Research and Application of On-Line Measurement of Liquid Point Velocity in Closed Circular Tube

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Abstract

In our work, there are many liquid flow meters used online that cannot be sent to the laboratory for traceability, but can only be traced online on site. Due to the unsatisfactory conditions of the liquid medium in the online closed circular pipe and the existence of serious corrosion on the inner wall of the pipeline, the internal structure of the pipeline cannot be detected during the online inspection, which makes it difficult to accurately measure the liquid flow rate in the pipeline online, resulting in inaccuracy of traceability. By studying the flow characteristics and velocity distribution of the liquid in the pipeline, a device that can detect the internal conditions of the pipeline and measure the liquid online is designed. The flow velocity curve is fitted by the algorithm of measuring point interpolation, and the flow velocity deviation is corrected by using a high-precision measurement standard device. Through the integration of the infinite flow unit, the flow rate in the online state is obtained. According to the measurement needs, the measurement points are added. After fitting and correction, the measurement accuracy of the flow velocity at the inner point of the closed tube is improved.

1. Introduction

Flow meters are widely used in energy/resource measurement and industrial process control. The accuracy of flow meter measurement directly determines the level of trade fairness and the level of industrial productivity. At this stage, the traceability of flowmeters is mainly divided into laboratory offline and field online. The standard performance and detection method used in the traceability of the technical institution laboratory are relatively advanced, and the technology is relatively mature, which is the preferred option for the implementation of flowmeter traceability. In actual work, the traceability of sending to the laboratory will be limited by the difficulty of disassembly and assembly of the flowmeter, production stop and other conditions, which cannot be realized. It is necessary to determine the accuracy under the actual use conditions. For the above situation, traceability needs to be implemented online on site. The most widely used non-contact ultrasonic flowmeter is used as the standard in the existing technical measures, but for pipelines with internal corrosion, pipelines with lining and unclear lining parameters, The method runs the risk of not reflecting the actual flow objectively, or even completing the measurement. In view of the above special circumstances, this paper intends to design a flow point velocity measurement equipment by studying the fluid flow state in the closed tube, and use interpolation algorithm to fit and correct the flow velocity curve, so as to improve the measurement accuracy of the flow point- velocity in the closed tube.

2. Research on point velocity measurement technology

2.1 The principle of flow measurement

According to the Euler method, the motion law of pipeline fluid is studied, that is, the motion of the fluid is described by analyzing the time-varying law of the motion elements of the fluid particles in a fixed point, a fixed section or a fixed interval. Through the theoretical analysis of the flow characteristics and velocity distribution of the pipeline liquid, the flow point-velocity measurement technology of the pipeline liquid is studied.

Measure the flow point velocity sequence on a fixed diameter of a section, arrange several differential pressure measuring points at different positions in the same radial direction and at different times close to each other, and distribute the same number of measuring points up and down the center of the section; The external geometric position of the sensor corresponds to the coordinate position of the flow velocity sequence of the points. At the same time, the number of flow velocity measurement points and the accurate positioning of the measurement position can be determined according to actual needs. it can fully reflect the actual distribution of the liquid flow velocity inside the pipeline in the industrial field. Each measurement point corresponds to the area of a semi-circle with the same area. Calculate the flow rate of the point through the relationship between the flow point- velocity and the differential pressure corresponding to the measurement point, and obtain the corresponding flow through the product of the flow rate and the corresponding semi-circle. The sum is the instantaneous flow on the section.

2.2 Subsection headings

In the field of engineering flow measurement, there are two measurement methods, one is real-time measurement, that is, the flow meter reflects the current fluid flow in real time, and the other is indirect measurement, which calculates the flow through the relevant parameters obtained by measurement. In this paper, a combination of two measurement methods is used to measure the flow velocity of characteristic points at different positions in the same radial direction in the pipeline in a time-sharing manner, and the flow rate of the corresponding section is obtained by the product of the velocity point and the area of the corresponding section. Then, the flow rate of the fluid on the entire effective section is obtained. By calculating the flow rate of the steady flow at a certain moment of the section by the point velocity group obtained from the same section at different times, fully considering the influence of the measurement and the feasibility of the realization, a sensor is designed to replace several sensors to carry out the actual flow measurement.

Since it is impossible to measure at an infinite number of positions (in this case, the measurement time will be infinitely long, and the conditions of steady flow cannot be guaranteed), according to the actual situation that the velocity distribution gradient will not step, the flow point-velocity group obtained from the measurement On the basis of the characteristic data, reasonable interpolation, the number of interpolation points depends on the number of points in the flow velocity group and the accuracy requirements of the measurement calculation.

For the fluid flow of a circular tube, since the flow velocity at the section is symmetrically distributed at the center, the flow velocity at a point on a certain diameter on the specified section can represent the flow velocity at each point on the ring where the point is located. The tiny area depends on the number of interpolation points and the corresponding coordinate values. Once the number of interpolation points is determined, the tiny area at the corresponding coordinates is also determined. The product of infinite tiny areas and the flow velocity of the corresponding point is the flow rate of the entire section, so the sum of the product of the flow velocity of all points of a section and the corresponding tiny area is approximately the flow rate of the section. The formula is expressed as follows:

$$Q_V = \int_A v dA = \int_A dQ_V \approx \sum \Delta Q_v = \sum v \Delta A \tag{1}$$

in the formula：

Q_V——flow of a section,m^3/h;

ΔA——small cross-sectional area,m^2;

v——point velocity corresponding to a section,m/s.

The positioning formula of the sensor probe: According to the different positions of the sensor probe above or below the center of the pipeline, it is divided into two different calculation formulas：

$$h_i = \frac{d_{\max} - d_{\min}}{2} + d_{\min} + d_i \tag{2}$$

$$h_i = \frac{d_{\max} - d_{\min}}{2} + d_{\min} - d_i \tag{3}$$

in the formula：

h_i——the position of the sensor probe in the pipeline corresponds to the indication on the scale,mm;

d_{max}——the display value on the scale corresponding to the sensor probe at the top of the pipe,mm;

d_{min}——the display value on the scale When the sensor probe is at the bottom of the pipeline, mm;

d_i——the distance of the sensor probe from the center of the pipeline,mm.

The calculation formula concentric semicircle area:

$$S_i = \frac{\pi \left(\frac{d}{2} \right)^2}{n} \tag{4}$$

in the formula：

S_i——the area of concentric semicircle,m^2;

d——the diameter of the effective circular section,m;

n——the number of inserted measuring points。

The product of the flow velocity of each measured point and the corresponding concentric semicircle area is the flow rate of the measured point, accumulate the flow of each part to obtain the instantaneous flow through the pipeline.

$$Q = \sum_{i=1}^{n} v_i S_i \tag{5}$$

in the formula：

Q——Instantaneous flow on a cross section;

n——the number of flow velocity measuring points on the section;

v_i——flow point velocity at the measurement point;

S_i——the area of the semicircle corresponding to the measurement point.

3. Design of flow point velocity measurement device

Due to the need to complete the measurement of flow point velocity under dynamic measurement conditions, it is necessary to specially design a measuring device to meet the needs of use. Through repeated tests and comparisons, determine the device principle and stable structure configuration that meet the requirements.

3.1 Principle of the flow point velocity measuring device

Based on the need for on-site online measurement and the analysis of the above measurement methods, The point velocity online flow measurement device should have the characteristics of easy portability, high accuracy, good stability, flexible adjustment, and small sensor disturbance. The project team made comparisons through repeated tests, and specially designed a flow sensor based on the principle of differential pressure that can be screwed in and out,Equipped with transmitters and integrator with high accuracy and stability, use a notebook computer to develop software programs to complete data acquisition, algorithm correction, and result processing procedures.

3.2 Structure of the flow point velocity measuring device

Comprehensively considering the device performance and field use conditions, and improving after testing and debugging. The device mainly consists of six parts:

⑴Plug-in flow sensor: improve the internal structure of the sensor to ensure the stability of the signal; design the external shape to ensure the support strength.

⑵Triple Advanced Sealing System: solve the leakage caused by the dynamic adjustment process.

⑶Signal transmission system: optimize the acquisition and transmission of analog signals to improve stability.

⑷ Sensor position adjustment system: the precise adjustment system can guarantee the accurate position of the sensor during measurement.

⑸Data acquisition and processing system: through the processing of test data and fitting correction, the accuracy of flow measurement is improved.

⑹ Online installation system: ensure accurate installation of sensors under different conditions on site.

4. Algorithm correction

In the actual point flow rate measurement, the more the number of flow velocity points, the more realistically reflect the flow velocity distribution of the pipeline liquid. But the actual measurement is impossible to select more points. Determine the number of measured points according to the internal structure of the pipeline and the specific conditions encountered during industrial field measurement, and select characteristic measurement points on the diameter. By measuring several effective feature points, the purpose of measuring the liquid flow rate in the pipeline is achieved. Using the continuity principle of flow velocity distribution in the flow field to carry out point interpolation calculation, through the calculation method of data interpolation to carry out flow velocity analysis and flow measurement, so that the measurement can more truly reflect the flow state of the liquid in the pipeline, so as to ensure more accurate measurement results.

This paper takes the data of DN200 diameter pipeline as an example.Calibrate the flow point velocity online measurement device on the laboratory standard device.The test chooses to measure the six flow rate states of the liquid in the pipeline, separately 5.6m/s, 4m/s, 2.9m/s, 2m/s, 1m/s, 0.5m/s, In each flow rate state, the number of measurement points is calculated according to the pipeline parameters, and the position of the measuring device sensor in the pipeline is adjusted to measure the flow rate of the effective characteristic point points. Before processing the interpolation algorithm, first, determine the interpolation interval (the interval between two adjacent flow velocity points on the pipe path), Secondly, the number of interpolation points is determined according to the pipeline parameter conditions, Finally, according to the flow velocity of the effective characteristic position point, the corresponding position of the sensor measuring point on the scale and the editing interpolation algorithm formula, determine the flow velocity corresponding to each interpolation point, and intuitively reflect the pipeline liquid in the form of a line graph of data points. The distribution of the point flow velocity under different flow velocity states, the flow value in the closed circular tube calculated after fitting is closer to the real flow rate, and the correction coefficient given after calibration on the laboratory standard device is more accurate,
the relevant test results are as follows:

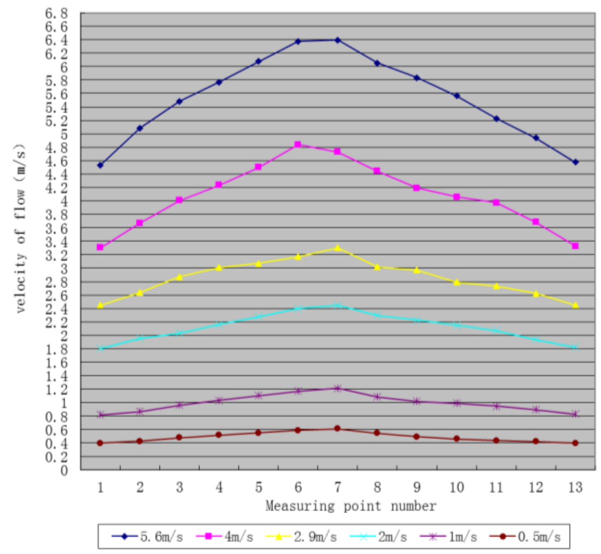

Figure 1: Flow velocity distribution chart before interpolation

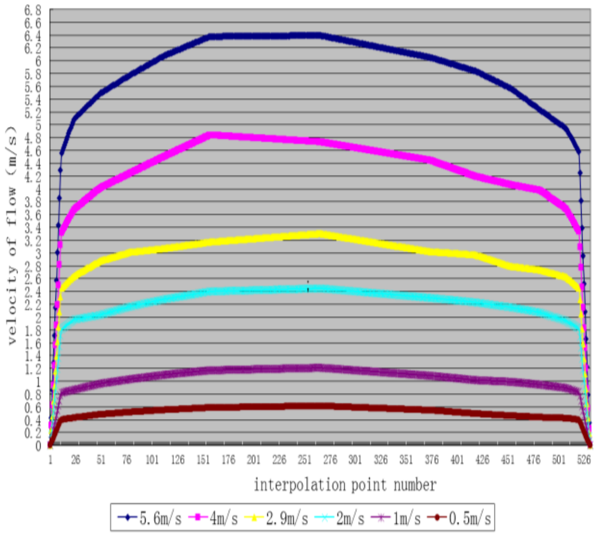

Figure 2: Flow velocity distribution chart after interpolation

The measured value of the calibration coefficient of the measured flow velocity point is corrected through the interpolation algorithm, the accuracy of the flow measurement is improved, and the measurement performance of the measurement equipment is improved, it provides a reliable guarantee for the flow measurement and flowmeter calibration of the measuring equipment in the field.

5. On-site online application

The research of the device system can provide different technical measures for solving the flow measurement under complex field conditions, and provide a reliable solution for the traceability of the flow meter used online. Expand the scope of field online applications through hardware design and data processing. The installation of the sensor is completed by the pressure drilling technology, and different sensors are selected for different pipes. Each sensor system is calibrated under laboratory conditions using a higher-accuracy metrology standard device to ensure accurate and reliable performance. After on-site online test, the existing installation location can be reused, improving the reproducibility.

6. Conclusion

The research on the online measurement technology of the flow point velocity of the closed circular tube has enriched our on-site online flow measurement method. The accuracy is improved by numerical analysis. With the continuous in-depth research of this project, the technical methods will be more perfect, and the data will be more reliable, which will help improve the traceability of online flow meter.

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