Researches on the Numerical Control System for Cutting Pipe Connecting Trace Based on Virtual Instrument Technology

YANG Shifeng[1], WANG Peiran[2]

College of Electronic Information and Automation, Tianjin University of Science & Technology, Tianjin, China
e-mail: yangsf@tust.edu.cn, wpr@tust.edu.cn

Abstract: It is in urgent need of high efficiency, high accuracy and low cost numerical control system for cutting pipe connecting trace in the areas of oil, bridges, power, constructions and so on. On the foundation of the study of operational principle, general mathematic model was founded based on different types of columnar pipe connecting traces in this paper, and a software system for cutting pipe connecting trace based on virtual instrument technology was designed. Computer system integration technology as well as virtual instrument technology was adopted to develop the numerical control system which has friendly interface and high efficiency. Experiment results showed that the manufacture system can satisfy the demands of techniques.

Keywords: pipe connecting trace; numerical control cutting; virtual instrument; lab windows/CVI

Pipes with different diameters are usually needed to be welded together in the areas of oil, bridge, power and so on. To ensure the quality of welding, the lines among the juncture of pipes are usually processed in the first step, then the welding is carried out. However, the lines are usually quite complicated. If the cutting job is done by hand, the workload will be very high. Now, to process pipe connecting trace, three steps are needed in most factories in home. Firstly, make the model. Then, draw the connecting trace and cut along the trace. At last, burnish the edge of the pipe. This method is not only low-efficiency but also low-quality[1]. Although numerical control cutting machines, such as flame cutting machine, Plasma arc cutting machine, laser cutting machine and so on, are equipped in many factories, numerical control programming is very difficult because of the variety of pipe connecting trace and their mathematical handling[2]. Now similar products in home have low technical performance and foreign products have a high cost, and what is more, most products can only process the pipe connecting trace between two pipes, which strongly restrict the development of pipe cutting industry. So it is urgent to develop numerical control cutting system[3].

The device developed in this paper aiming at the problems in present products which is based on the analysis of two pipes can process the situation of several pipes connecting together. Because it has so many advantages, such as easy-operating, high-efficiency and so on, it can fully meet the demands of factories.

1 The Principle of the Numerical Control Cutting System

Firstly, welding torch which is fixed up welding platform is moved to where the connecting trace will be cut by pulley. Then the composite movement between following x-axis's linear motion and the rotation of the pipe forms the connecting trace. All through the cutting process, welding torch is located at the peak of the pipe section z-axis, so the y-axis and z-axis weight is zero. The some increment need to be interpolated at the x-axis when a step angle is moved by the pipe. In this way, a connecting trace will be completed by x-axis's interpolation corresponding to pipe's rotation. The structure of the numerical control cutting system shows in Figure 1.
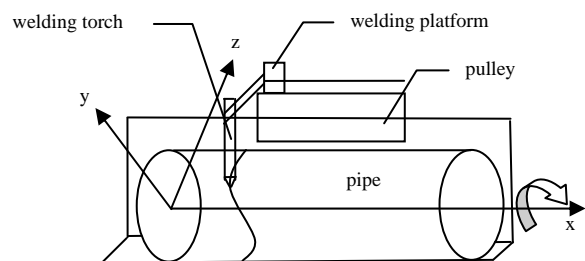

Figure 1. Sketch scheme of the structure of the numerical control cutting system

2 The Structure of the Hardware System

The cutting system is composed of industrial control computer and stepping motor control card. PCL-839+ which is adopted in this device, has three on-board pulse generators which is used to supply direction and pulse signals for three stepping motor respectively. The pulse frequency range is 1~200 kHz. The card supply positive-negative pulse control mode and pulse-direction control mode. There are also 16 input/output optically isolated TTL compatible channels[4]. They are used to output welding torch's on/off control signal. The implementing devices are made up with high-precision step motor and drivers corresponding to them. The structure of the platform of the hardware system is showing in Figure 2.
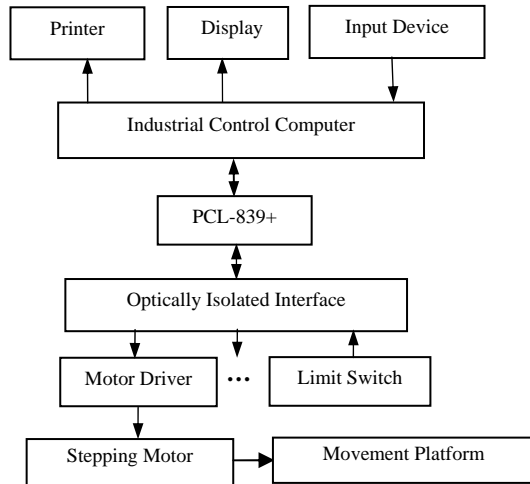

Figure 2. Structure of the hardware platform of the system

3 The Foundation of Mathematical Model of Pipe Connecting Trace

The general case between two connecting pipes is used to explain the mathematical model. Reference [5] is mainly referred here.

In Figure 3, R is the radius of the main pipe while r is the radius of the branch pipe. θ is the declinational angle between main pipe and branch pipe. e is the eccentricity between main pipe and branch pipe. P is a random point on the pipe connecting trace. α is the rotational angle of main pipe while β is the rotational angle of branch pipe. s is the distance between point P and fixed end on the main

pipe. l is the distance between point P and fixed end on the branch pipe . Point C is the nodal of axis between main pipe and branch pipe. S is the distance between point C and fixed end on the main pipe. L is the distance between point C and fixed end on the branch pipe.
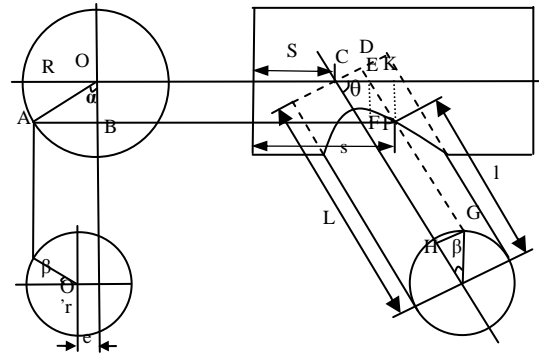

Figure 3. Sketch scheme of connecting trace between two pipes

$$R \cdot \sin \alpha = r \cdot \cos \beta + e$$
$$\alpha = \arcsin \frac{r \cdot \cos \beta + e}{R} \tag{1}$$
$$R \cdot \sin \alpha = r \cdot \cos \beta - e$$
$$\alpha = \arcsin \frac{r \cdot \cos \beta - e}{R} \tag{2}$$
$$l = L - DP = L - DE - EP$$
$$= L - \frac{r \cdot \sin \beta \cdot \cos \theta + R \cdot \cos \alpha}{\sin \theta} \tag{3}$$

$$s = S + CE + EK$$
$$= S + \frac{r \cdot \sin \beta}{\sin \theta} + \frac{R \cdot \cos \alpha}{tg \theta}$$
$$= S + \frac{r \cdot \sin \beta + R \cdot \cos \alpha \cdot \cos \theta}{\sin \theta} \tag{4}$$

α in formula (3) and (4) has to be replaced with formula (1) in the front half, and replaced with formula (2) in the behind half.

The derivation of the formulas above is based on the case of two pipes connecting together, which can be used as the basis to deduce formulas of multi-pipes connecting together. Firstly, calculate the set of processing lengths M, in the cases of single branch pipe connecting with main pipe and other branch pipes. To ensure all the pipe connecting traces can be welded together well corresponding to any degree of angle β, the peak on the connecting trace, that is the nearest point to the fixed point,

must be chose as an element of set M. Then choose the smallest value in every column of M to form a 1 dimension array N. The array N is the set of processing lengths of present branch pipe. Similarly, the set of main pipe and other branch pipes can also be calculated in the same way.

$$M = \left\{ \begin{array}{l} l_{11}, \quad l_{12}, \quad l_{13}......l_{1t} \\ l_{21}, \quad l_{22}, \quad l_{23}......l_{2t} \\ \qquad\qquad ... \\ l_{n1}, l_{n2}, \quad l_{n3}.....l_{nt} \end{array} \right\}$$

$$N = [l_{c_1 1}, \quad l_{c_2 2}, \quad l_{c_3 3}......l_{c_n t}]$$

n is the number of points divided in one circle, it is determined by the pulse-angle of stepping motor. t is the number of branch pipes. C_n is label of the row the smallest value lies.

To cut pipe connecting trace with stepping motors, set N has to be changed into other form. Here the incremental form is used to locate next cutting point.

$$\Delta l_t = l_{c_n (t+1)} - l_{c_{n\text{-}1} t}, (0 < t < n)$$

$$\Delta l_n = l_{c_1 1} - l_{c_n n}$$

$$N' = [\Delta l_1, \quad \Delta l_2, \quad \Delta l_3......\Delta l_n]$$

N' is the set of lengths welding torch moves. Changing the lengths into number of pulses and sending them to stepping motor control card, the pipe connecting trace can be cut out together with the pipe's rotation.

4 The Structure of the Software System

Lab Windows/CVI, developed by National Instrument Corporation, facing the area of computer measurement and controlling, is selected as the platform of software system. Like other developing software, all its files are organized in a project, such as source code write with C, include header files, user interface files and so on. Lab Windows/CVI also supplies several means to link with external code or software, such as DLL, DDE, ActiveX and so on[6]. It is the movement control functions, sup-

plied by stepping motor card in PCL839.LIB, are called to realize the control on stepping motor.

Friendly HMI (human machine interface), showing in Figure 4, is designed by means of Lab Windows/CVI's powerful graphic design interface. It is composed of a main process interface, parameters input interface and other promoting interface. A real-time tracking window is set in the main process interface to facilitate users' observation on the shape of the curve and the progress of the processing. Indicator lights and numeric window, used to indicate the number of present pulse, are also designed in the HMI, to ensure that users are clear about the situation of the device. Additional, to deal with emergent situation, buttons to realize functions like recur and emergent stop are also added to HMI. Before processing, users have to input a list of parameters, such as diameters, thickness, length of pipe, rate of processing and so on, in the parameters input interface. Promoting interfaces are used to feedback the present status of the device.
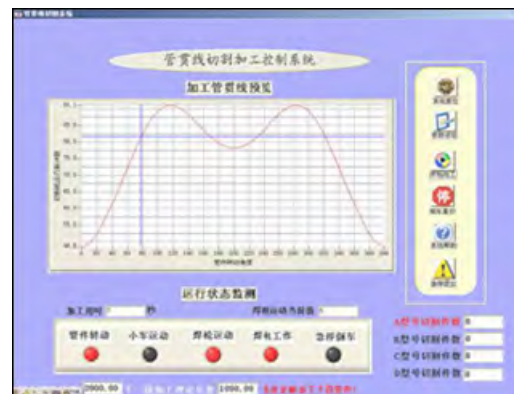

Figure 4. HMI of the system

DDE (Dynamic Data Exchange) technology is used to process data. As an important character, DDE is a protocol in fact. It is used to exchange data between programs. It allows applications to execute data exchanging and remote order with windows messages, all what is needed just the way to found the link for data exchanging, then applications will exchange data automatically[7]. The detail process is that，first of all, write parameters of the pipe into Excel, calculate the results according to the formulas. Then read the number of pulses back to Lab Windows/CVI, call the movement function to finish the

cutting. The number of pulses is saved in Excel, which may be used to process the same connecting trace next time. The key program refers to the operation of DDE is shown below.

```
//Set up hotlink with some cell in Excel
SetUpDDE-
HoLink(datalink,"R5C12:R5C68",CF_TEXT,5000);
//Write parameters into the cell
ClientDDE-
Write(datalink,"R5C12:R5C68",CF_TEXT,&cellValstr,strlen(c
ellValstr),0);
// Set up hotlink with cells processing parameters lie
SetUpDDEHot-
Link(datalink,"R16C2:R415C2",CF_TEXT,5000);
//Read back the number of pulses from Excel
for(i=16;i<=415;i++)
{
    //Initialize the members with 0
    memset(cellValstr,48,sizeof(char)*14);
    strcpy(index,"R");
    Fmt(xuhao,"%s<%d",i);
    strcat(index,xuhao);
    strcat(index,"C2");
    strcat(index,"\0");
    //Read the value of some cell
    ClientDDERead(datalink,index,CF_TEXT,cellValstr,15,0);
    sscanf((char*)cellValstr,"%lf",&cut_pulse_len[i-16]);
}
```

Because the cutting process occupies too much resource of the system, uses' operation can't be responded or the screen can't be refreshed in time. To solve these problems multithread technology is adopted in the program. Multithread is several threads running in a process, that is to say, several tasks are executing in an application. Multithread has many advantages, such as preventing blocks, decreasing the interaction between running process and user interface, playing the multiprocessor's capability to the most degree and so on.

The cutting machine selected in the system is Oxya cetylene because of the requirement of technology. On one hand, if the cutting rate is too high, it is difficult to cut through the pipe. On the other hand, the edge and corner will be melted if the rate is too low. So, during the progress of cutting the rate must be kept constantly. According to the length welding torch moves, the thickness and diameter of the pipe to regulate the rate pulses are sent out dynamically, which keeps the cutting rate constant. The flow chart of the software system is shown in Figure 5.
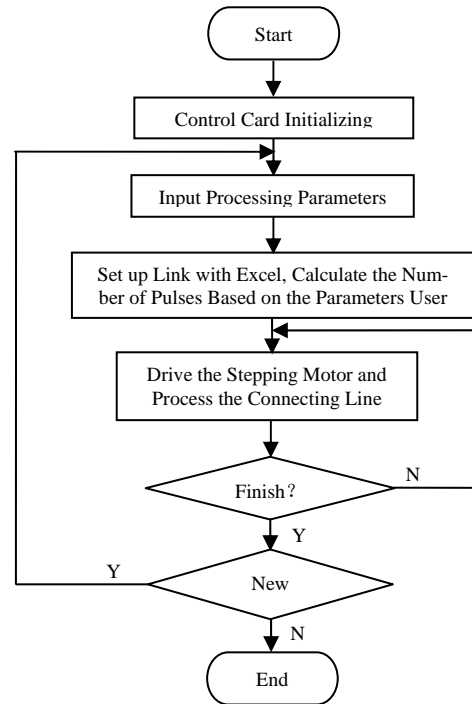

Figure 5. Flow chart of the software system

5 Conclusions

Aimed at the difficulty lies in the area of pipe connecting trace processing, mathematical model is founded, and computer systematic integrating technology is adopted to construct the numerical control system. Practice shows that the system can finish cutting task accurately and efficiently, which satisfied the demand of control over movement. The hardware and software of the system are open to the users, which is convenient for the users to carry out maintenance and upgrade.

References

[1] Wang Lingqi.The Method of Cutting Trace Control for Intersecting Lines[J].Mechanical Engineer,2003,(2):21-22.
[2] Li Li.Mathematic model of pipe intersecting line NC cutting and its automatic programming system developed[J]. Electromaching & Mould, 2001,(6):35-38.
[3] Ge Guozheng.Design of NC flame cutting machine applied on pipe intersection line[J].Welding Technology, 2006, Vol.35(2):

45-47.

[4] Dang Pengpai.Application of Stepping Motor Controllor PC -839[J] Small & Special Electrical Machines, 2005, Vol.33 (1): 32-35.

[5] Tang Yonggui.Reckoner Enchiridion of Plate Metalwork Outspread [M].Beijing:Metallurgical Industry Press, 2002.1.

[6] Wang Jianxin,Yang Shifeng,Sui Meili.Measuring Technology and Engineering Application Based on Lab Windows/CVI[M]. Beijing:Chemical Industry Press, 2006.

[7] Liu Junhua.Design of Virtual Instrument Based on Lab Windows/CVI[M]. Beijing:Publishing House of Electronics Industry, 2003.