

# Application of PLC in Pneumatic Measurement Control System

WanJun Zhang<sup>1, 2, 3, 4, \*</sup>, Feng Zhang<sup>1, a</sup>, Jingxuan Zhang<sup>1, b</sup>, Jingyi Zhang<sup>2, c</sup> and Jingyan Zhang<sup>2, d</sup>

<sup>1</sup>Quanzhou Institute of Information Engineering, Fujian 362000, China

<sup>2</sup>Qingyang Xinyuan Engineering Co., Ltd., Gansu 745000, China

<sup>3</sup>Lanzhou Industry and Equipment Co, Ltd, Gansu 730050, China

<sup>4</sup>Xian Jiao tong University, 710049, Shanxi, China

\*Corresponding author e-mail: gszwj\_40@163.com, <sup>a</sup>zhangwanjun40@163.com,

<sup>b</sup>gszhangwj40@163.com, <sup>c</sup>tszhangwj40@163.com, <sup>d</sup>116543048@qq.com

**Abstract.** Aiming at the complicated structure and poor applicability of traditional pneumatic measurement control system, a method of pneumatic measurement PLC and inverter control is given. Firstly, based on the brief introduction of pneumatic measurement control, the PLC and inverter control system is established, then the control of pneumatic measurement is realized through PLC control, and finally the pulse encoder counting and collecting data are dynamically detected by means of frequency conversion speed control. Automatic control system is established by PLC technology, which is feasible and effective in practical application. Experimental results show that the mathematical expression of the system is consistent with the results of image simulation. The controller is running well and meets the requirements of pneumatic measurement control.

## 1. Introduction

The traditional pneumatic control technology mostly uses relay CNC servo control system. Usually, the mathematical model of controlled object of CNC servo control system is generally unknown. Aiming at multi axis CNC servo control system, Lanzhou Industry and Equipment Co. Ltd, Lanzhou University of technology researchers [1-19] proposed an NURBS algorithms which based on real-time interpolation and compensating error. When using modern control theory and intelligent control to control, it is necessary to know the mathematical model of the system accurately.

The traditional pneumatic control technology mostly uses relay contactor control, which has the disadvantages of large volume, many mechanical contacts, complex wiring, and many faults. If the control system adopts the traditional control method, the motor drag loss energy will be about 30% of the original, which will seriously waste electricity, making the air compressor prone to failure and reducing its service life. Due to the reliability and convenience of PLC control system, it has been widely used in CNC machine tools and has replaced the early relay control loop system. PLC [2-23] uses various types of switches and sensors to achieve control by allocating I/O points.

Pneumatic measurement [24-26], it is a kind of non-contact measurement. It has high accuracy, small measuring power, and has a self-cleaning effect on the workpiece under test, and is not affected



by the surface material of the workpiece. PLC controls the use of compressed air as a medium, using the characteristics of the flow or pressure of air in the pipe to change with the gap between the nozzle and the workpiece to convert the size or displacement into the flow change or pressure change signal. Measurement.

However, in recent years, many experts and scholars at home and abroad have put the main research directions on PLC programming and hard software research and pneumatic measurement. [27-29], literature [24-26] the structure and control method of pneumatic measurement of workpiece are given, but its applicability in differential pressure pneumatic measurement is poor. Documentation [30-38] the control structure of PLC is complex and its applicability is not strong.

This paper presents a control system for the application of PLC and inverter in pneumatic measurement technology. The control system is stable, safe and reliable, and easy to operate. Finally, the experimental results show that the mathematical expression of the system is consistent with the results of image simulation. The controller is running well and meets the requirements of pneumatic measurement control.

## 2. Working principle of pneumatic measurement system

Differential pressure pneumatic measurement gas path diagram [2], as shown in Figure 1. After the compressed air from the gas source 1 through the filter 2, the air intake valve 3 and the regulator 4, there is a constant pressure  $P_c$ , the adjustable flow valve 5 and the-measurement nozzle 6. And ... At the time of measurement, the backpressure gas path is under the same environmental pressure and temperature, so that the impact of the external environment (pressure, temperature, humidity, etc.) on the measurement is minimized, and the measurement accuracy is high and the stability is good. The difference in the force of the flow formula of the two cavities through a sub-critical state of a section according to fluid mechanics knowledge is:

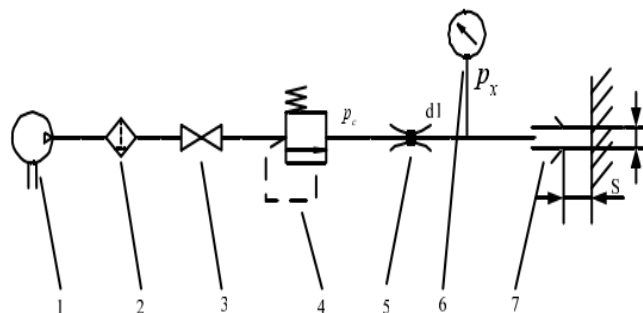
The basic principle of pneumatic measurement is introduced with pneumatic back pressure pneumatic measuring system, and the schematic diagram is shown as follows:

$$\Delta P = P_c - P_x \quad (1)$$

$$\Delta P = f(S) \quad (2)$$

In the formula:  $P_c$ -adjust zero cavity pressure;  $P_x$ -Measurement cavity pressure.

In general, the adjustable flow valve is constant during the measurement process after adjusting the back pressure  $P_c$  before measurement, that is, the  $P_c$  is a constant. The measurement cavity pressure  $P_c$  changes with the change of measurement gap  $s$ .  $\Delta P$  is detected by Silicon pressure resistance differential pressure sensor 10 as the measured signal, and the size of the measured parameter  $s$  can be measured after the output is amplified.



1. Gas sourcer, 2. Filter, 3. Intake valve, 4. Gas sourcer, 5. Orifice, 6.  $p_x$ , 7. Orifice spacing.

**Figure 1.** Bad press type spirit move to measure spirit road principle diagram.

When the back pressure  $p_x$  gradually drops from  $p_c$  to  $p_x \geq 0.0894 \text{ MPa}$ ; the main nozzle is subcritical under the condition III, and the gas flow velocity at the baffle is in a critical state. According to fluid dynamics knowledge, the flow rate  $g_1$  through the main nozzle and flow through the baffle are  $g_2$ , respectively:

$$g_1 = C_1 \frac{\pi d_1^2}{4} \sqrt{2g p_c \gamma_c \left[ \left( \frac{p_x}{p_c} \right)^{\frac{2}{m}} - \left( \frac{p_x}{p_c} \right)^{\frac{m+1}{m}} \right] \frac{m}{m-1}} \quad (3)$$

$C_1$ —the flow coefficient at the orifice (main nozzle);

$d_1$ —orifice diameter;

$p_c$ —work pressure (absolute pressure);

$p_x$ —back pressure (absolute pressure);

$m$ —the constant entropy index, for air;

$\gamma_c$ — $p_c$  under the severe gas.

$$g_2 = c_2 \pi d S \left( \frac{2}{m+1} \right)^{\frac{1}{k-1}} \sqrt{2g \frac{m}{m+1} p_x \gamma_x} \quad (4)$$

Where,

$$g_2 = c_2 \pi d S \sqrt{2g \frac{m}{m-1} p_x \gamma_x \left[ \left( \frac{p_0}{p_x} \right)^{\frac{2}{m}} - \left( \frac{p_0}{p_x} \right)^{\frac{m+1}{m}} \right]} \quad (5)$$

$d$ —measuring nozzle diameter;

$c_2$ —flow coefficient at nozzle baffle;

$S$ —clearance at nozzle baffle;

$\gamma_x$ — $p_x$  Lower gas severity;

$p_0$ —atmospheric pressure (absolute pressure).

According to the principle of continuous flow,  $g_1 = g_2$  is substituted by the gas equation of state

$\frac{\gamma_c}{\gamma_x} = \frac{p_c}{p_x}$  into formula  $g_1 = g_2$  and simplified

$$p_x = p_c \left[ \frac{1}{2} + \frac{1}{2} \left( 1 + 4 \frac{A^2}{B_1^2} S^2 \right)^{\frac{1}{2}} \right]^{\frac{m}{1-m}} \quad (6)$$

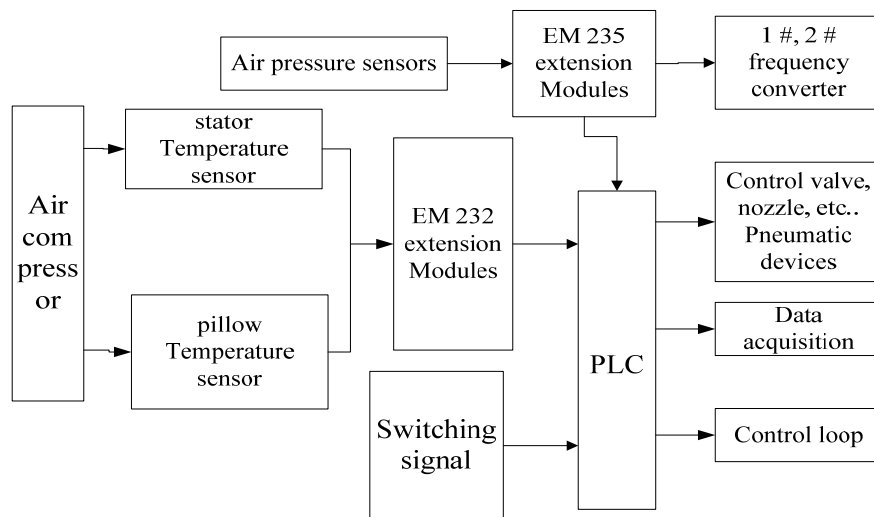
Among them:

$$A = \frac{c_2 d}{c_1 \frac{d_1^2}{4}}, \quad B_1 = \frac{\sqrt{\frac{m+1}{m-1}}}{\left( \frac{2}{m+1} \right)^{\frac{1}{m-1}}} \quad (7)$$

### 3. Control Method for Pneumatic Measurement System

The pneumatic control system consists of the following parts: PLC, inverter (1 # and 2 #), motor, compressor, Relay, switch, button, Transformer, Extender (EM235 and EM232), air pressure sensor, stator temperature sensor, bearing Sensors, data acquisition devices, etc., the system structure as shown in Figure 2.

The control system uses the decompression gas  $\Delta p$  as the control object, uses the long-distance air switch to detect the pressure  $p_x$ , and the inverter is fed into the standard pressure  $p_c$  to convert it into an electrical signal, and is sent to the A/D transformation module for modular conversion. Then the PLC compares the detected pressure value with the pressure setting value. According to the pressure difference  $\Delta p$ , the resulting control signal  $f$  is equivalent to the measured gap  $s$  of the nozzle baffle and is sent to the inverter to control the speed of the motor. In order to make the pressure close to the set value, the inverter controls the pneumatic measurement device.

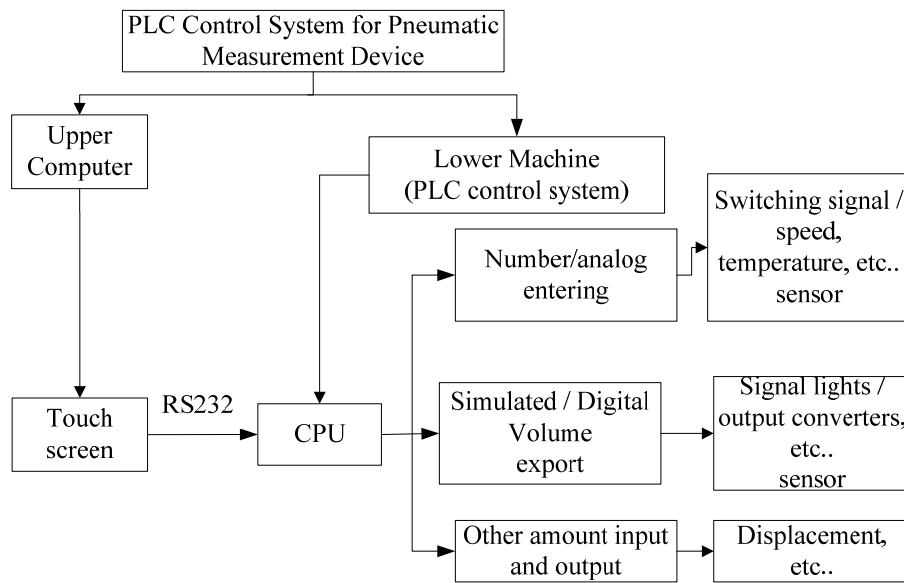


**Figure 2.** Pneumatic measurement PLC system diagram.

## 4. Design of Control System Hardware Pneumatic Measurement Device

### 4.1. Pneumatic measurement device control system hardware

The pneumatic measurement device PLC control system consists of two parts: the upper computer and the lower machine. The upper computer consists of a touch screen. The lower machine (PLC control system) includes the CPU and the number/analog input, the number/analog output, and other modules. Used to control air pressure, temperature and speed to achieve pneumatic measurement control, the composition of the system is shown in Figure 3.



**Figure 3.** PLC control system diagram.

#### 4.2. Distribution of PLC I/O points for pneumatic measuring devices

According to the requirements of pneumatic control measurement, Siemens PLC S7-300 CPU 224 was selected as the control core, and an EM235 was expanded as an analog input module to achieve the conversion of analog and digital quantities. The input signals were collected by multi-channel switches, and the pressure velocity was measured using a digital filter. The output signal of the pressure sensor is converted from the standard signal of the pressure transmission controlled by the EM235 to 0 to 5 volts to complete the distribution of the EM235 I/O point, and the control inverter makes the pulse encoder count. EM232 is an input/output extension module of I/O.

It has four I/O input points and can meet the extended use of pneumatic measurement. Finally, according to the capacity of each unit, a suitable power supply module CQM1-PA203 is selected to provide 24VDC power supply for PLC. The allocation of PLC I/O points is a necessary preparation before PLC programming, and the allocation of PLC I/O points corresponds to the designed system hardware. The distribution table of PLC I/O points for pneumatic measurement devices, as shown in Table 1, lists the PLC ladder maps for pneumatic measurement. After programming, they can be downloaded from dedicated communication cables to PLC [9-15], running PLC program to achieve the distribution of PLC I/O points for pneumatic measurement devices.

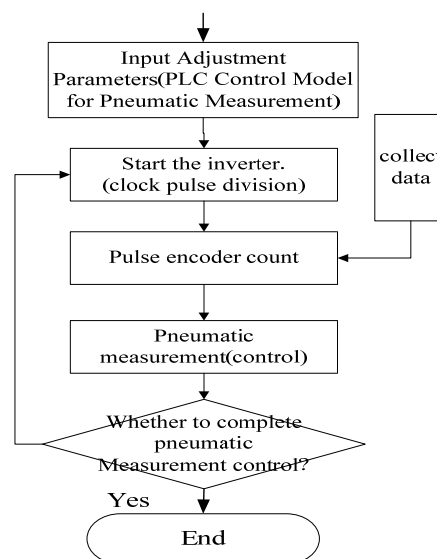
**Table 1.** Wind power generator PLC I/O allocation table

Input device	Enter point number	Output Name	Output point number
Start button	X <sub>0</sub>	Hand / Automatic Signal	Y <sub>30</sub>
Stop button	X <sub>10</sub>	1 # inverter signal	Y <sub>1</sub>
Hand / Auto conversion	X <sub>1</sub>	1 # Electrical indicator	Y <sub>2</sub>
Air pressure switch	X <sub>2</sub>	1 # Air compressor indicator light	Y <sub>3</sub>
Speed switch	X <sub>3</sub>	2 # inverter signal	Y <sub>5</sub>
Stator switch	X <sub>4</sub>		
Encoder 1	X <sub>5</sub>		
Encoder 2	X <sub>6</sub>		

## 5. Design of Control System Hardware and Software for Pneumatic

### 5.1. PLC Control System Software Design

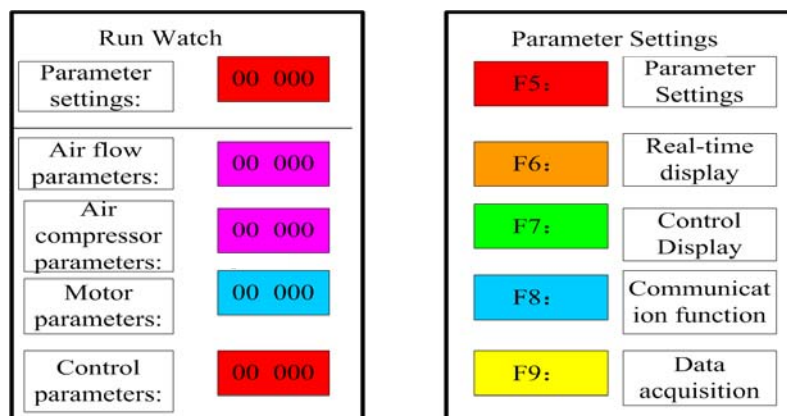
The software design of this control system is mainly the design of PLC pneumatic measurement principle control. The pressure transmitter measured that the pressure value  $p_x$  was converted by the extended module EM235 modulus, and the pressure difference  $\Delta p$  was converted by the EM235 modulus, and the pressure difference  $\Delta p$  was obtained by comparing the PLC with the zero-cavity pressure PC and the measuring cavity pressure  $p_x$ . The resulting control signal  $f$  is equivalent to the measurement of the gap  $s$  of the nozzle baffle, and is input to the inverter. The frequency converter count compares the pressure value to complete the pneumatic measurement.



**Figure 4.** Flow chart of PLC software control.

### 5.2. Interface design for touch screen

According to the key points of the touch screen PLC setting, the PLC touch screen software design, as shown in Figure 5. Press the function key "F0" to show the PLC running monitoring screen in the display window; Press the function key "F1" to show that the PLC operation parameter setting screen appears in the window.



**Figure 5.** Block Diagram of touch screen software settings.

## 6. Experiment simulation and analysis

In this study, pneumatic measurement is controlled in a PLC-controlled environment in the laboratory. The pneumatic measurement exists in the following relations  $\Delta P = P_c - P_x$  and  $\Delta P = f(S)$ , so that  $f = f(S)$  can obtain the measured differential pressure  $f = f(S)$  and the data for measuring the gap between the nozzle baffles as shown in table 2. The experimental installation platform is shown in Figure 6.

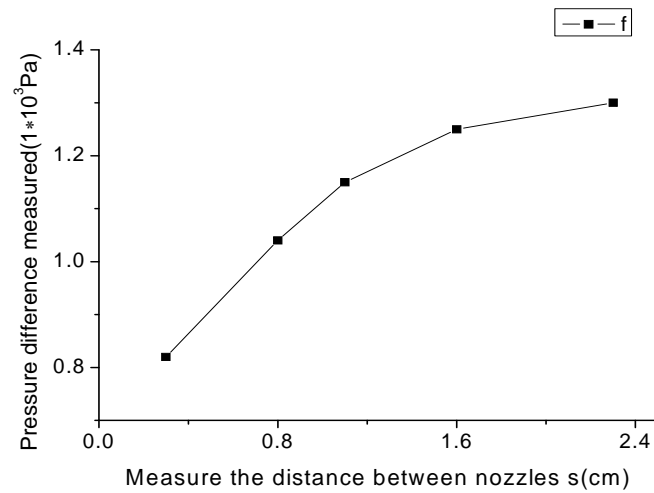


**Figure 6.** Experimental platform.

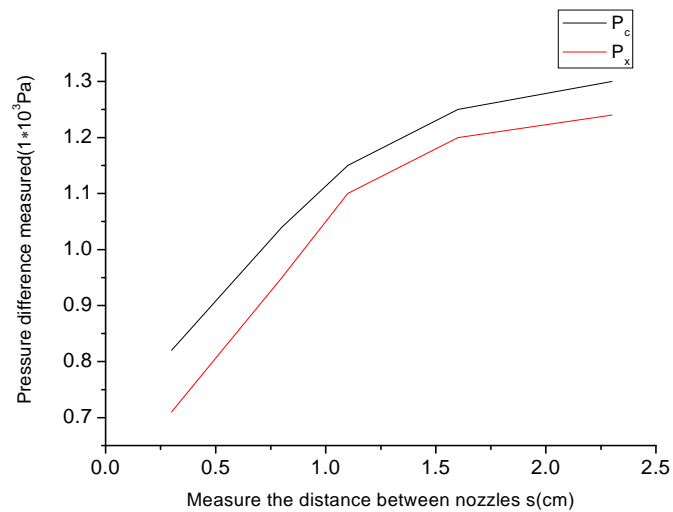
**Table 2.** Experimental data sheet

$s(cm)$	$f(1000pa)$
0.3	0.82
0.8	1.04
1.1	1.15
1.6	1.25
2.3	1.30

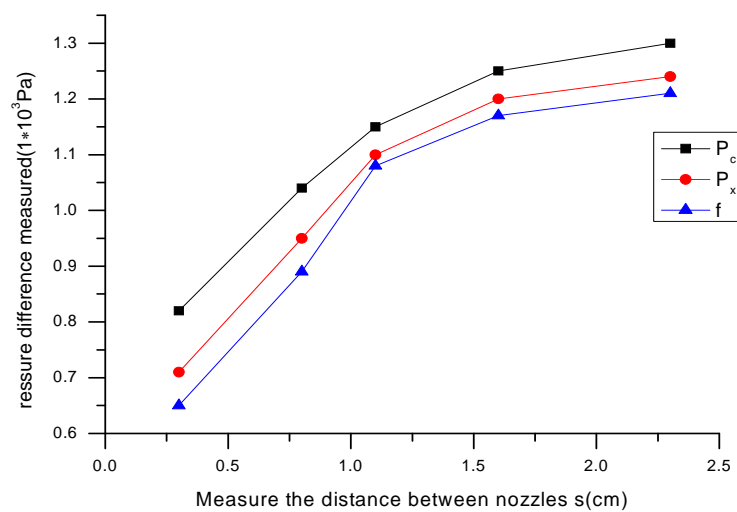
The pneumatic measuring device was chosen as the experimental equipment. The main nozzle diameter is 0.3, and the rated pressure is obtained from the experimental data.  $s - p_c$  and  $s - p_x$  baffle gap-pressure composite comparison map,  $s - f$  baffle gap-pressure difference map, as shown in Figures 7, 8 and 9.



**Figure 7.** Fender clearance-measurement of gas.



**Figure 8.** Flapper gap-pressure difference chart.



**Figure 9.** Comparison chart of gap pressure plate.



The pneumatic measuring device motor is started at 0.24 m/s. The pressure increases as the speed increases. When the speed is increased to a certain degree, the pressure difference curve is close to a straight line, indicating that the pressure has reached the rated pressure and meets the needs of the establishment of the control curve of the pneumatic measurement device. The realization results show that the controller is running well and meets the requirements of pneumatic measurement control.

## 7. Summary

(1) On the basis of pneumatic measurement, a control system of PLC and inverter was established. The control system used the decompression gas  $\Delta p$  as the control object, used the long-distance air switch to detect the pressure  $p_x$ , and the inverter was fed into the standard pressure  $p_c$  to convert it into an electric signal. The A/D conversion module is sent to the modulo conversion, and then the PLC compares the detected pressure value with the pressure setting value. According to the pressure difference  $\Delta p$ , the resulting control signal  $f$  is equivalent to the measured gap  $s$  of the measurement nozzle baffle. The input converter controls the speed of the motor, so that the pressure is close to the set value, so that the inverter controls the pneumatic measurement device, which has a strong reference in the pneumatic measurement.

(2) The system software design mainly includes two parts: the upper computer and the lower computer. The upper computer monitors the touch screen, and the touch screen software design realizes the visualization operation of human-computer interaction. The lower machine controls the PLC system, receives the field status detection signals, realizes the control of the pneumatic measurement device, dynamically detects the pulse encoder count and collects the data information. The software is adaptable and universal, and can be used in some PLC control systems.

(3) Experiments show that the mathematical expression established by the measurement system is consistent with the results of image simulation; the controller is running well and meets the requirements of pneumatic measurement control.

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Author: Wanjun Zhang received the, M.S. and Ph.D. degrees from, Lanzhou University of technology, Xi'an Jiaotong University, in 2011 and 2018, respectively. I am currently an associate professor in the School of Mechanical Engineering, Xi'an Jiaotong University, I am currently an Senior Engineer and Senior economist in Lanzhou Industry and Equipment Co., Ltd. His research involved in artificial intelligence, NC, control of complex mechatronic system and failure diagnoses.

First author (communication author): Zhangwanjun, male, born in 1986, doctoral student in engineering(bachelor's degree in law and management), professorial senior engineer, senior economist (mechanical engineer, CNC senior craftsman), Senior member of China Society of Mechanical Engineering, Senior member of China Agricultural Machinery Society, Senior member of the China Agricultural Machinery Engineering Society, senior member of the China Instrument Instrument Society, member of the China Invention Society, director of the China Invention Society, director of the Gansu Invention Society, member of the Standing Committee of the Committee of Experts of the Modern Manufacturing Engineering (Chinese Core, Science and Technology Core), member, and review expert. Mainly engaged in numerical control technology equipment, new energy research and electromechanical transmission control work. We have authorized more than 250 patents for invention and utility models as the first applicant (patentee) and inventor, and nearly 200 patents for design as the first applicant (patentee) and inventor, and published more than 50 academic papers in core or above journals. SCI/EI/ISTP has more than 40 searches papers, including more than EI 30 papers, SCI 5 papers. Email: gszwj\_40@163.com.

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