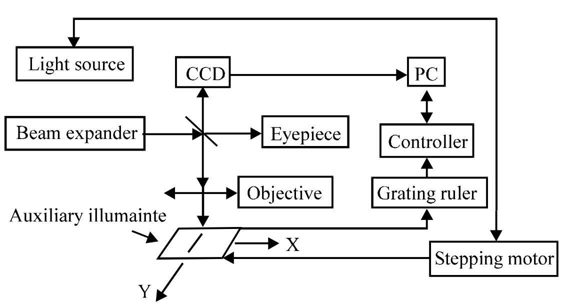

Fig. 1: Laser micro machining system composition

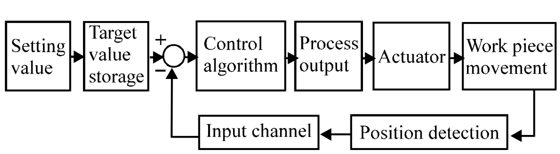

Fig. 2: Motion control system composition

based on deviation value. The output signal transfers to actuator (stepping motor) to drive X-Y platform, so the work piece would move according to set value

Obtain the setting value obtained: There are three patterns to obtain the setting value:

- Obtain the processing locus through observation on the work piece for processing. CRT of PC and X-Y platform has their coordinates. Each pixel of CCD image corresponds to one coordinate point of CRT and X-Y platform. Through the observation of CCD, the relationship between CRT and work piece on the X-Y platform will be established. This pattern will create locus document of regular graphics such as straight line, line, circle or arc. Controller can control the processing locus if the information (include starting point, the turning point, end point or radius, center, starting point, end point and mode of motion) download to the controller
- PC editing documents. PC editing documents include text document and image document. Text document, such as word document notepad file, can convert to TXT intact. For TXT documents its core stores word stock pointer or called vector pointer remove the description field. By using the methods of table lookups, Fonts files in Windows corresponding lattice library, lattice that character takes 16 bytes, or Chinese character takes 32 bytes can be obtained. The lattice and motion mode are as the processing locus download to controller. The image files that PC editing, because of no overlap between its features gray and background gray, can be converted to binary graphics by using Two-Value processing. Binary graphics after scaled are meet to demand of laser micro machining
- Many poetic or moral pictures can upload to PC through image input device such as digital camera and scanner. These pictures could be transferred to Two-Value image by using image processing techniques. The Two-Value image downloads to controller in the form of the lattice as the processing locus

Communication protocol design: Use RS232 bus to communicate between PC and motion control system. RS232 itself does not contain a special communication protocol; therefore, to implement a communication system, we need complete the communication protocol design according to the actual situation of software and hardware.

Communication interface: using RS232 serial communication interface, baud rate: 9600 BPS, 8 data bits, 1 stop bit and white parity bits.

Design principle:

- Waiting feedback for re-sending. PC sent a frame of data to lower computer at a time. Lower computer executed command according to received data and feedback the result to PC. The next step of PC was based on the feedback information
- Start text (STX), End text (ETX) and Check bit means the start of communication, end of a frame and flag of communication correct or wrong.

COMMUNICATION PROTOCOL DESIGN

Frame structure design: In the range of the communication protocol design principle and the requirement of laser micro machining system, the frame structure was consisted of 6 sections as Table 1:

- **STX:** Mean start of a frame of data. It was the flag that beginning to receive a frame of data. This system used BEH, EBH as STX
- **Bytes:** Bytes consumed by all data in current frame
- **Function code:** Function flag represented by current frame
- **Data:** Data content in current frame
- **Checksum:** It was used to judge whether data correct or not. The content of checksum was: Sum of STX, Bytes, Function Code and data in Table 1; maintained lowest 1byte; split this 1 byte into higher bit (H) and lower bit (L). then the checksum was consist of 5L and 5H
- **ETX:** Mean the end of a frame of data. This system used 0DH as ETX

Function code and data content design: According to machining and controlling method that laser micro process could do. There were 10 kinds of function codes, include 1 kind of feedback signal:

- X-Y platform reset command

Function code: 01H. Data content consumed 1byte and mean stepping motor speed. This frame consumed 8 bytes:

- X-Y platform relative positioning command

Table 1: Communication protocol frame structure

STX	Bytes	Function Code	Data	Check-sum	ETX
2B	1B	1B		2B	1B

Function code: 02H. The step number that platform moved in X and Y direction, respectively. Data content consumed 7 bytes. Where, lower bit of step number in X direction (1 byte), higher bit of step number in X direction (1 byte), direction bit (00H means forward direction, 10H means backward direction, 1 byte), Y direction was same as X direction, movement speed (1 byte). This frame consumed 14 bytes:

- X-Y platform closed-loop positioning command

Function code: 03H. Platform reached specified coordinates using grating ruler coordinates as feedback signal. Data content consumed 7 bytes. Where, lower bit of X coordinate (1 byte), higher bit of X coordinate (1 byte), empty bit (1 byte), Y coordinate was same as X coordinate), movement speed (1 byte). This frame consumed 14 bytes

- Download line segment image (assembling index table)

Function code: 04H. Data content consumed 4 bytes. Where, lower bit of row number (1 byte), higher bit of row number (1 byte), scanning number (1 byte), offset step pitch (1 byte). This frame consumed 11 bytes. Row number means row number that the whole image needs to be printed. Scanning number was determined by precision of image process and laser spot size. Offset step pitch was the step number that moved to next row and it was determined by laser spot size and step pitch of motor:

- Download line segment row index table

Function code: 05H. Date content consumed (4×row number) bytes. Where, 1st row (2 bytes), segment number in 1st row (2 bytes), 2nd row (2 bytes), segment number in 2nd row (2bytes),..., nth row (2 bytes), segment number in nth row (2 bytes). This frame consumed (4×row number+7) bytes.

- Download row content

Function code: 06H. Data content consumed [6×(number of current row +1)+2] bytes. Where, nth row ((2 bytes), start point X coordinate (3 bytes), Y coordinate (3 bytes), middle point 1st X coordinate (3 bytes), Y coordinate (3 bytes), middle point 2nd X coordinate (3 bytes), Y coordinate (3 bytes), ..., middle point nth X coordinate (3 bytes), Y coordinate (3 bytes), end point X coordinate (3 bytes), Y coordinate (3 bytes). This frame consumed [6×(number of current row +1)+9] bytes:

- Execute segment image command

Function code: 07H. Data content consumed 1 byte. It means platform movement speed. This frame consumed 8 bytes.

- Broken line machining command

Function code: 08H. The image was a broken line. Data content consumed [8×(number of broken point)+1] bytes. Where, X and Y direction of the nth broken line were all consumed 4 bytes. The first 2 bytes were step number of movement, the 3rd byte was direction bit (00H means forward direction, 10H means backward direction), the 4th byte was machining bit (10H means light and 00H means dark). This frame consumed [8×(number of broken point)+7] bytes:

- Arc machining command

Function code: 09H. The image was a arc. Data content consumed 22 bytes. Where, movement speed (1 byte), X coordinate of center (3 bytes), Y coordinate of center (3 bytes), X coordinate of start point (3 bytes), Y coordinate of start point (3 bytes), X coordinate of end point (3 bytes), Y coordinate of end point (3 bytes), radius (3 bytes). This frame consumed 29 bytes:

- Feedback signal

Function code: F0H. Data content consumed 7 bytes. Where, status information (1 bytes. 00H was normal state, 01H was receiving error and asked for resending. 02H was the 2nd receiving error. It means communication error when this byte was 03H. 08H was executing error.) Coordinate information (current X coordinate of grating ruler, 3 bytes, current Y coordinate of grating ruler, 3 bytes). This frame consumed 14 bytes

Communication protocol flow chart: The communication protocol flow chart of PC and lower computer were shown in Fig. 3 and 4.

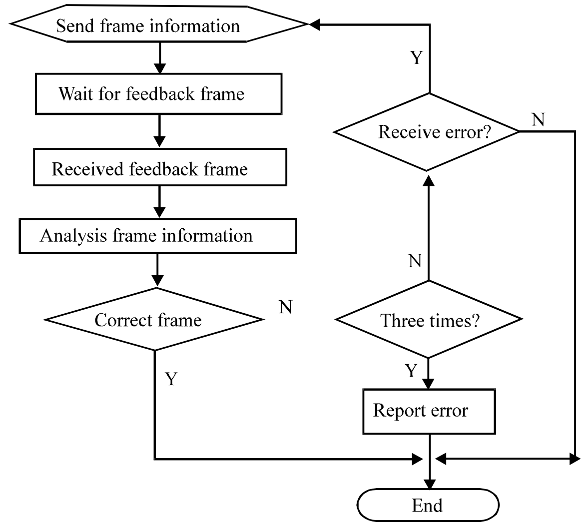

Fig. 3: PC communication protocol flow chart

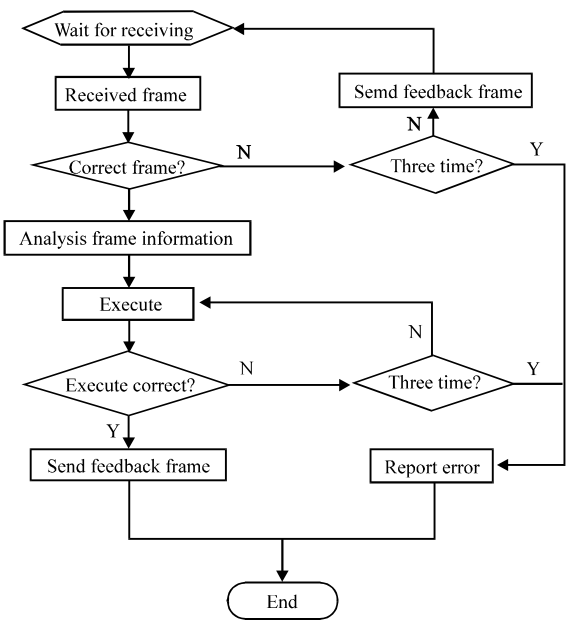

Fig. 4: Lower computer communication protocol flow chart

DISCUSSION

In the laser micro machining system, the communication between PC and lower computer were in the asynchronous half duplex mode. PC sent whole image information to lower computer before machining starting. Lower computer needed long time to execute command after receiving data when the image was complex. So the waiting time for feedback signal should be long enough. A segment image machining required 4 frame data. They were assembling index table, line segment row index table, row content and Execute segment image command.

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