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Embedded based Flow Control for Industrial Furnace Automation

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***Abstract*— This paper presents a microcontroller based approach to minimize manual dependent operations related to flow control of liquid in industrial environment. Embedded system based prototype model was constructed to control the flow of liquid. In this model, flow of liquid is controlled by monitoring temperature and weight of liquid. According to weight and temperature conditions of liquid, flow tap of furnace is restricted by microcontroller. The performance of prototype model is tested with different weight of liquid at different temperature. The experimental results show that this model gives good performance in controlling flow of liquid based on the information of temperature and weight of liquid. This can be used for automation of furnace in industry.**

Keywords—Automation, Flow control, Liquid, Furnace .

I. INTRODUCTION

Tower furnace is used for melting purpose in various industrial production processes; mostly for preparing molten in die casting process. For melting the material in furnace, large amount of heat is required. Melting of metals, glass and other material has been a vital manufacturing process for several thousand years, producing molten liquids that can be poured and solidified into useful shapes. Sometimes this type furnace of operation is manually controlled.

The demand for good quality, better efficient and automated machine has increased in the industrial sectors of production plant. Production plants require monitoring and inspection at frequent intervals.

There are possibilities of errors in measurement of parameters of liquids at various stages involved with workers. These errors can be reduced by use automation in furnace operation. To achieve desired automation in furnace operation and to minimize human intervention, there is need to develop a system that monitors the furnace operation and helps to reduce the errors caused by humans. Also manual handling of furnace with high temperature molten is very risky in industrial environment. It may cause injury to human body.

II. LITERATURE SURVEY

Automation is use of various control system for operating equipment's such as machine, process in factory, boilers, Furnace and other application with reduced human involvement. Automation of different process in casting industry helps to improves control over different process parameter which leads to ease of production with higher efficiency. In casting industry furnace is work on very high temperature. Most of the furnace use to produce molten for casting. So monitoring temperature and level of molten in furnace is also important. There are different technique proposed by researchers in automation of furnace and related activities. Conventional PI controller system is used to control only linear function of furnace; but for nonlinear operations conventional PI controller has limitation [6].

For nonlinear and complex operations of such furnace system is covered by fuzzy system. Implementation of such system using fuzzy logic with the help of controller is complicated [7]. Precise control of process temperature has become increasingly important in today's semiconductor industry [8-10]. Moon and lee proposed a hybrid algorithm with fuzzy system and conventional PI control for the temperature control of TV glass furnace [11]. Radakovic presented an application result of fuzzy controller of temperature and its rate of change in resistance of chamber furnace [12]. Zahari Taha and Sigeru Omatu describe a new approach in which neural network is used to obtain the optimal parameters of a conventional PI controller. With this approach the whole plant is reduced to a first order system. In this approach the network issued to obtain a mapping of a process inputs to its outputs [13].Different control algorithms (PI, PID, Fuzzy system, neural networks) have been used for different operation control in furnaces [6-12].

General system which used in small scale casting industry for furnace operation control is shown in figure 1. In this system operations are control by PLC (programmable logic controller). Mostly in high temperature applications related to furnace, thermocouple is used to continuously measure temperature of molten and measured temperature is shown on display. In molten handling process once the desired temperature is achieved (i.e. 800 degree Celsius) for collecting required amount of molten from furnace, flow tap is opened manually by worker. The molten is collect in storage tank. Quantity of molten collected in storage tank is measured with the help of scale provided on container. In this method of using scale on container for quantity measurement probability of error is high. Tap control by worker add human error because it is not possible to close tap at exact level of molten in storage tank. Handling such molten material at high temperature is so risky for workers; it may cause injury to workers. To avoid any type of accident, control of flow tap and molten handling operation need to be carried out by automated systems.

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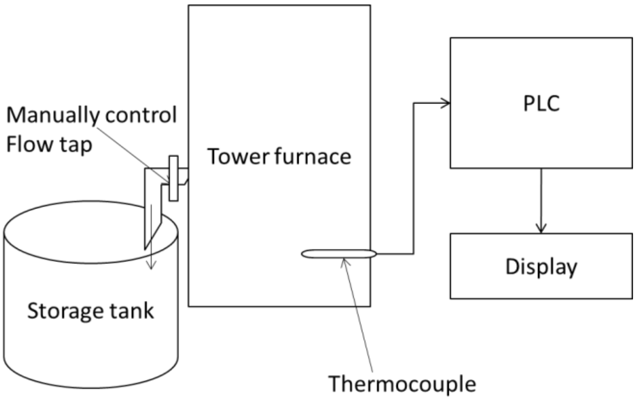

Fig. 1 Block diagram of Existing system

In this paper, microcontroller based approach has been described that minimize manual dependent operations in industrial environment. The main focus of described method is to develop safe and economical embedded system to eliminate manual handing of flow tap and molten.

III. SYSTEM DEVELOPMENT

There are many questions regarding the safety of workers who are working in small scale casting Industry, especially in molten handling process. Figure 2 shows proposed controller based system for control of flow tap and quantity of molten need to be collected. This system has different operations which overcomes limitations of previous existing system.

Control of flow tap is based on the following parameters

1) Temperature of molten in furnace.
2) Level of molten in furnace.
3) Quantity of molten need to be fetched from furnace.

For observing these parameters different sensors are used thermocouple to measure temperature, continues level probe for level measurement and loadcell for quantity of molten.

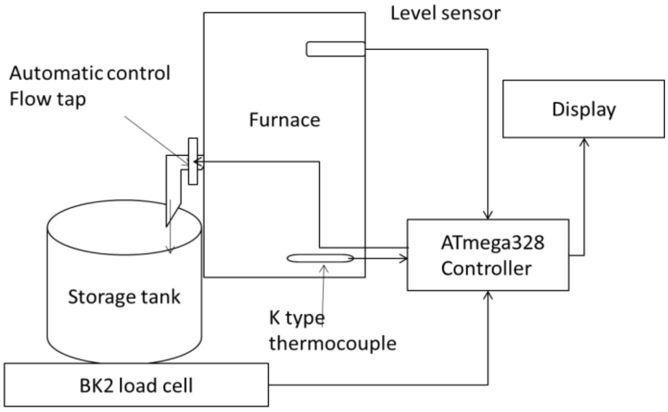

Fig. 2 Block diagram of proposed system

A. ATmega328

The Atmel 8-bit AVR RISC-based microcontroller combines 32 kB ISP flash memory with read-while-write capabilities, 1 kB EEPROM, 2 kB SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible timer/counters with compare modes, internal and external interrupts, serial programmable USART, a byte-oriented 2-wire serial interface, SPI serial port, 6-channel 10-bit A/D converter (8-channelsinTQFP and QFN/MLF packages), programmable watchdog timer with internal oscillator, and five software selectable power saving modes. The device operates between 1.8-5.5 volts. The device achieves throughput approaching 1 MIPS per MHz [1].

B. K type thermocouple

A thermocouple is a temperature-measuring device consisting of two dissimilar conductors that contact each other at one or more spots. It produces a voltage when the temperature of one of the spots differs from the reference temperature at other parts of the circuit. Thermocouples are a widely used type of temperature sensor for measurement and control, and can also convert a temperature gradient into electricity. Thermocouples for practical measurement of temperature are junctions of specific alloys which have a predictable and repeatable relationship between temperature and voltage.

$$V = E(T_{sense}) - E(T_{ref}) \tag{1}$$

Different alloys are used for different temperature ranges. Properties such as resistance to corrosion may also be important when choosing a type of thermocouple. Type K (chromel– alumel) is the most common general purpose thermocouple with a sensitivity approximately 41 µV/°C. It is inexpensive, and a wide variety of probes are available in its −200 °C to +1350 °C range (−330 °F to +2460 °F).The measured voltage can be used to calculate temperature T_{sense}, provided that temperature T_{ref} is known [3]

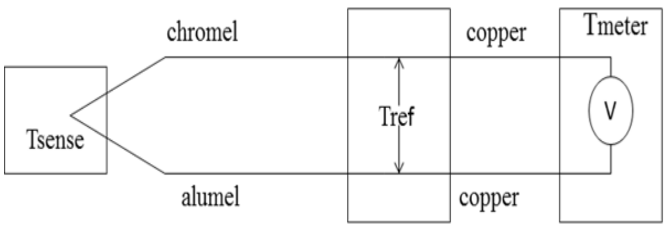

Fig. 3 K type thermocouple

C. BK2 type load cell

This sensor is a stainless steel shear beam load cell with an improved potting. It is suitable for use in industrial environments.

Key Features

1) Wide range of capacities from 200 kg to 2000 kg
2) Stainless steel construction
3) Environmental Protection IP67
4) Very low profile design
5) High input resistance
6) Calibration in mV/V/Ω [4]

Fig. 4 BK2 type load cell

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D. Continuous level probe

It works in the submerged condition with an appropriate protective tube at a melt temperature of greater than 800°C and can therefore also be used in closed systems without forced air cooling. This sensor has a system that directly registers the exact Level in the molten metal through a protective tube. With an airtight adapter available from system the probes can also be used in closed systems with low pressure castings [5].

IV. SYSTEM OERATION FLOW

In proposed system program is develop to control collection of molten in storage tank through flow tap. We need to check three basic conditions to open and close flow tap.
Condition 1) Molten achieved a set value of temperature.
Condition 2) Storage tank is placed on platform which is attached to load cell.
Condition 3) Required amount of molten need to be fetched is set.
Figure 5 shows flow of events in system operation for molten handling.

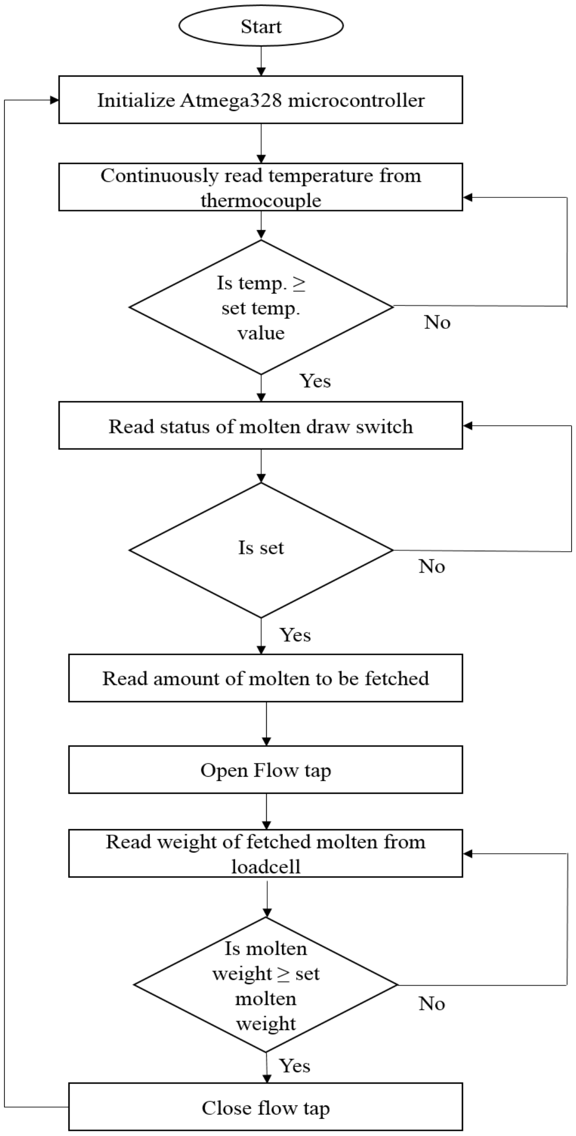

Fig.5: Flow of events in system operation

In the first step, ATmega328 controller initialize IO ports and also read preset parameters like temperature of molten need to achieve before opening of flow tap. Then controller read temperature of molten from thermocouple and check is temperature of molten exceeds set temperature. If temperature of molten exceeds set temperature then controller read status of molten draw button, if it is set controller read amount of molten be fetched. After this events flow tap get open and controller continuously read weight of molten fetched from loadcell. When weight value from loadcell equal or greater than provided weight value of molten to be fetched, flow tap get close and control of system goes again at first step.

A. Experimental Setup

In experimental setup, holding chamber of furnace having storage capacity is up to 10 litres. Height of holding chamber is up to 25 cm. Thermocouple is used to measure temperature of liquid and a load cell having range up to 6 kg is used to measure weight of liquid. Four float switches are used to measure level of liquid in which 1st switch indicate 25% level of liquid, 2nd, 3rd and last switch indicate 50%, 75%, 100% level of liquid respectively. If liquid level is below than 25% or exceed than 100% then for alert buzzer and red led gets active. Heater is used to increase water temperature. When temperature of liquid exceeds 90 degree Celsius then heater will be off with the help of relay. On other side if temperature below to 35 degree Celsius then heater will be on automatically through relay. For flow tap, solenoid value is used which operated on 24V power supply. Figure 5 shows complete setup of prototype for furnace flow tap control.

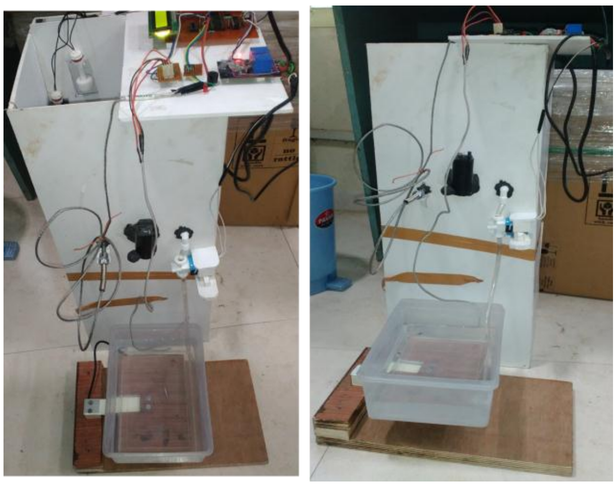

Fig. 5 Prototype for furnace control system

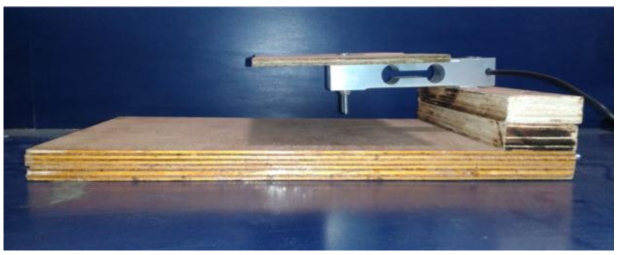

Fig. 6: Weighing platform

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V. RESULT

Performance of the designed prototype system for control of flow type is tested by varying following parameters
1) Temperature of liquid need to achive.
2) Liquid need to be fetched from tank.
Table 1 shows different values of set temperature, measured temperature, weight to be fetched and actual weight of liquid fetched through flow tap for proposed system tests.

Table.2

Sr. No.	Set Temp. (°C)	Temp. measured by thermo-couple (°C)	Set weight of liquid need to be Fetch (Kg.)	Actual weight of liquid collected in tank (Kg.)	Error (gm.)
1	35	38	1	1.025	25
2	35	39	2	2.040	40
3	36	40	3	3.049	49
4	36	37	4	4.056	56
5	38	39	5	5.070	70

Also error in molten fetching process i:e difference between set weight of liquid to be fetch and actual weight of liquid fetched is calculated. Error in molten fetching process varies from 25 gm. -70 gm. which is tolerable for the process.

Accuracy of thermocouple is examine comparing thermocouple temperature readings with thermometer readings for some condition. Table 2 shows error in thermocouple reading. In readings of thermocouple error varies from 1.1 °C to 1.3°C.

Table.2

Sr. No.	Temperature measured By thermocouple (°C)	Temperature measured by thermometer (°C)	Error in thermo-couple reading (°C)
1	38	39.2	1.2
2	39	40.1	1.1
3	40	41.2	1.2
4	37	38.3	1.3
5	39	40.3	1.3

From conducted tests and presents data we can say design system shows good performance in terms different parameter measurement and control flow tap. System show good control over different event in process and able to close flow tap when set liquid weight is fetched from prototype furnace.

V. CONCLUSION

This paper mainly focused on sensing and measuring parameters and according to that parameters control flow tap of furnace. The system is stand-alone application operated by controller and easy to maintain space problem. On the above discussion we can say that microcontroller based control system has a good stability and sensitivity to control such type of operation, but there is main challenge to carried out this whole operation at high temperature in Casting industry.

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