Performance improvement of Sinter Machine #2, Sinter Plant, Bokaro Steel Plant, through implementation of advanced automation system

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The function of the sinter plant is to supply the blast furnaces with sinter, a combination of blended ores, fluxes and coke which is partially ‘cooked’ or sintered. In this form, the materials combine efficiently in the blast furnace and allow for more consistent and controllable iron manufacture. Materials enter the sinter plant from storage bins. They are mixed in the correct proportions using weigh hoppers. The weighed materials pass along the conveyor to the mixing drum, where water is added as a calculated percentage of the weight of material entering the drum. The mix material is fed onto the strand from the hopper by a roll feeder. The quantity of material in the feed hopper itself is held constant by automatic adjustment of the feed rates from the individual material bins feeders. The raw mix is ignited by the ignition hood, which is fueled by a mixture of coke oven gas & blast furnace gas. A separate control system is provided to maintain a fixed hood pressure by adjusting the wind-box dampers immediately under the ignition hood. The sinter strand is a moving conveyor of hot sinter, which continues to ‘cook’ after leaving the hood, where the air is pulled from the sinter by a strand draught fan. The draught on the strand is maintained at a preset value by controlling the main fan louver from pressure measurements in the wind main. This governs the point at which burn through occurs. After leaving the strand, the hot sinter is cooled in straight line cooler. The sinter making process is shown in Figure 1.

The sinter making process substantially depends on the efficient functioning of a series of operations. Due to their complex nature and frequent process fluctuations, a precision automation system is imperative in each of these operations, which is also significant for sinter quality improvement and optimum resource utilization. The application of advanced Process Automation Controllers (PAC) coupled with powerful programming tools and Human Machine Interfaces (HMI) is essential for composite operations to sinter making. A state-of-the-art PAC-based process automation and control system has been developed and successfully implemented in Sinter Machine #2 of Bokaro Steel Plant. The system includes high-end dual redundant PAC processors, redundant communication networks, operator’s consoles, instrumentation system and weigh feeder control mechanism.

![Sinter making process](image)

Fig. 1: Sinter making process

The automation system provides a comprehensive process control and visualization system for entire Sinter Machine #2 of Bokaro Steel Plant. It incorporates a precise hopper level cascaded control mechanism accomplished through feed rate regulation of four conveyors discharging raw mix in balling drums. The system also envisages the speed
control of two nos. of balling drums, sinter machine and straight line coolers. The desired moisture of raw mix, which is a critical parameter for sinter quality, is achieved through feed water flow control prior to balling drum. The ignition furnace temperature is controlled by adjusting the gas/air ratio. Furnace temperature, gas and air flow rates are the key process inputs of this control. An efficient Human Machine Interface (HMI) facilitates online control, operation and monitoring of Sinter Machine #2. The salient features of HMI include Burn Through Point (BTP) display, Bar Graph Representation of wind box temperature and pressure, Ignition Furnace thermal condition, Raw Mix moisture, etc. The HMI also accentuates graphical pop-up displays and historical trending of key sinter plant parameters, alarm annunciation as well as enables networking connectivity for plant wide ERP.

The advanced process control system has significantly improved the performance of sinter machine. The average daily sinter production has been improved by 5 per cent. The precision ignition furnace temperature control has reduced the Specific Heat Consumption by 6.6 per cent. Process control and electrical delays have reduced by 90 per cent. The figures demonstrate that significant benefits can be reaped by the application of advanced process automation in the actual plant process control.

Introduction

Sintering is a crucial part in ironmaking process. The natural iron ore occurring in the mines contains impurities like alumina, silicate, phosphorous, sulphur, etc. The ores are generally beneficiated to minimise these impurities and enrich iron percentage. However, this beneficiation process creates some fine grains with size less than 10 mm, which cannot be charged directly into blast furnaces. This is because it is not possible to charge too many fine materials in blast furnace as it would lead to a blockage of flow of the reducing gas. Further, coal also cannot be charged into a blast furnace due to the lack of physical strength required to withstand the conditions inside the furnace. Mainly due to the above reasons, prior to charging in blast furnaces, iron ores fines are pre-treated for sinter formation. The sintering process involves agglomeration, i.e. heating of raw mix, which primarily consists of iron ore fines, coke breeze, metallurgical wastes, lime, dolomite, etc. to produce a semi-molten mass that solidifies into porous pieces of sinter with the size and strength characteristics necessary for feeding into the blast furnace. The sintering of iron ore is imperative for improving blast furnace productivity, hot metal quality and minimising resource utilization in the ironmaking process.

Sinter making process comprises of many sub-processes like primary mixing of raw materials (iron ore, dolomite, lime, fines, etc.) followed by secondary mixing of raw materials with water in balling drum, maintaining the level in hopper bin within the desired limits, controlling the temperature in ignition furnace at the desired levels, controlling the speed of sintering machine and straight line coolers to the levels so that the sintering process completes before the material leaves the sintering bed. Besides, the overall suction and pressure maintaining the individual wind-box pressure and temperature also needs to be continuously monitored. For tighter control over the process, the monitoring and control of the various process parameters need to be stringent. This calls for an efficient control system to take care of the control needs. An advanced integrated automation system has been implemented in Sinter Machine #2 of Sinter Plant, Bokaro Steel Plant, jointly by RDCIS and Plant. The automation system facilitates a comprehensive control panacea for controlling various process parameters from balling drum weigh feeders to sinter coolers as mentioned above through state-of-the-art Programmable Automation Controller (PAC)-based process control system. A user-friendly Human Machine Interface (HMI) has also been developed for centralized monitoring and control of sinter machine. The automation system has resulted in significant improvement in plant performance in terms of productivity and energy savings.

Architecture of Automation System

The architecture of automation system has been carefully designed to cater to the requirement of cascaded process control loops of sinter plant as explained above.
The overall performance of sinter machine depends on the accuracy of individual control actions each contributing to sinter quality. The automation system facilitates an online PAC-based control and visualization system for Sinter Machine #2 of Bokaro Steel Plant. To ensure the uninterrupted plant operation, PAC is selected with high availability, fault tolerant and dual redundant configuration w.r.t. processor, communication and networking. The field instrumentation is connected to the system through various analog and digital input/output cards. The I/O cards are linked with processors through redundant networks. The operation of sinter machine is controlled and monitored from two dedicated operators’ console. The processor and operator’s consoles are also connected through redundant Ethernet networks. The PAC system is dovetailed with weigh feeder and hopper level control system for seamless operation. The schematic of system with process control modules is depicted in Figure 3.

**Implementation of Sinter Machine Control Modules**

Sinter Machine No. 2 at Bokaro Steel Plant is facilitated by two nos. of secondary balling/nodulizing drums. Raw mix is fed into the balling drums through two dedicated weigh feeders for each drum. After the water mixing in the balling drum, the material falls through two conveyors into the hopper. The primary control variable in this segment of Sinter Machine is feed rates of weigh feeders, which are controlled through dedicated controller panels. The load cell and conveyor speed signals are the key process inputs. Based on hopper level signal as estimated through weight of raw mix in the hopper, a dedicated controller in the hopper level control panel generates set points for individual weigh feeder feed rates. Based on actual and set feed rates, the individual controllers in weigh feeder panels generate a reference signal for Variable Frequency Drives (VFD), which finally controls the feed rates of conveyors. The safety and other electrical interlocks are also taken care by the weigh feeder panels.

All weigh feeder control panels, hopper level control panel and PAC system have been seamlessly integrated for bi-directional communication. The desired hopper level set point is communicated to the hopper level control panel from PAC. The PAC also has the provision of directly adjusting feed rates of individual feeders. All the salient weigh feeder and hopper level control signals are available in PAC HMI for monitoring and control.

The moisture content in the raw mix after balling drum is a very crucial parameter for sinter quality. Water is sprinkled on the raw mix inside the rotating balling drum. Moisture is controlled by regulating water flow rates through glove valve mounted electro-mechanical actuators in feed water flow pipes. The actual water flow rate and output raw mix moisture are salient process inputs. The desired water flow rate is computed by PAC based on actual input weigh feeder feed rates. Based on the above signals, PAC controls the water flow rate by continuously regulating the water pipe actuators. The rotational speeds of balling drums are also controlled by PAC. Temperature control of Ignition Furnace is another critical parameter for sinter machine. The temperature control is accomplished through cascaded heating gas and combustion air ratio control. The furnace temperature is measured by two nos. of thermocouples. Based on actual temperature signal, the primary temperature controller module generates set points for heating gas and combustion air flow controllers. The latter controllers are coupled through gas/air ratio and their input variables are respective flow signals. The flow controllers regulate the heating gas and combustion air to achieve desired Ignition Furnace Temperature. Hearth suction, gas and air pressure are other variables used for monitoring. All the above control and monitoring are accomplished by PAC. Wind-box pressure and temperature are extremely crucial for sinter plant operation. Sinter Machine #2 of Bokaro Steel Plant comprises of 24 nos. of wind boxes. The control system facilitates several visualization graphics of wind box temperature and suction in the form of animations, bar graphs, trends, etc. The Burn through Point (BTP) wind-box position is displayed on the HMI. This helps the shop operator to adjust machine speed, considering the production requirement and quality targets. PAC renders an effective tool for controlling the Sinter Machine Speed. The actual machine speed as measured by encoder-based sensor is the key input process variable. The machine speed is abutted with electrical and safety interlocks. Another parameter related to the sinter machine speed is Straight Line Cooler (SLC) Speed. PAC also controls the speed of SLC-based on actual speed reference signal and sinter machine speed. The number of sinter cooler blowers to be operated for effective cooling of hot sinters can also be operated from the system.

The system renders a centralized control and monitoring system for all the aforesaid operations, which are widely located inside the sinter plant. A user-friendly Human Machine Interface (HMI) system has been developed using animations, Graphics User Interfaces (GUI), pop-up screens, etc. Graphics tools have
been provided for various adjustments and fine tuning of control actions. Instantaneous and historical trends have been facilitated for analysis of process parameters and improvement in shop performance. Various audio-visual alarm annunciations have been provided to ensure safety interlocks and for maintaining process within the permissible regime. The centralized control and HMI facility has adduced an expeditious and convenient operation of entire Sinter Machine #2. The overview screen of HMI is shown in Figure 4, below.

![Fig. 4: HMI Screen depicting Sinter Plant Process Parameters](image)

**Results and Conclusion**

The PAC-based automation system is controlling Sinter Machine #2 at Sinter Plant Complex of Bokaro Steel Plant. The system exemplifies an online industrial application of PAC-based control system. The sinter plant performance has been significantly improved due to online supervision of the entire process by centralized control system. The HMI developed to facilitate the shop floor with many user-friendly GUI screens, pop-ups, animations and trends. The system has contributed to achieving a very efficient temperature control within ± 10°C accuracy under normal operating conditions. Besides above controls, the hopper bin level controls have also been revamped with new auto bin level control system, resulting in immense benefit to the shop. The auto level control system has been networked and integrated with the PLC system. The auto system takes care of the hopper level, thereby reducing machine stoppages due to bin getting empty or over filled. With the new system in place, the operational efficiency has increased as all the controls have been integrated and made available in the operator console. This has resulted in reduction of machine stoppages due to process and electrical delays by 90 per cent, reduction in specific heat consumption by 6.6 per cent and increase in average daily production by 5 per cent. The above results illustrate that significant benefits can be achieved by introducing the appropriate Automation System and carefully integrating it with actual online process control.

![Fig. 5: Operator’s Consoles for Centralized Control & Monitoring](image)

**Trends depicting accurate control of Process Variables**

![Fig. 6: Historical Trend of Sinter Machine Speed Control](image)

**References**


