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Research on the Platform for Measuring Accuracy of Plunger Metering Pump

Yan Shi[1, a], Kang Liu[1, b], Yun Xu[1, c], Yinghua Liao[1, d] and Hao Pi[1, e]

[1]School of Mechanical Engineering, Sichuan University of science and engineering, Zigong, China.

[a]sy71email@163.com, [b]315381847@qq.com, [c]1214004131@qq.com, [d]191151820@qq.com, [e]976420823@qq.com

Abstract

Metering pump is a special pump specially used for accurate measurement of fluid, which can be used for the measurement of flammable, explosive, highly toxic, high viscosity and low viscosity fluids, as well as for the measurement of complex fluids such as crude oil, brine and other solid-liquid mixtures. With the improvement of automatic control requirements in the production process, more strict standards are put forward for the metering pump. In this paper, the mechanical structure of the plunger metering pump is studied. Aiming at the improvement of the metering accuracy by PLC control, an effective experimental device is built to test the metering accuracy of the metering pump.

Keywords

Metering pump, precision control, experimental platform.

1. Introduce

Metering pump is a kind of reciprocating pump, which is specially used for high-precision metering of liquid transportation. It undertakes the metering and adding task of strong corrosive, toxic, high viscosity and high-pressure medium in the process. At present, it has been widely used in the fields of biopharmaceutical, sewage purification, petroleum processing, food production, environmental protection and so on. It has become an indispensable fluid machinery in the process industry. At present, most of the metering pumps focus on the design of traditional mode, that is, with gear and crank connecting rod as the structural form of transmission mechanism, the volume is huge and the structure is complex. According to the rated measurement range, this paper designs the principle of the plunger type metering pump experimental device, and builds the experimental device. In the design and construction of the experimental device principle, the factors such as safety and environmental protection can be considered, and the experimental device can be debugged. According to the debugged experimental device, the main parameters affecting the metering accuracy of the metering pump are analyzed. The output parameters of the metering pump under different parameters are tested Data: according to the experimental data, eliminate the experimental data with large error, analyze the effective data based on the principle of statistics, analyze the influence of input frequency and dwell time on the performance of metering pump, find out the influence mode of each parameter, and get the corresponding functional relationship. At the same time, find out the optimal dwell time by measuring the change rule of oil output at different dwell time, In order to control the flow stability of the metering pump and provide theoretical basis for the error compensation of the metering pump accuracy, the operation characteristics and effective conclusions of the metering pump are obtained in the form of charts or tables, and reasonable suggestions for the engineering design are put forward.

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2. Metering Accuracy of Metering Pump

The metering accuracy of the metering pump is a response to the recurrence or dispersion of the flow change of the pump under the specific working conditions. The high metering accuracy of the metering pump indicates that the flow has good recurrence or small dispersion. Similarly, the low metering accuracy indicates that the flow of the pump has poor recurrence or large dispersion. The metering accuracy of the metering pump can be obtained shown as Eq1.

$$E = \pm \frac{K}{Q_m} \sqrt{\sum_{i=1}^{n} (Q_i - Q_m)^2 / (n-1)} \times 100\% \tag{1}$$

Where,

E—Measurement accuracy,K—Coefficient, based on the number of measurements shown as table 1,n—Measurement times,Qm—Arithmetic mean of N times flow measurement value,shown as Eq2.

$$Q_m = \frac{\sum_{i=1}^{n} Q_i}{n} \tag{2}$$

Where,

Qi—The ith flow measurement.

When calculating the metering accuracy of the metering pump, generally n = 10. At this time, look up table1 to get k = 3.25.

Table 1. Coefficient table

n	5	6	7	8	9	10	15	20	25	30	40
K	4.60	4.03	3.71	3.50	3.36	3.25	2.98	2.86	2.80	2.76	2.70

For the metering pump, since the flow can be adjusted within the range of 0-100%, the metering accuracy corresponding to different flow is also different, and the rule of metering accuracy and relative stroke change is shown in Figure 1. When the relative stroke is small, the value of measurement accuracy e is large, and decreases with the increase of relative stroke s / Smax. At this time, the flow of the metering pump has good reproducibility and small dispersion. When the relative stroke increases to about 35%, the measurement accuracy tends to be stable, and its stable value is near e = 1. When the relative stroke reaches the maximum stroke, the measurement accuracy does not change significantly, so in phase When the stroke is in the range of 35% - 100%, the flow of metering pump has poor reproducibility and large dispersion.

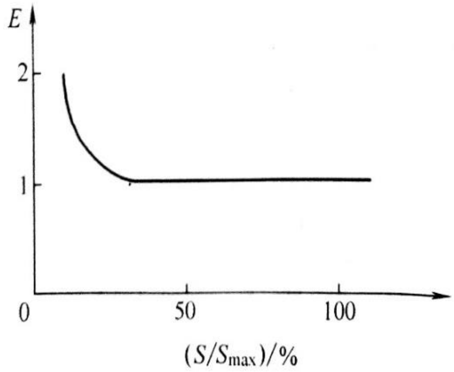

Fig 1. Law of measurement accuracy change

In general, the metering accuracy of the metering pump is the accuracy when the flow is at the maximum. There are three main factors that affect the measurement accuracy. They are the accuracy of the flow regulating mechanism, the accuracy of the indicated value, the design accuracy of the hydraulic end, the rationality of manufacturing, the machining accuracy and the rationality of the pipeline system design

3. Experimental Device

When the input frequency is in the range of 1100-1900hz, study the influence of frequency on the flow and delivery volume of metering pump, design the experimental scheme and carry out the experiment; when the input frequency is in the range of 1000-1700hz and the residence time is in the range of 10-60s, study the influence of residence time on the left and right oil delivery time of metering pump under different frequencies, design the experimental scheme and carry out the experiment. Test the output parameter data of the metering pump under different parameters; according to the experimental data, eliminate the experimental data with large error, analyze the effective data based on the principle of statistics, obtain the operation characteristics and effective conclusions of the metering pump in the form of chart or table, and put forward reasonable suggestions for the engineering design.

3.1. Principle of Experimental Device

The high-precision metering pump experiment platform is mainly composed of two single cylinder double acting metering pumps, pipeline system, PLC control system, detection and measurement system and oil tank. The metering pump used in the experiment is refitted from the common plunger metering pump, which has the characteristics of good sealing effect, stable oil output during operation, large pressure bearing capacity of the cylinder block, and more oil output in one stroke, etc.; through the combination of sensor and PLC controller, the metering automation of the metering pump is realized, and the error caused by the operation of personnel is reduced; the metering accuracy is high, the metering range is wide, and the response is sensitive The experimental data can be read and displayed directly by computer, which is convenient and accurate.

The experimental device is shown in Fig.2.

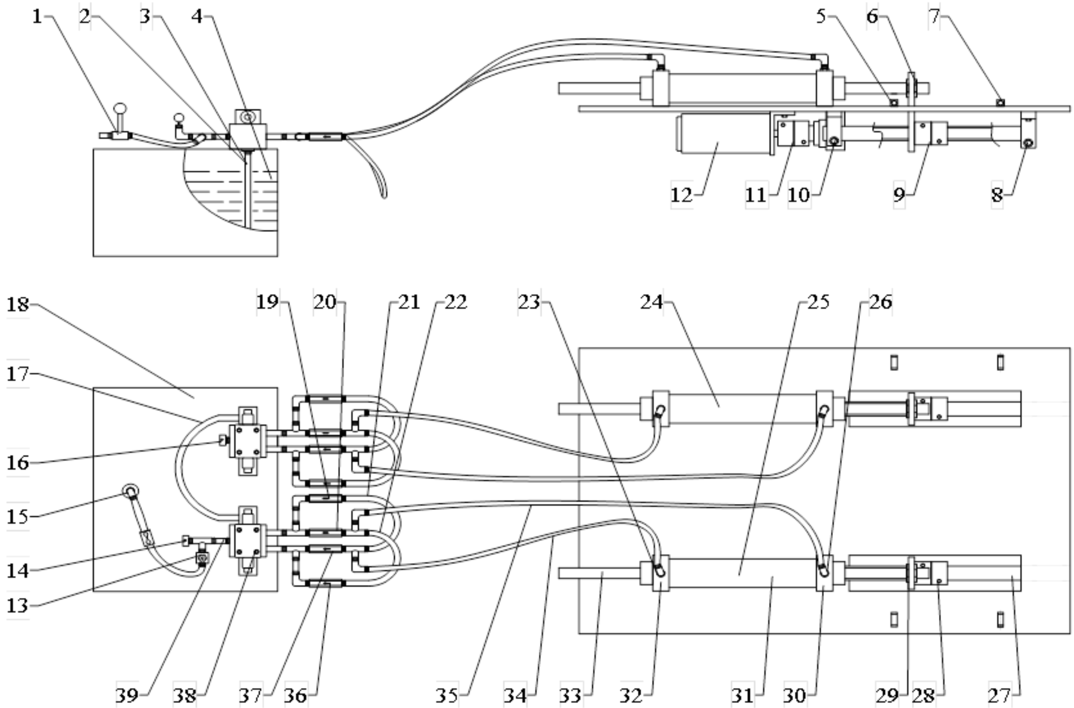

Fig 2. The experimental device

1—turbine flowmeter, 2—pump 1 oil inlet pipe,3—pump 2 oil inlet pipe, 4—wear-resistant hydraulic oil, 5—left proximity switch, 6—compression nut,7—right proximity switch,8—screw support seat (right), 9—drive connector, 10—screw support seat (left),11—coupling,12—stepping motor,13—overflow valve,14—shock proof pressure gauge 2,15—total oil outlet,16—shock proof pressure gauge 1,7—pump 1 oil outlet pipe,18—Oil tank,19—suction check valve 1,20— suction check valve 2,21—left suction pipe of pump 2,22—right discharge pipe of pump 2,23—left oil inlet and outlet of pump 2, 24—metering pump 1,25—metering pump 2,26—right oil inlet and outlet of pump 2,27—screw rod,28—solid screw,29—connecting plate,30—right end cover of pump 2,31—hydraulic cylinder,32—left end cover of pump 2,33—piston rod,34—left oil inlet and outlet pipe of pump 2,35—Oil inlet and outlet pipe on the right side of pump 2,36—discharge check valve 1,37—discharge check valve 2, 38—solenoid valve,39—oil outlet.

The experimental platform is composed of two sets of metering pump systems. When the equipment works normally, the metering pump 2 operates continuously. When it moves to the travel stop to accelerate and decelerate, the metering pump 1 starts to move to compensate. Because the metering pump is single cylinder and double acting, when it works, one end of the oil inlet and one end of the oil outlet. When the step motor 12 drives the piston rod 33 of the metering pump 2 to move to the left through the screw rod 27, the liquid is discharged from the left side of the pump and inhaled from the right side. At this time, the pressure on the left side is constantly increasing. When the pressure difference increases to 0.5bar, the drain check valve 37 is opened, and the liquid in the hydraulic cylinder 31 is discharged into the oil pipe 34 through the oil inlet and outlet holes 23 on the end cover 32, and then flows out of the oil outlet 39 of the three position four-way solenoid valve 38 through the opened check valve 37. Finally, it is discharged into the oil tank 18 through the turbine flowmeter 1 and the main oil outlet for recycling, Discharge the liquid. In this process, the turbine flowmeter 13 completes the data collection and transmits it to the computer; the pressure of the discharged liquid can be adjusted by the overflow valve 13, and the adjusted pressure can be read on the pressure gauge 14. At the same time, the pressure on the right side is constantly decreasing, forming a negative pressure in the cylinder. When the pressure difference increases to 0.5bar, the suction check

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valve 20 is opened, and the hydraulic oil in the oil tank 18 is sucked through the oil inlet pipe of the pump 2, then it is controlled by the solenoid valve to enter the oil inlet and outlet pipe 35 on the right side of the pump 2 through the opened check valve 20 and the elbow, and enter the hydraulic cylinder at the oil inlet and outlet port 26 on the right end cover 30 to complete the liquid suction work. When the connecting plate moves to the left to approach the switch 5, the switch sends a signal to the PLC control system to control the step motor 12 to move in the opposite direction, so that the screw rod 27 drives the piston rod 33 of the metering pump 2 to move to the right.

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When the piston moves to the right, the left side of the pump draws in the liquid and the right side drains the liquid. At this time, the pressure on the right side of the hydraulic cylinder 31 increases continuously. When the pressure difference in the pipe reaches 0.5bar, the drain check valve 36 opens. The liquid in the right side of the hydraulic cylinder enters the oil pipe 35 through the inlet and outlet ports 26 on the right end cover 36, and then enters the three position four-way solenoid valve 38 through the elbow and the transition oil pipe 22, and then enters the three position four-way solenoid valve 38 through the opened drain check valve 36, and flows out from the oil outlet 39 backward, the most After that, it is discharged into the oil tank 18 through the turbine flowmeter 1 and the main oil outlet for recycling, so as to complete the liquid discharge. At the same time, the pressure on the left side gradually reduces to form a negative pressure. When the pressure increases to 0.5bar, the suction check valve 19 is opened, and the hydraulic oil in the oil tank 18 is sucked through the oil inlet pipe of the pump 2. Then, it is controlled by the solenoid valve to enter the oil inlet and outlet pipe 34 on the left side of the pump 2 through the opened check valve 19 and the transition oil pipe 21, and enter the left side of the hydraulic cylinder at the oil inlet and outlet port 23 on the left end cover 32 to complete the liquid suction work. When the connecting plate moves to the right near the switch 7, the switch sends a signal to the PLC control system to control the stepping motor 12 to change the rotation direction, so that the piston moves to the left. Through this control method, the metering pump can continuously carry out reciprocating motion to realize the continuous oil output of the metering pump.

When the metering pump 2 moves to the position close to the left and right stop points, its piston will slow down and stop first, and then accelerate. During this period, the large change of the piston movement speed will change the discharge flow and volume of the metering pump 2, affecting the metering accuracy. In order to compensate the error in this period, start the metering pump 1 for liquid suction and discharge, that is, when the proximity switch senses the connecting plate, the switch sends a signal to enable the PLC control system to control the step motor of the metering pump 1 to start, so that the metering pump 1 enters the normal working state, and the liquid suction and discharge. The liquid discharged from the metering pump 1 flows into the solenoid valve 38 through the oil outlet pipe 17, and returns to the oil tank through the turbine flowmeter 1 together with the liquid discharged from the metering pump 2. During this process, the pressure of the liquid discharged from metering pump 1 is read by pressure gauge 16. This way can ensure the measurement accuracy of the whole system and improve the stability of the system.

The movement speed of the piston and the stroke of the metering pump are adjusted. The movement speed is controlled by the frequency of the input pulse signal. The stroke is adjusted by changing the position of the two proximity switches.

3.2. Composition of Experimental Platform

The preliminary construction of the platform is carried out by pipeline diagram, wiring diagram and metering pump schematic diagram. After the first successful construction, the metering pump experiment platform includes the metering pump working platform, electrical control cabinet, detection and measurement system, pipeline system, etc. Among them, the working platform of metering pump is composed of two sets of single cylinder double acting metering pump driven by stepping motor and driven by screw rod, light rod guide rail, support frame and other components, the physical structure of which is shown in Fig.3, the electrical control cabinet includes PLC controller, a / D converter, stepping motor driver, two 24V rectifiers, two sets of electromagnetic relay and air switch and other components, with specific layout As shown in Fig. 4, the detection and measurement system is composed of two sets of position sensors, turbine flowmeter and two pressure gauges, and the pipeline system is composed of oil pipes, one-way valves, electromagnetic reversing valves and other equipment. The actual figure is shown in Fig.5.

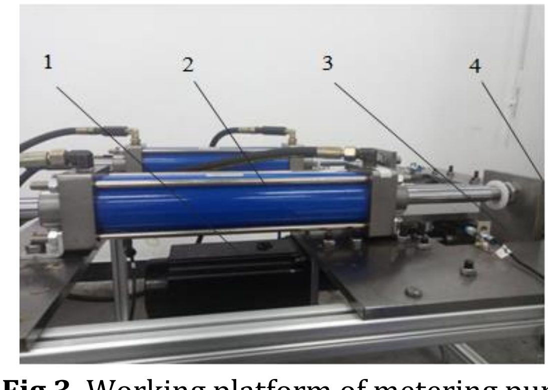

Fig 3. Working platform of metering pump

1—Stepper motor, 2—Metering pump, 3—Proximity, 4—Connecting plate

Fig 4. Electrical control cabinet
1—A\D module, 2—PLC, 3—Relay, 4—Air switch, 5—Stepper motor driver, 6—rectifier

Fig 5. Piping system
1—tank, 2—electromagnetic relay, 3—Check valve, 4—Pressure gauge

3.3. Experiment Platform Debugging

After the initial construction of the metering pump experimental platform, it can't operate normally and can't meet the working requirements of the experiment. Only after continuous trial operation, problems in the device are found in the operation, and through replacement or modification of some parts, continuous debugging and correction, can the experimental platform operate normally and be used for subsequent data measurement and program To achieve higher measurement accuracy and convenient, visual operation. In the process of debugging, the following problems are studied and improved.

3.3.1 Range of oil outlet pressure gauge

During the trial operation of the experimental device, when the hydraulic oil is discharged, the pointer of the pressure gauge does not deflect, and the important parameters of the oil pressure in the experiment cannot be obtained. After consulting the data, it is considered that the range of the initially purchased pressure gauge is too large, which is 0 ~ 16MPa, while the oil outlet pressure of the built experimental device is only 0.2 ~ 0.5MPa. After the pressure gauge with range of 0 ~ 1.6Mpa is replaced, the oil pressure can be displayed normally. The pressure gauge before and after commissioning is shown in Fig.6.

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Fig 6. Comparison diagram of pressure gauge before and after commissioning

3.3.2 Connection form of pipeline system

When the metering pump is in trial operation, the oil output of one stroke is very small, which is quite different from the required oil output. After analysis, it is considered that it is caused by the pressure difference between the hydraulic cylinder of the metering pump and the pipeline. This problem can be improved by changing the position of the one-way valve in the pipeline system. The one-way valve, which was far away from the metering pump, was installed near the metering pump, and the effect was good. The pipeline system after commissioning is shown in Fig.7.

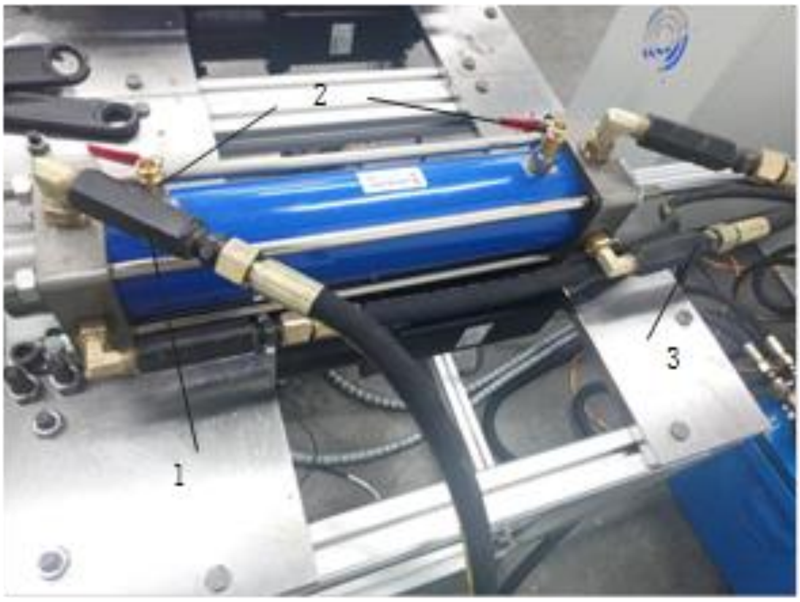

Fig 7. Piping system diagram after commissioning
1—Inlet check valve, 2—Exhaust valve, 3—Drain check valve

3.3.3 Metering pump structure

During the trial operation of the metering pump, a large amount of gas was found in the discharged liquid. In order to solve this problem, first check whether there is leakage between the pipeline system and the metering pump. After reconnecting each interface with the liquid

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raw material belt, there is still a small amount of gas. Because the leakage is inevitable, the hole is opened at the top of the hydraulic cylinder of the metering pump and the exhaust valve is installed. After such modification, the gas in the discharged liquid is significantly reduced.

3.3.4 Proximity switch position

Because the maximum stroke of the metering pump is different from the length of the screw rod and the guide rail, in order to ensure that the piston of the metering pump will not collide with the left and right end caps in the working process, it is necessary to control the movement stroke of the piston by adjusting the position of the left and right proximity switches on the working platform. In the process of debugging, by constantly changing the position of the sensor, we can find two better positions with better effects The proximity switch is fixed in these two positions, and this stroke is used as a reference in subsequent

3.3.5 Relationship between input frequency and motor speed

In order to facilitate the subsequent analysis and processing of the experimental data, it is necessary to read, store and display the readings on the flowmeter through a computer. In order to achieve this process, the output signals of the turbine flowmeter must be converted. According to the model of turbine flowmeter, its measurement range is 0.1-0.6m3/h. When there is liquid passing through the turbine of flowmeter, the flowmeter converts the flow into a pulse signal of 1-3000hz, which is converted by a / D conversion module and outputs a current signal of 4-20mA. The transformation diagram is shown in Fig.8. Then the D / a conversion module in the control cabinet is converted to a digital quantity of 0-16000, and the transformation diagram is shown in Fig.9. Then the corresponding digital quantity is recorded in the memory of PLC, which can be read by computer software.

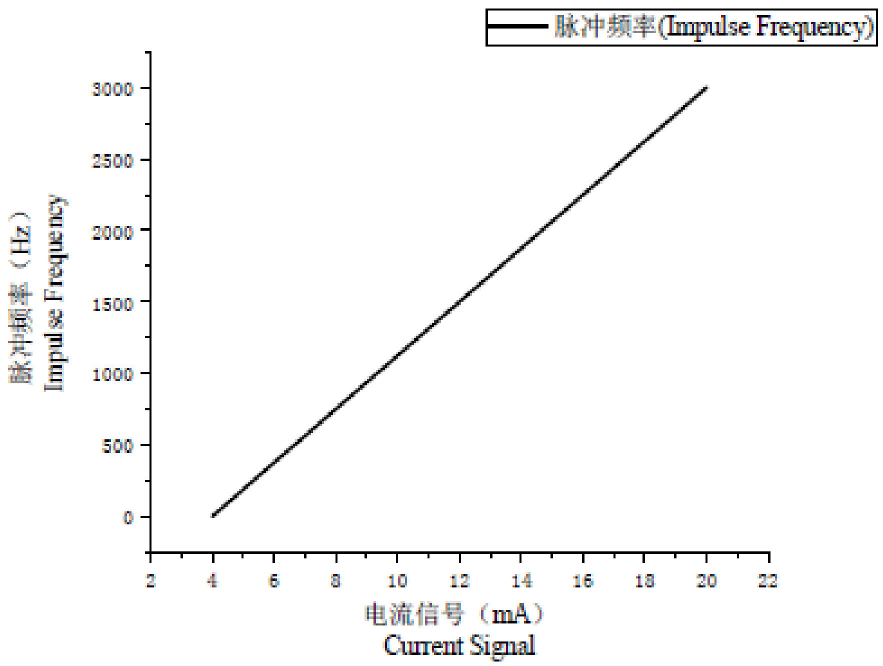

Fig 8. Frequency current diagram

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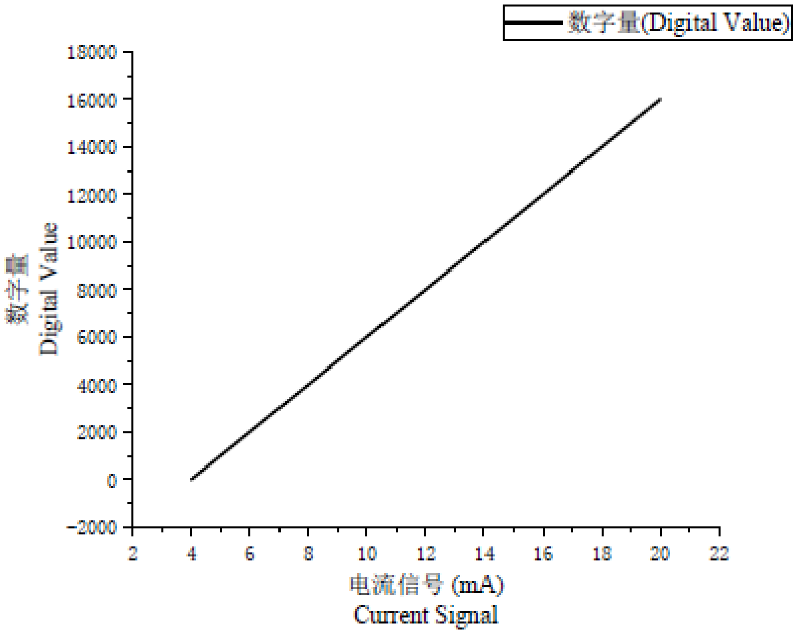

Fig 9. Digital quantity current diagram

After the digital quantity is obtained on the computer, the measured value of turbine flowmeter can be converted and the data can be recorded in real time. The instantaneous flow shall be calculated by the following formula, shown as Eq3.

$$Q = 3600 \times \frac{f}{K} \tag{3}$$

Where,

Q—instantaneous flow value of flowmeter, m3/h, f—output signal frequency of flowmeter, Hz, K—instrument coefficient, 8325.35 n / L, N—number of turbine flowmeter blades.

3.3.6 Reading and writing principle of flowmeter indication

The stepper motor in this experimental device is driven by the stepper motor driver. Its output state is determined by the nature of the input pulse signal, the frequency of the pulse determines the speed of the motor, and the number of pulses determines the number of turns of the motor. The specific transmission process is to input the pulse frequency on the display screen according to the experimental requirements. This signal is transmitted to the stepper motor driver through PLC, and then it is subdivided by the driver. In this experiment, the fine fraction is set as 2, so the motor speed can be obtained by the following formula, shown as Eq4

$$N = \frac{f}{m \times 360 / \theta} \tag{4}$$

Where,

N—step motor speed, M—fine fraction, M= 2, F—input frequency, Hz, θ—step angle, θ = 1.2 ^{0}.

4. Experimental Scheme Design

The main factors affecting the metering accuracy of the metering pump include the input frequency of the motor (the speed of the stepping motor), the residence time of the piston at the left and right stops of the stroke, the nature of the medium transported, the discharge pressure at the outlet of the experimental device and the stroke of the metering pump. Before the test of the metering pump, analyze the factors affecting the accuracy of the metering pump, and measure all the influence relations. The basic frame diagram of the test is shown in Figure10.

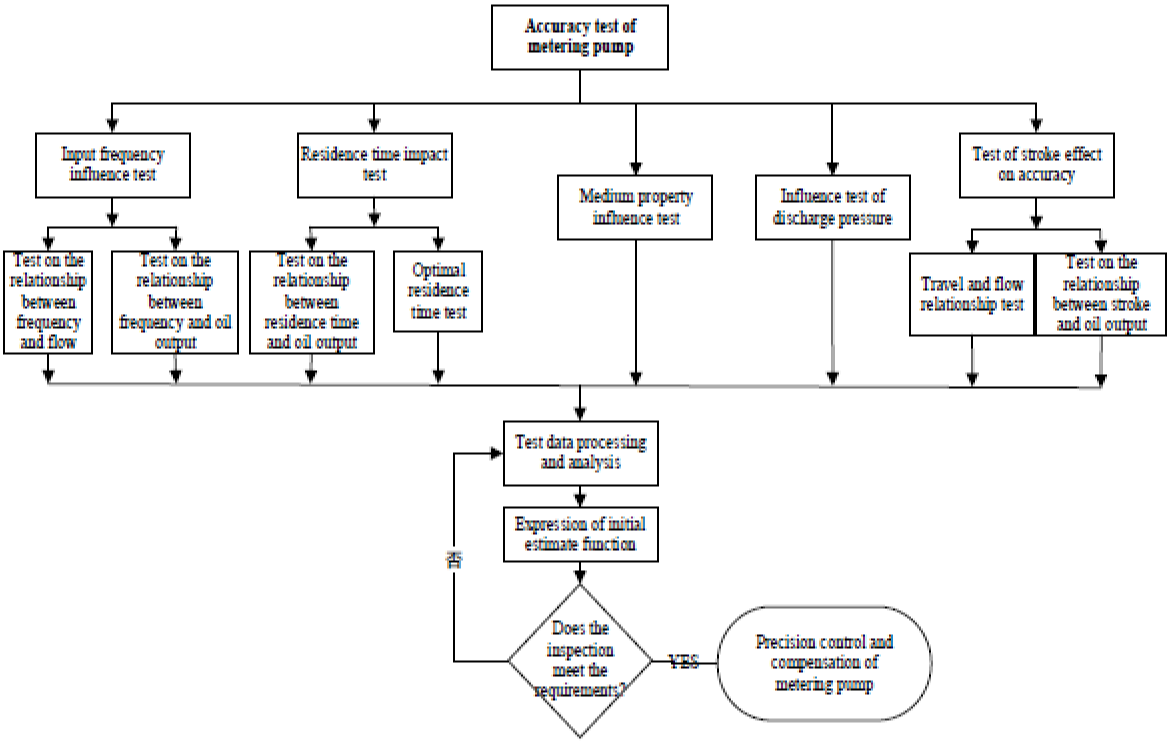

Fig 10. Technical route of experimental research

Limited by the experimental conditions and other factors, this design only studies the mathematical model of the influence of stepping motor input frequency and dwell time on the flow of metering pump, dwell time at left and right stop points and the oil output of a stroke and the type of the influence relationship.

5. Conclusion

In this paper, the plunger metering pump is taken as the research object to achieve high-precision metering by combining the control of metering pump with PLC. The experimental principle and device are designed by using the research method of combining theory with practice. The data results of the platform show that the measured data are tested for normality, and the flow, oil volume and oil time in this experiment are obtained It can be concluded that the normal distribution is obeyed, which is in good agreement with the numerical simulation results, so the structure and principle of the device are reasonable.

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