Temperature data acquisition and remote monitoring of ladle based on LabVIEW

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Abstract

Ladle is an important container parts, plays a vital role to storage and operation of steel smelting. The length of the ladle service life directly affects the efficiency of steel production and the cost of production. The service life of the ladle is mainly affected by thermal mechanical stress of ladle lining, thermal mechanical stress is mainly caused by the severe changes of temperature, in order to fully understand the working state of ladle to ensure the safety of the ladle, the ladle temperature monitoring is particularly important. Ladle design of remote monitoring system uses the structured and modular design thought, on the basis of using the LabVIEW virtual instrument platform; realize the collection of ladle temperature data and remote monitoring. Establish ladle remote client monitoring system by TCP communication protocol, realize the ladle monitoring networked. This system uses the real-time waveform display and friendly human-computer interaction interface, greatly enhanced the real-time and visibility of the ladle remote detection system.

Keywords: the ladle, LabVIEW, remote monitoring list

1 Introduction

Ladle is an important fundamental of steel production in the steel mill, each working procedure in the process of steel-making is required to complete with ladle, and the temperature conditions of ladle directly affect the quality problem of the iron and steel production, especially in high efficiency continuous casting production. Ladle will be impacted by high temperature from molten at work, affecting the service life of the ladle, so the collection of temperature of ladle and precise monitoring is very important. The traditional monitoring equipment for ladle is relatively backward in our country, and its security, reliability and precision and automation degree is low, a lot of testing equipment is in need of upgrading [1]. This paper based on the LabVIEW platform will get the ladle temperature data by sensors, then monitor the collected data with the remote monitoring system based on LabVIEW and determine whether the temperature value is in the normal range, this help the remote workers to rule out the fault in production timely, thus avoid the damage of high temperature to ladle lining, can greatly improve the using efficiency of the ladle, improving the steelmaking efficiency of steel.

2 Structure and life of ladle

The ladle model is as shown in Figure 1. The ladle is mainly composed of trunnion, work layer, permanent layer, ladle wall, impact block, vent brick, nozzle bricks and other parts. Ladle wall has a small slope, lift ladle through the trunnion, and complete the movement of the ladle.

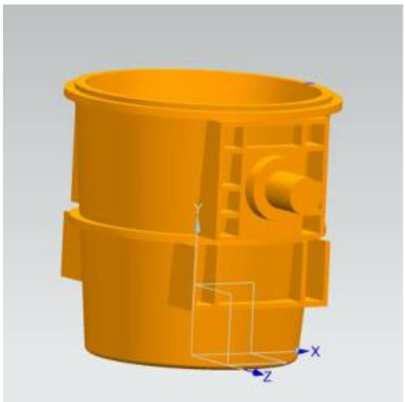

FIGURE 1 Model of the ladle

Figure 2 is the plane view of ladle bottom. There are mainly impact block in the bottom of the ladle, vent brick and runner brick.

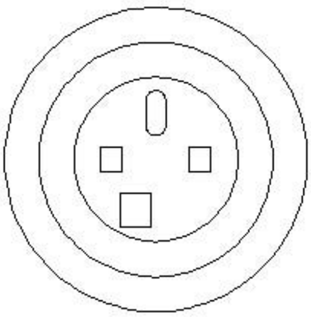

FIGURE 2 Structure figure of ladle bottom

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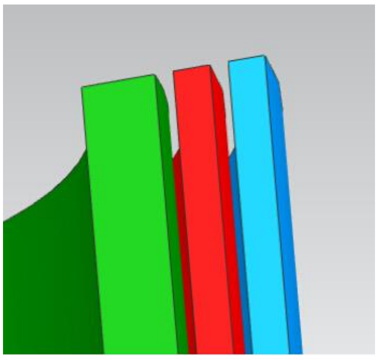

FIGURE 3 Three layer structures of ladle

Ladle generally is consists of three layers, from the inside out are working layer, permanent layer and ladle wall. The material of working layer is commonly alumina and magnesia carbon, material of permanent layer is commonly micro expansion high aluminium, the three layer structure use different materials, so the temperature of ladle is in security.

Ladle life will directly affect the production efficiency of iron and steel and the cost of steel production in steel production. Erosion and burst of refractory lining in the iron and steel production, causing the penetration of liquid steel in the ladle, this is the most common damage in the process of iron and steel production. Thermal mechanical stress and chemical erosion is the main reason of the lining damage. Which the direct reason of resulting the damage of the ladle refractory and the crack of lining layer is the thermal mechanical stress. The damage principle of thermal mechanical stress is that as the temperature of ladle lining layer in a dramatic changes, the produced thermal stress make the micro cracks in the materials gradually spread, eventually led to the fracture and peeling of inner layer material.

The heat transfer phenomenon of temperature in engineering can be roughly divided into three categories: thermal radiation, heat convection and heat conduction. To mainly affect the temperature of ladle are heat convection and heat conduction.

a. Heat convection

Macro relative motion caused by different temperature inside fluid parts caused the heat transfer through mutual movement.

$$q = \lambda \Delta T A, \quad (1)$$

where $\Delta T -$ object temperature difference on both sides (K), $A -$ surface area of convective heat transfer $\left(m^2\right)$, $\lambda -$ surface convective heat change coefficient $\left(W/\left(m^2 * k\right)\right)$.

b. Heat conduction

Each parts with different temperatures or different objects in an object's, through the collision and movement of the microscopic particles in the objects transmitting energy, this way of heat transfer is contacted each other between objects.

$$q = -\lambda A\left(dt/dx\right), \quad (2)$$

where $A -$ area $\left(\left(m^2\right)\right)$, $\lambda -$ heat transfer coefficient $\left(W/\left(m^2 * k\right)\right)$, $t -$ temperature, $x -$ coordinates on the surface of the heat.

The sharp temperature change of ladle, will make the life of the ladle affect greatly, as the ladle is in the process of working, there happened damage phenomenon, such as lining erosion or burst, ladle needs different levels of maintenance, thus affect the normal production schedule of the steel. Monitoring and displaying every area of the ladle temperature timely, and set the corresponding alarm monitoring, can timely understand the working status of the ladle. Make a corresponding adjustment for the ladle operation according to the monitoring the situation, improving the service life of the ladle.

3 Temperature data collection of ladle

Data collection is a bridge connecting external physical world and the PC, in order to realize the monitoring of ladle temperature signal, first ladle work quantities should be converted into electrical signals of analogy quantities by sensors, then converts processed analogy signals to be the identified digital quantity on ladle remote computer monitoring system, and send to the ladle remote monitoring system [2]. Data acquisition system of ladle obtain needed information from the monitoring objects by sensors, and converts the output signal to the identified digital signal by computer, and then put into the computer to carry on the corresponding processing, get the required data. Ladle data acquisition has a variety of software and hardware combination, can choose appropriate from several combination as the hardware and software of this system.

Good or bad data of acquisition system performance of ladle remote monitoring system is mainly determined by the speed and precision of the ladle data [3]. On the premise of ensuring the accuracy of the collected ladle data, should improve the speed of the ladle data as possible, in order to meet the real-time of ladle data acquisition and processing [4]. Table 1 ladle data acquisition system, generally can be divided into five parts:

TABLE 1 Data acquisition composition of the ladle monitoring system

Sensor	Sensor of monitoring Ladle is a sensor can monitor ladle temperature, and convert the detected signal into the needed signal form to put
Signal	A quantity from a ladle monitoring sensor, signal is transmission medium of ladle data acquisition system, signal usually has two forms, digital and analogy
Signal conditioning	Convert collected temperature signals of ladle to a standard and identifiable signal through a series of transformations
Data acquisition hardware	Data acquisition hardware of ladle monitoring system is the device that convert simulation quantity to digital quantity for ladle monitoring signal
Driver program and application software	The application software of ladle monitoring system is the LabVIEW virtual instrument software and related hardware driver

Data acquisition system of ladle remote monitoring system is shown in Figure 4.

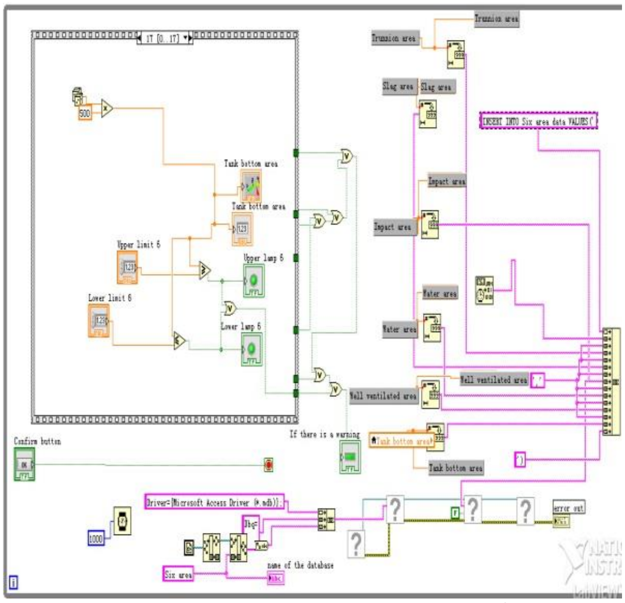

FIGURE 4 Temperature data acquisition system of ladle

The main functions of the data acquisition system are man-machine interface, data acquisition, data display, data storage, printing and output as well as secondary calculating of data shown in the following table.

1) The man-machine interface of ladle data acquisition system.

In the ladle data acquisition, staff dialogue to data acquisition system of the ladle through the mouse, keyboard or touch screen, complete ladle data collection.

2) Data collection of the ladle.

When data acquisition system is working, it will collect for analogy signals into the system or other signals in accordance with the previous ladle collection cycle.

3) Data display of ladle data acquisition system.

The collected temperature data of ladle are displayed in the form of that watchers are convenient for watching, displaying interface is commonly images, forms, trend charts and so on.

4) Storage of the ladle collection data.

Ladle state change is a slow process, set a certain time interval for the storage of collected ladle data, store the collected important data of ladle, and store it to the specified database, convenient for future reference.

5) The ladle data collected printing.

After the ladle data collection, we need to output the data collected to print, in order to understand the performance of the ladle; it will be the required to set a certain time interval to print the data in the form of a graph or table.

6) Secondary calculation of ladle data.

Comparing the collected first data of ladle by the sensor with normal numerical range at work, then making secondary calculation, to identify the running status of the ladle.

4 Ladle temperature remote monitoring

Network communication is an important aspect of Ladle's remote monitoring; the LabVIEW software has a strong network communication function and remote communication function of LabVIEW allow LabVIEW users write remote communication software to realize the remote communication function [5]. Ethernet technology is now widely adopted by the computer network technology, the media access and control mode is adopted by the collision detection of the carrier to listen on multiple accesses. To establish a network publishing of LabVIEW needs to be more than 2 PC through communication lines connected and established communication [6]. So you can through the establishment of communication network to provide resource sharing, communication service, coordination load, data transmission and remote fault diagnosis other functions so on.

From the composition of the entire computer network, which is made up of many WAN and LAN together [7]. Node of the Internet is consisting of the PC, subnet segment, servers and other equipment, which can be established through LAN and telephone line connected to the Internet. Throughout the development of network technology, LAN technology is a focus in the fastest, users can make use of local area network (LAN) in the Internet technology, which brings a lot of convenience [8]. LAN topology structure mainly can be divided into star structure, bus structure, and ring structure and so on. In these several topology types, bus structure is the most simple topological structure, whose local area network (LAN) is based on public information channel [9]. Although this structure is not easy to fault detection, it is easy to be extended and easy to maintenance and installation Each PC machine on the network has an own logo, that is the IP address of the PC, which generally consists of four part numbers. Ladle of network monitoring system is a trend of modern ladle monitoring, combining the Internet and monitoring of the ladle system together, which can make full use of network resources and improve the efficiency of monitoring.

TCP/IP protocol is one of the most basic Internet protocol, TCP and IP forms the core of TCP/IP protocol, both LAN and the Internet are widely adopted, TCP/IP protocol. The application layer, transport layer, network layer, link layer make up the TCP/IP protocol suite. IP is Network protocol, which belongs to Network interconnection layer protocol. In order to transfer the data to the destination, you will need to print data sending into a datagram, and then add the header to datagram and sent to the destination [10]. Because IP layer service is a connectionless service, it is difficult to guarantee the reliability of data in data transferring, which is the reason that seldom directly used IP in LabVIEW programming. TCP is transmission control protocol that is a transport layer protocol, which needs to link first in the data transmission, and most of the network data transmission use TCP transmission control protocol (TCP) now. TCP uses bits of circulation in data transmission and a session needs to be established on the data exchange [11]. In order to guarantee the reliability of data, through the TCP data will be assigned a sequence number. When data in the transmitted is divided into several small pieces, the receiver can specify whether the data has been received. During the data transfer, the data of the receiver must carry on the confirmation, which realized by sending a reply. When using TCP transmit data, you need to call the IP network protocol, but compared with TCP/IP network protocol, TCP will not repeat or miss data and more reliable in data transmission.

In the use of remote data transmission, TCP client port settings should be consistent with server port, at the same time the client need to specify the right IP address [12]. So as to it can realize correct network interconnection. The design of server-side as shown in Figure 5, TCP server program will first collect the temperature data in the production of the ladle, then write to the TCP server, finally send the data to client.

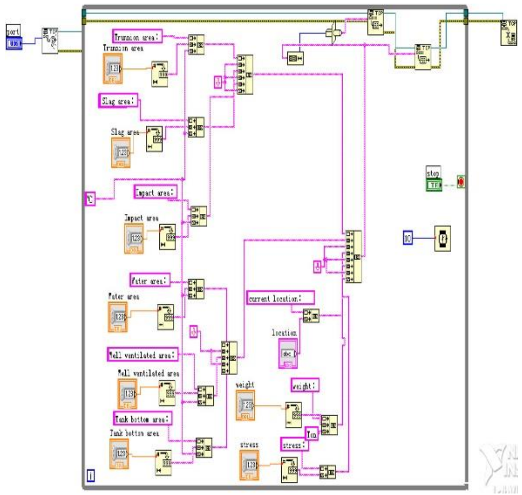

FIGURE 5 The TCP server program

The program diagram of client as shown in Figure 6, The remote monitoring the client program diagram of ladle is programming under the While loop structure, in order to ensure the data writing continuity, with setting the frequency of data writing [13]. In addition to set two attribute node, TextFontSize and Text TextColor, it convenient to observe display window of the front panel data, so that it can read out data transmitting.

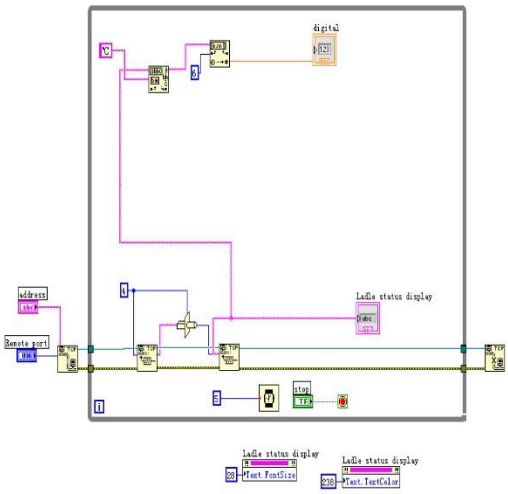

FIGURE 6 The client program of ladle remote monitoring

In the working of ladle, if the temperature status of the ladle is not informed in a timely manner, you will appear many problems, for example:

1) The temperature is too low, so that molten steel solidification needs to be reheated.

2) The temperature of ladle is too low, so the ladle must be heated to a certain temperature before picking up the molten steel.

3) When the ladle is shipping to the continuous casting desktop, too low temperature needs to be reheated.

Because the monitoring object is ladle, system should real-time monitor the ladle temperature data (the temperature of the six, trunnion area, slag zone, under the impact area, the water area, breathable area, and tank bottom area). And count and analysis the acquisition of data, calculate the upper and lower value of collecting data and compare to the setting value, judge whether the working condition of the ladle is normal [14]. It can alert when it is not normal operation, thus reducing the failure rate of the ladle work.

Establish ladle remote monitoring system of remote data transmission module and a remote monitoring server, and then write the data needing to transfer to the remote communication program, which established via TCP communication protocol. To establish a ladle remote monitoring client, you can read the monitoring data of the ladle transmitted from the server, so that to realize remote monitoring [15].

In order to ensure the ladle in production has a good process to produce good quality steel and to study the relationship between temperature field and stress distribution, the need for monitoring the temperature of the ladle six area, trunnion area, slag zone, under the impact area, the water area, breathable area, tank bottom area, is necessary. The temperature monitoring of the ladle front panel diagram as shown in the figure below

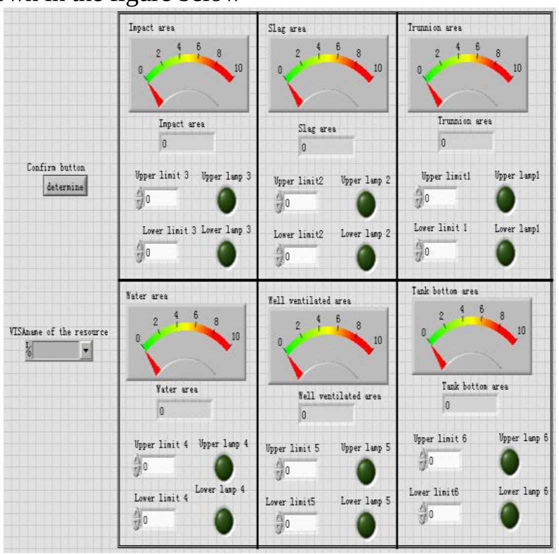

FIGURE 7 The front panel of temperature monitoring

This system is designed to meet the temperature detection, while meet the demand for six area temperature monitoring, in this program using the sequential loop structure to achieve six area through a serial port to read six regional temperature requirements. Each interval of temperature upper and lower limit value should combine the ladle located automatically to set, which meet the demand of temperature of ladle in any position.

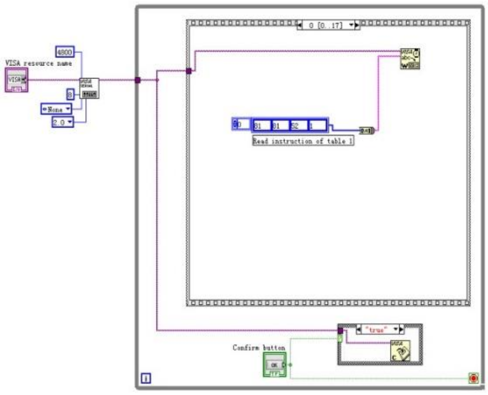

FIGURE 8 Send instruction to the monitoring instrument

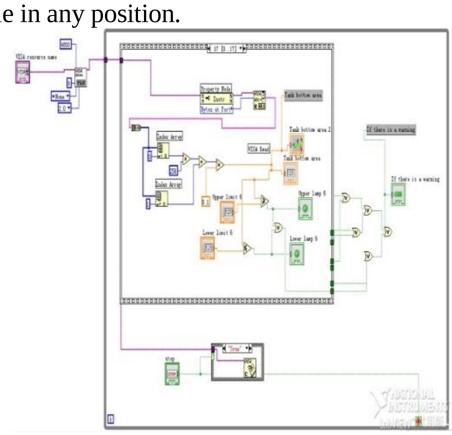

FIGURE 9 Read temperature of six temperature zone

Read the six area temperature value and write temperature data collected through global variables into the database established connection. The temperature monitoring by temperature monitoring module has the six districts, through a serial port of one monitoring module to realize six areas temperature monitoring, that need to be established connection to the temperature acquisition instrument by VISA Write. To judge the collected temperature data with the upper limit and lower limit value, when is greater than the threshold value or less than the lower limit value can change warning light color.

5 Conclusions

The length of the life of the ladle has a vital role on iron and steel production, and the real-time monitoring for ladle production status is conducive to improve the efficiency of steel production. Based on the ladle as monitoring object, this paper starts from virtual instrument technology, then collects and monitories of the temperature parameters of the ladle, next makes a further analysis and research on the data, to ensure that the working temperature of ladle has been in a normal range, thus educes the failure rate, greatly extends the life of the ladle, raises the productivity of the steel.

Acknowledgments

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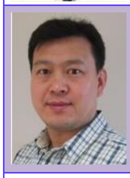

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