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Design and Application of Multi-point Temperature Measuring Device for PE Pipeline Butt Fusion Welding

Fei Yang[a], Huabin Wen[b], Xinxin Zhang[c], Tao Lu[d], Songze Ye[e]

College of Mechanical Engineering, Sichuan University of Science & Engineering, Yibin 644000, China.

[a]yf1149130671@163.com, [b]sichuanwhb@sina.com, [c]2573694023@qq.com, [d]948696961@qq.com, [e]1475345869@qq.com

Abstract

PE pipeline is widely used in many fields, such as urban gas transportation, and the quality of its welding joints is an important factor affecting the service life of PE pipes. In order to study the change of temperature field during PE pipeline heat-butt fusion welding, designed a multi-point temperature measuring device based on non-contact infrared temperature sensor MLX90614. Used STM32 micro-controllers, read the temperature value measured by MLX90614 sensor through SMBus protocol, and real-time display of temperature measurement results. The results show that the non-contact multi-point temperature measuring device has good applicability in Butt Fusion Welding. During the endothermic phase, the surface temperature of the pipe is gradually decreasing and the temperature is highest near the center line of the weld..

Keywords

Temperature measurement; MLX90614; STM32; PE pipeline; Heat-butt fusion welding.

1. Introduction

PE pipeline has many advantages such as non-toxicity, light weight, low cost, high strength, high temperature resistance, corrosion resistance and so on. It has been widely used in the construction of water supply pipeline and gas pipeline[1]. Daijun Yang[2-4] studied the influence of process parameters on the quality of welded joints in the butt fusion welding process of PE pipes. The results show that the performance of welded joints of pipeline is greatly affected by the temperature of heating plate, welding pressure and heating time. The higher the temperature of heating plate, the longer the heating time, the thicker the thickness of molten layer, the longer the cooling time required for the pipeline. At the same time, the more molten plastic is extruded during the pressure welding stage, and the larger the welding ring formed. Ziwei Fan[5] studied the mechanical properties of PE gas pipeline welded joints at different temperatures by tensile failure tests, and established the relationship between the maximum stress, elongation at break and temperature of PE gas pipeline welded joints. The research shows that the existence of crimping is likely to cause stress concentration and affect the service life of PE pipes. Removing the crimping can increase the elongation at break of samples. Temperature has a great influence on the quality of welded joints. As the temperature increases, the tensile strength decreases while the elongation at break increases. Both Lijun Liu[6] and Yan Liu[7] simulated the temperature field of PE pipeline butt fusion welding. Lijun Liu used thermocouple temperature automatic acquisition system to detected the welding temperature field changes, and compared by simulation and experiment. The study found that at the end of the heating, the temperature of PE pipe does not reach the maximum. The maximum temperature value occur in the pressure welding stage. The reason was that the latent heat of phase change in the process of

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pressure welding caused the temperature to increase further. The study also found that in the process of pressure welding of pipeline, the axial stress of the pipe gradually changed from tensile stress to compressive stress. Yan Liu measured the axial temperature of the outer surface of PE pipe during welding by used the M7500 infrared video camera. Compared with the simulation results, it was found that during the cooling process of the PE pipe welding joints, the radial temperature distribution of the pipe joints was uneven, and the temperature difference between the inner and outer walls caused insufficient crystallization, which affects the welding quality.

This paper designs a non-contact temperature measuring device based on MLX90614 infrared temperature sensor. The temperature distribution at the endothermic phase of PE pipeline butt fusion welding under different standard size ratios was measured, and the variation law of temperature field during PE pipeline butt fusion welding process was obtained. Related research on PE pipeline butt fusion welding has reference significance for improving the safety and reliability of the pipeline.

2. Introduction of MLX90614 sensor

The design is mainly to monitor the temperature change of the surface of the welded pipeline during the endothermic phase of the PE pipeline butt fusion welding process. According to "CJJ 63-2018 Technical standard for polyethylene(PE) gaseous fuel pipeline engineering", the temperature of the heating plate during pipeline butt fusion welding is 225±10℃. Therefore, it is necessary to ensure that the temperature measurement sensor can withstand a certain temperature and has strong anti-interference ability.

MLX90614 is a typical thermopile IR detector, which works based on the principle of electric potential effect of temperature difference. Melexis's digital infrared temperature sensor MLX90164-DCI integrates two chips developed and produced by its company: infrared thermopile sensor MLX81101 and digital signal processor (DSP) chip MLX90302. Its internal components mainly include: infrared thermopile sensor, low noise amplifier, 16-bit analog-to-digital converter and DSP unit, etc[8]. The sensor is suitable for long-distance temperature measurement and has two output modes of PWM and SMBus. The normal working ambient temperature is -40~125℃, the maximum temperature range of the measured object is -70~380℃. 3V or 5V power supply voltage can be selected, and the standard accuracy at room temperature is ±0.5℃[9].

Figure 1 is a schematic diagram of PE pipeline temperature measurement. When the temperature is measured during the pipeline welding process, the temperature measurement element is installed by using the heat insulation device, not only to ensure that the measurement sensor measures the surface of the pipe vertically, but also to prevent temperature interference with the measurement device.

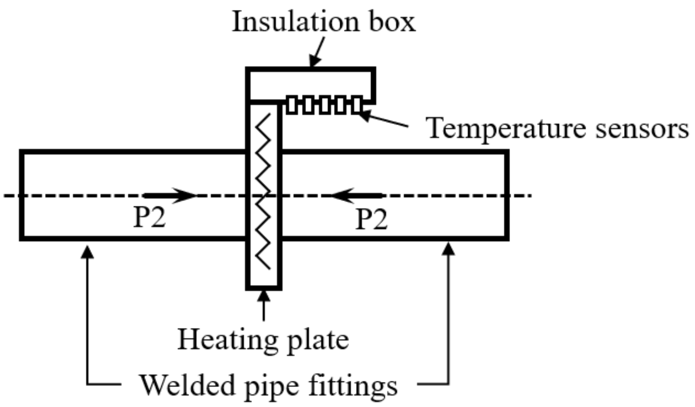

Fig.1 Schematic diagram of PE pipeline temperature measurement

Figure 2 is a distribution diagram of temperature measurement points of PE pipeline. During pipeline welding, staggered measurement method is adopted to ensure that the device can accurately display the temperature change of pipeline surface during endothermic phase of PE pipeline welding.

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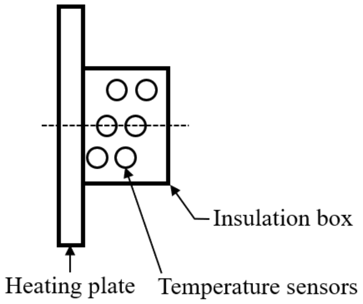

Fig.2 Distribution diagram of temperature measurement points of PE pipeline

3. Hardware design

The multi-point temperature measuring device in this paper mainly includes infrared temperature sensor, microcontroller, display device, power module and USB data transmission module. Among them, the single chip microcomputer adopts STM32F407VET6, the infrared temperature sensor adopts MLX90614-DCI, and the display device adopts 3.2-inch TFT LCD screen. The overall structure diagram of temperature measurement system is shown in figure 3. The internal structure diagram of the infrared sensor is shown in figure 4. The infrared thermopile sensor MLX81101 absorbs the infrared radiation during PE pipeline butt fusion welding and converts it into an electrical signal, which is amplified by a high-performance and low-noise operational amplifier inside the MLX90302. The analog-to-digital converter converts the amplified signal into a digital signal, and the DSP reads the digital signal. At the same time, and the ambient temperature is detected by the infrared detector as a compensation signal, and will be output to the DSP together. The digital signal in DSP transforms the corresponding temperature value through operation, and the measurement results are kept in the internal RAM of MLX90614. The STM32 controller reads the temperature signal measured by the thermocouple through the SMBus bus and sends the processed final temperature to the display device for real-time display[10].

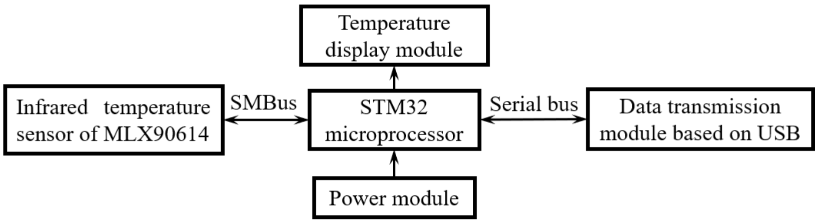

Fig.3 Structure diagram of temperature measurement system

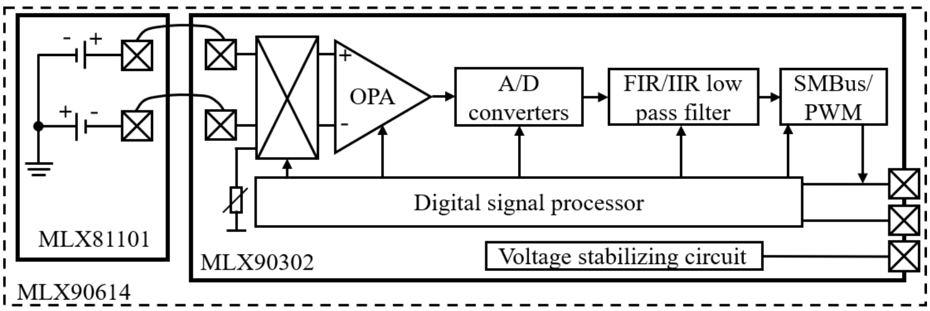

Fig.4 Internal structure diagram of MLX90614

4. Software design

4.1 Data transfer protocol

The MLX90614 sensor and STM32 single chip microcomputer are used to transmit data through SMBus protocol. Among them, the single chip microcomputer is used as the master device to communicate with the slave device MLX90614. The data transmission format of MLX90614 is

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shown in figure 5. The shade represents the data transmission direction: slave device to master device, and the blank represents the data transmission direction: master device to slave device[11].

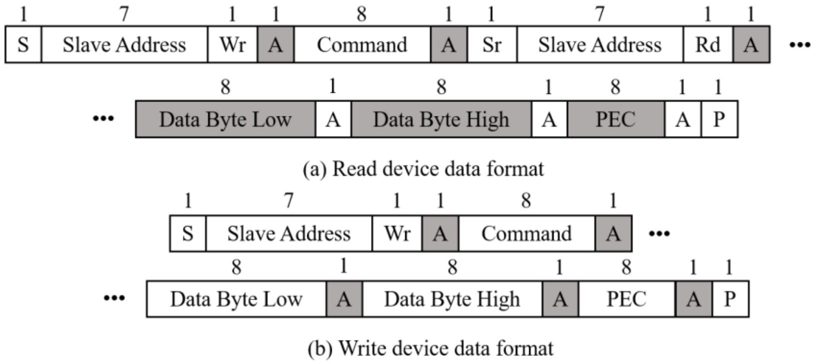

Fig.5 Data communication format

The data transmission timing of MLX90614 is shown in figure 6. The data on PWM/SDA can be changed after SCL becomes low level of 300ns, and the data is captured on the rising edge of SCL. The 16-bit data is transmitted twice, one byte at a time. Each byte is transmitted according to the format of the most significant bit(MSB) before and the least significant bit(LSB) after, and the ninth clock in the middle of the two bytes is the reply clock.

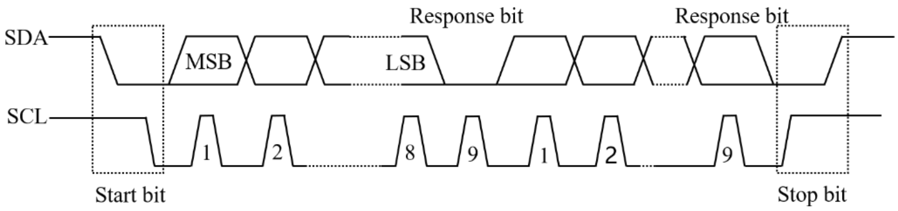

Fig.6 Data transmission timing

4.2 General program flow

The program flow chart of multi-point temperature measuring device is shown in figure 7. The program design of the whole temperature measuring device mainly includes three parts: the main program, the infrared temperature measuring program and the LCD display program. The main program realizes temperature measuring and display functions by calling subprograms of the other two modules. The whole work flow is as follows: the initialization of MCU is mainly to the crystal oscillator initialization, the corresponding I/O port initialization, the IIC bus initialization and the serial port initialization. After that, the MLX90614 initialization sets the emissivity of the measured object to the corresponding value.

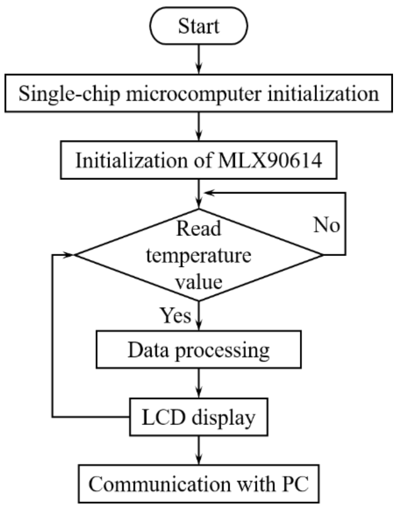

Fig.7 Program flow chart of temperature measuring device

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5. Application and Experiment

Using PE gas pipeline for PE100 grade as the material, and butt fusion welding of PE pipeline with a diameter of 90mm, among which two different standard size ratios are selected for each pipe for two sets of experiments. The multi-point temperature measuring device is installed on the heating plate, and non-contact temperature measurement is carried out on the five measuring points. The distances from the measuring points to the center line of the weld are 5.5mm, 7.5mm, 9.5mm, 21mm and 31.5mm, respectively. The multi-point temperature measuring device is shown in figure 8. The welding equipment is SKC-B160DZ type manual PE pipeline butt fusion welding machine as shown in figure 9. The technical description of this type of pipeline butt fusion welding machine is shown in table 1.

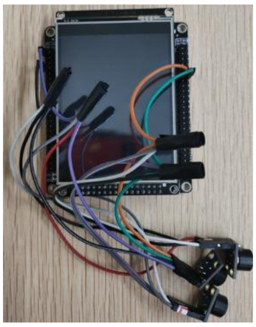

Fig.8 Multi-point temperature measuring device

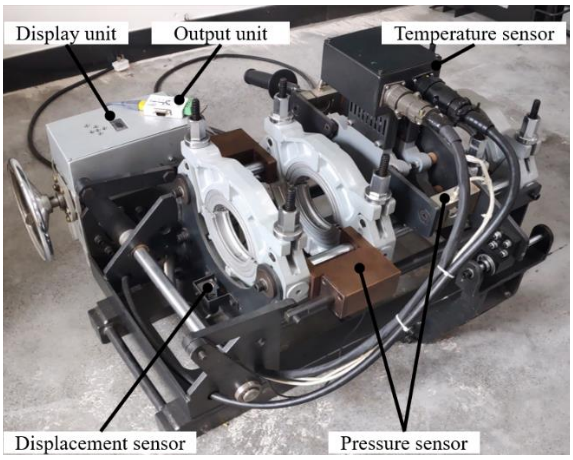

Fig.9 Experimental equipment of PE pipeline butt fusion welding

Tab.1 Technical description of PE pipeline butt fusion welding equipment

Designation	Explanation
Working range	φ63～160mm
Welding material	PE、PP、PVDF
Environment temperature	-5～45℃
Working voltage	230V±10%，50HZ
Total power	2.7KW
Insulation resistance of the whole machine to ground	＞1MΩ
Heat resistance of hot plate surface coating	＜300℃
Surface temperature difference of heat plate	≤±5℃

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The welding process parameters of PE pipeline in this experiment is shown in Table 2.

Tab.2 Welding process parameters of PE pipeline (PE100)

Nominal diameter/mm	Standard Dimension Ratio(SDR)	Wall thickness of pipeline /mm	Welding pressure /KG	Heating time /s
φ90	11	8.2	11.1	82
φ90	17	5.4	7.2	54

It can be found from the curve of the surface temperature along the axial direction at different times during the endothermic phase of the PE pipeline butt fusion welding (figure10 and figure 11). When the PE pipeline butt fusion welding, the surface temperature of the pipeline advances uniformly along the axial direction. The temperature is highest in the area closest to the weld center line, and then gradually decreases along the axial direction. The growth rate of temperature value in the area closer to the weld center line changes from rapid to slow. This is due to the moment at the beginning of the pipeline butt fusion welding endothermic phase, the pipeline in the area close to the weld center line absorbs the heat of the heating plate and gradually transformed into molten state, and the temperature value increases rapidly. After that, due to the heat transfer property of PE pipeline, the temperature is transferred along the axial, which makes the temperature growth rate of the area closer to the weld center line slows down, while the temperature in the area distant to the weld center line gradually increases.

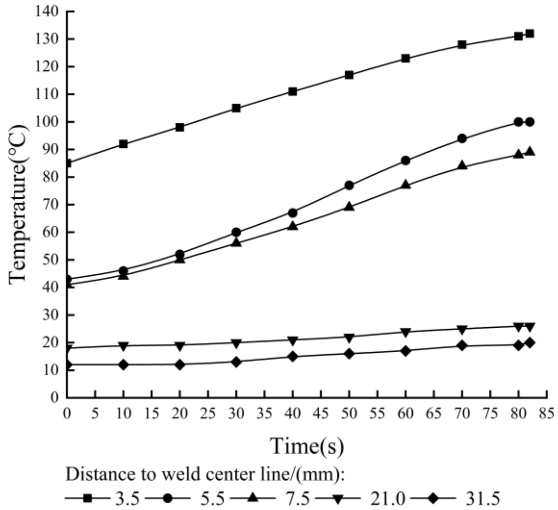

Fig.10 Curve of axial temperature change at different time in endothermic phase(φ90、SDR11)

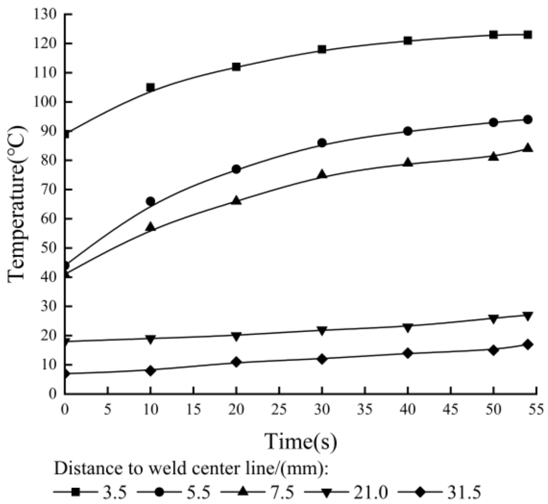

Fig.11 Curve of axial temperature change at different time in endothermic phase(φ90、SDR17)

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6. Conclusion

In this paper, a multi-point temperature measuring device based on non-contact infrared temperature sensor MLX90614 was developed to measure the temperature field of PE pipeline butt fusion welding. According to the measurement results, the following conclusions can be obtained:

(1) A number of non-contact infrared temperature sensors MLX90614 are used to form a measuring tube bundle to measure the temperature of the melting section during PE pipeline butt fusion welding, which can accurately reflect the change rule of the temperature of pipeline melting section with time.

(2) It is of great significance to monitor the temperature change of the pipeline end face in real time to ensure the quality of pipeline butt fusion welding.

(3) The device has high measurement accuracy and fast responding speed, which can effectively reduce the risk factor during PE pipeline butt fusion welding, and provides a new way to monitor the temperature change of the pipeline during PE pipeline butt fusion welding.

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