Detection of Cast Iron Composition by Cooling Curve Analysis Using Thermocouple Temperature Sensor

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***Abstract*—**In the foundry practice, the thermal analysis for the various types of cast iron is used. Thermal analysis is a procedure which used to determine inoculants action to decide the percentage of carbon equivalent liquids, carbon and silicon levels. The analytical solution for molten Cast Iron composition measurement is used to explain mechanism of cooling curve of molten cast iron. Thermal inspection can be used to detect metallurgical processes and distinguish potential problems such as low nodule count, under cooled graphite and carbide/chill propensity. The use of thermal analysis is based on the conclusion of the cooling curve – temperature versus time. In proposed system an analytical solution for molten Cast Iron composition measurement is used to explain mechanism of cooling curve of molten cast iron. In the foundry practice, the thermal analysis for the various types of cast iron is used. Thermal analysis is used for the determination of inoculants performance, which determines the percentage of carbon equivalent liquids, carbon and silicon levels. The solidifying metal alloy shows particularities such as thermal arrest, under cooling, change of slope etc. Thermocouple cups are preferred for the thermal analysis of molten cast iron. Thermo cup have quartz protected, high grade type K thermocouple. This method overcomes the various long lasting, time consuming and extravagant steps used in the dictating the composition of the casting.

Keywords— *Alloyed cast iron, Thermocouple, solidification, cooling curve, Thermal analysis*

I. INTRODUCTION

Cast Iron composed of carbon, carbon equivalent, silicon, Manganese, Phosphorus and sulphar. In the recently years there has been improving attentiveness in solidification of thin wall ductile cast iron. One of the first application of thermal analysis (TA) in cast iron is for the estimation of the chemical composition, or pinpoint of the carbon equivalent (CE). For analysis of cast iron composition various methods are used like chemical titration, spark source optical emission spectroscopy. For the solidification of ferrous and non - ferrous alloys, cooling curve analysis or thermal analysis technique is mostly preferred.

This method implies non-chemical based measurement, hence less time consuming and can be implemented during melting, pouring process. When heat treatment is carried out on a material its structural changes turn out and chemical Composition can endure changes such as fusion, crystallization, melting, decomposition, transition and expansion. Using thermal analysis such changes can be monitored. Thermal analysis is belong to material science where the possessions of matter, substance are studied as they change with temperature or transposition. Temperature measurement, and foremost tool, in analysis of solidification, has rarely been used. The temperature sensor such as thermocouple used for the temperature measurement affect on solidification of the casting, the unusual approach is in thin wall castings where the heat content of the melt is small and set side by side to the cooling power of the TC. The thermocouple cups are used for thermal analysis. These cups are non-returnable measuring cups for the thermal analysis of cast iron. The used thermo cups are made of high – grade silica sand and are fitted with a robust and steady connecting system. The cup have a quartz protected, high-grade type K thermocouple. The cup has tellurium for the steadfast thermal analysis reading of CE, C, and Si of cast iron. Metal starts cooling steadily from the corners so results are harmonious. The thermocouple wire is thicker and can stand firm against higher temperatures, the key features of a thermal analysis are sample holder comprising thermocouples, sample containers or ceramic cup and temperature recording and analysis system etc. Cooling curve is a graphical plot of the changes in temperature with time for a material over the uninterrupted temperature range through which it loose heat. In this technique, alloys with different compositions are unfreeze and then the temperature of the mixture is determined at definite time intervals while losing heat back to room temperature. In solidification process of cast iron the initial and final phase temperatures are determined from its cooling curve. Then these temperatures are used for the construction of graph.

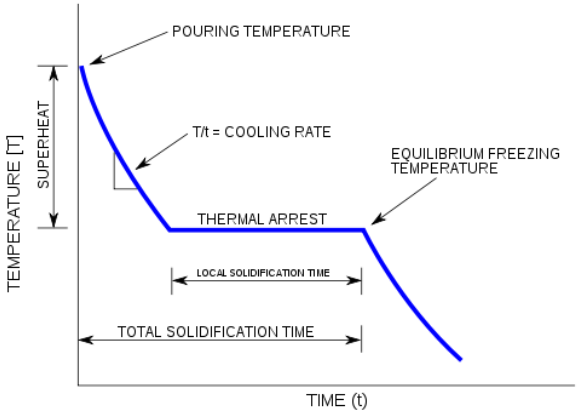

Fig 1. Cooling Curve

Above figure indicates that, the pouring temperature is initial point of graph that is starting temperature of metal. Thermal arrest is nothing but when phase change occurs that is temperature stay constant. The slope of the cooling curve at any point is known as cooling rate. The chemical composition in cast iron is as shown in Table I.

TABLE I. THE AVERAGE CHEMICAL COMPOSITION FOUND IN CAST IRON

Element	**C**	**Si**	**Mn**	**P**	**S**
Wt %	3.31	1.89	0.64	0.018	0.073

Chemical composition is in the required range and it is privilege by fulfilling necessary mechanical properties of metal. Because most cast steel should meet some special properties besides of tensile strength and elongation, so chemical composition will be the most important inspection

II. RELATIVE STUDY OF EXISTING METHODS

A. Induction coupled Plasma Optical Emission Spectrometry (ICP-OES)

This type of method is an analytical method and used for detection of trace metal. This is a flame technique method for estimation of metal composition with a range of flame temperature of 6000 to 10,000K. In this method the RF power of 1150 watts is used. The plasma flow of 15L/min and plasma view at axial mode for all the elements. The temperature evaluated to be in the locality of 10,000K.In this method the spectrophotometer. Thermo fisher ICP with optical emission equipment's are used with i TEVA software. The metal composition standard prepared of any working concentration is monitored at different poible emission lines for metal composition by finding solution. This emission lines are pertain at target RF power of 1150W.The response for metal composition were estimated [1]. But this method takes only liquid samples.

B. Electrochemical Method

In this method the electrochemical cells are used. The cell formed of two electrical conductors i.e. electrodes dipped in a satisfactory electrolyte solution. The conditions are necessary for development of current in a cell is as follows the electrodes must be attached superficially with metal conductor, for motion of ions from one to another rather by virtue of a salt bridge. It is necessary the two electrolyte solutions must be in connection with each other. The electron transfer reaction must arise at each of the two electrodes. A small potential exist at the attachment into the electrolytes and the solid electrode which is known as liquid junction potential. When we change the meter with a low Resistance wire the circuit is accomplished and charge flows. Three marked results observed beneath of this condition as: a) copper ions wander apart from the electrode into the solution. Sulphate and hydrogen sulphate ions pass towards the metal. b) In the other beaker silver ions go from the solution so as to near the electrode and anions move aside from it. c) Inside the salt bridge charge is sustain by potassium ions to the right and chloride ions to the left. Limitation of this process is that metal removal rate is slow; disposal of potentially harmful by products and it requires the handling of dangerous chemicals.

III. PROPOSED SYSTEM

The general block diagram of proposed system is as shown in figure.

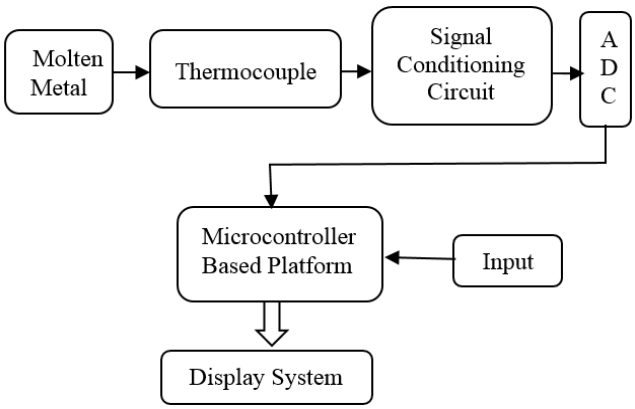

Fig. 2 Proposed System

The proposed system used for analysis and measurement of cooling curve of cast iron for composition measurement using thermocouple. Microcontroller based platform will be used for measurement and analysis of metal composition like Carbon, Silicon, Carbon equivalent, Manganese, Phosphorous and sulphar etc.

From figure, the molten metal is input to the system. A thermocouple generate a temperature- dependent voltage as a consequence of the thermoelectric effect, and this voltage can provide information to measure temperature. The operating principal of thermocouple is when two unlike metals are

connected, a foreseeable voltage is generated that associate with the difference in temperature between the measuring junction and reference junction. A thermoelectric electromagnetic field (EMF) is result in within the thermocouple when temperature gradient exist between hot junction and cold junction. The magnitude of the EMF is equivalent, and is associated with the temperature difference between the two points, not just the temperature of the measuring junction. Signal conditioning circuit require for controlling an analog signal in such a way that it encounter the essentials of the next stage for further processing. For the preamplification of the signal in the signal conditioning stage, operational amplifiers are used. ADC transform an input analog voltage to a digital number corresponding to the magnitude of the voltage.

The temperature of involving several arrests and the outlay of change in temperature at different points are measured with the help of an embedded thermal couple. Thermocouples are most satisfactory for measuring over a huge temperature range, up to 1800°c. In this plateau detection technique is used. In this technique, the transient response of sensors and system is shrug off to obtain steady state response and firmly established by taking several samples. Once it place in its detection criteria the temperature is put on show. This technique shows precise temperature and push aside incorrect reading by giving error messages. Plateau detection technique is recommended for measurement of molten metal temperature. In case of plateau detection method, once thermocouple is dipped into molten metal first peak temperature is disregard and it make certain 7 constant readings for a period of one second and reveal true temperature readings. The key point to take into consideration that thermocouples measure the temperature difference between two points, not absolute temperature. In present work, thermocouple is stipulating with the microcontroller based platform indicating device by a remarkable wire known as the compensating or extension cable. Extension cable uses wires of marginally the same conductors as used at the thermocouple in essence. These extension cables are usually assemble in an appropriate form to carry over long distances- typically as malleable insulated wiring or multi core cables. They are usually enumerate for the accuracy over a more inadequate temperature range than the thermocouple wires. It is endorse for best accuracy. The extension cable or compensating cable must be opt for to peer the thermocouple. It generates a voltage analogous to the temperature difference between the hot junction and cold junction and is fix in the correct polarity so that the additional voltage is added to the thermocouple voltage, remunerating for the temperature difference between hot and cold junctions.

Microcontroller based system is used for the analysis of cooling cycle, required time period for successive samples storage will be obtained and number of sample will be stored. From the sequence of input data Solidious point and Liquidous point will be obtained. Using analytical tools and equations, composition analysis for Si, C, and Carbon equivalent will be done. Input keys are used for user interface to system. For displaying estimated values and curves display system is used.

The equations necessary for the practical use of thermocouples are derived from the basic definition of the Seebeck Effect.

$$\%C = 4.30 – 1/3\ (\%Si + \%P)$$

The impact of Si and P can be intimate concerning carbon, therefore the conviction of Carbon Equivalent Value:

$$CEV = \%C + 1/3\ (\%Si + \%P)$$

The CEV of a cast iron provide with a recommendation about how much its ingredients distinguish from the eutectic composition. When the carbon equivalent is lower than, equal to, or higher than 4.30 then cast iron is assess to be hypoeutectic, eutectic or hypereutectic respectively. Instead of CEV, the influence of Si and P is occasionally intimated by the saturation degree (Sc), comparing the total carbon content of the iron with the carbon content of the strict eutectic composition:

$$Sc = \%C_{total} / [4.30 – 1/3\ (\%Si + \%P)]$$

If Sc = 1, it means that the iron composition be consistent with exactly with the eutectic composition. Values lower or higher than 1, in concur with respectively with hypoeutectic or hypereutectic cast iron.

IV. CONCLUSION

Temperature based cooling curve is less time continue compared to titration based chemical analysis. Thermocouple based temperature measurement is most accurate and widely used. Due to use of microcontroller based platform, temperature recording and analysis of Carbon equivalent, Manganese, Phosphorous and sulphar etc. using solidus point and liquidous point. To measure ingredients, major components of cast iron can be easily analyzed using this method. The metal composition can be instantaneously analyzed and can be changed when melting process is going on.

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