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An Intelligent Permeability Optimization System at Sinter Plant of Rourkela Steel Plant

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Abstract - The permeability of sinter mix is one of the vital parameters that affect the performance of sintering process. The amount of water added in the granulation drum has a significant effect on the permeability of the sinter bed and sinter machine productivity. Considering the variation in input feed materials and the parabolic nature of permeability-moisture curve, the optimum level of water addition is a difficult task for the operator to determine. Therefore a mathematical model based intelligent permeability measurement system is developed which determine the required amount of water to be added in granulation drum to achieve the optimum permeability based on the given input material.

Keywords- sinter, permeability, mathematical model, moisture control, control system

I. INTRODUCTION

The sintering process is a pre-treatment step in the production of iron, where fine particles of iron ores and in some plants, also secondary iron oxide wastes (collected dusts, mill scale), are agglomerated by combustion. Agglomeration of the fines is necessary to enable the passage of hot gases during the subsequent blast furnace operation.¹

The productivity of sinter plant depends on the air flow through the sinter bed. This in turn primarily depends upon the suction under grate and the permeability of charge mix. Permeability – moisture curves are parabola shaped, passing through a maximum at the point where the moisture is optimum. It is known through various laboratory experiments and literature that 1 % deviation of moisture from optimum, leads to 10% drop in sinter productivity. Hence precise control of water addition to achieve higher productivity cannot be over emphasized.

Earlier method of determining optimum moisture of sinter mix in Sinter Plant-I (SP-I) of Rourkela Steel Plant (RSP) was totally based on the operator's perception, which varies from operator to operator. More over the control of water flow was also done manually which makes the process more tedious and needs constant monitoring because the nature of charge itself varies constantly.

Considering above problems and the importance of optimum permeability in sinter making, a mathematical model based automatic permeability optimization system by online dynamic moisture control was introduced at SP-I of RSP. Taking various signals like feed rate, bunker weight, % moisture, water flow rate etc. as input, the mathematical model calculates the permeability of green charge mix and based on the estimated permeability value and the water being added, the working point on the parabolic relation of permeability and moisture is estimated.

II. BED PERMEABILITY

The first stage of sinter making involves granulating a mixture of iron ore fines together with fluxes, coke breeze and recycled undersized sinter in a large rotary drum. Water is sprayed on to the cascading particles, increasing the mean size and tightening the size distribution of the mix. The resulting granules are fed onto a moving grate and the top of the bed ignited. During the sintering process the flame front descends down the bed of granules under application of suction until the entire mass of material has been converted into a porous but physically strong block of sinter. This is then crushed, screened and the product fraction fed directly to the blast furnace.

During the sintering process, convective heat transfer drives the flame front down the packed bed. Since the strand speed is directly dependent on rate of heat transfer across the bed height, hence productivity during sintering is a strong function of the gas flow velocity. According to the Ergun Equation¹, gas flow velocity across a packed bed is dependent on the bed properties: void space in the bed; mean particle diameter; nature of particles (e.g. surface roughness, channel tortuosity) and particle shape by²

$$\frac{\Delta P}{L} = 150 \frac{\mu(1-\varepsilon)^2}{\phi^2 d_p^2 \varepsilon^3} U + 1.75 \frac{\rho(1-\varepsilon)}{\phi d_p \varepsilon^3} U^2 \quad \text{Eq. 1}$$

Where ΔP = pressure drop across the bed, L = height of the bed, μ = gas viscosity, ε = void space in the bed, d_p = granule mean diameter, U = gas flow velocity, ρ = gas density and Φ = particle shape factor.

The above mentioned equation shows that the gas flow velocity is very much dependent on changes in bed permeability. A slight decrease in bed permeability results in a significant reduction in the gas flow velocity under a given set of conditions.

Bed permeability is generally measured in Japanese permeability Units (JPU) and can be calculated based on the following equation^{3,4}:

$$JPU = \frac{F}{A} \left(\frac{L}{\Delta P} \right)^{0.6} \quad \text{Eq. 2}$$

Where F=air flow rate (m³/ min), A=cross sectional area of the bed (m²), L=height of the bed (mm) and ΔP=pressure drop across the bed (mm H₂O).

In order to study the bed permeability as a function of mix moisture, various laboratory scale experiments were carried out by varying the % of moisture in a controlled manner. The results for four different ores are presented in Fig.1 and show quadratic equations fitted to the experimental data. It can be seen that bed permeability increases with increasing moisture before passing through a maximum (P_{max}) and decreasing at higher moistures.

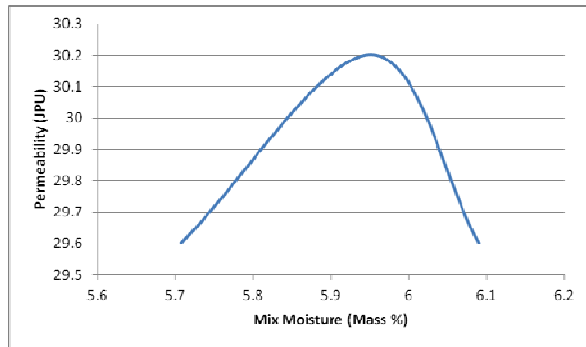


Fig. 1: Bed permeability as function of mix moisture⁵

Based on various experiments it was found that, 1% deviation from the optimum moisture leads to 10% drop in permeability and in turn 10% drop in sinter machine productivity.

III. PERMEABILITY OPTIMIZATION SYSTEM

A. The Need of Permeability Optimization System

Previously SP-1 of RSP used to follow a very age old practice in which the operator at regular intervals used to make “laddo” (handmade lump) of charge mix post bunker to perceive whether the moisture is optimum or not. Accordingly he controls the water flow. This method was not much effective because it was totally based on the operator’s perception, which varies from operator to operator. More over the control of water flow was also done manually which makes the process more tedious and needs constant monitoring because the nature of charge itself varies constantly.

Considering above problems and the importance of optimum permeability in sinter making, RDCIS along with RSP has introduced an intelligent permeability optimization

system at both the sinter machines of SP-1 at RSP. The system admits compressed air through a metering device into the charge mix bunker. The green permeability is estimated in charge mix bunker by taking input signals of flow rate of compressed air which is coming through a pipe into the bunker and the back pressure developed due to resistance posted by the charge mix to the air flow inside the bunker. The air flow rate and back pressure are measured by flow and pressure transmitters installed in the compressed air line. Height of the charge mix in the bunker and the average area are calculated using the load cell signal at regular intervals. The PLC based data acquisition system retrieve those data from these transmitters and make it available to the program in PC for calculation of permeability. Taking those various signals as input, the mathematical model calculates the permeability of green charge mix and based on the estimated permeability value and the water being added, the working point on the parabolic relation of permeability and moisture is estimated.

B. System Description

The general arrangement of the permeability measurement system and water control is given in Fig.3. This is a PLC-PC based system. The compressed air @ 50 to 100 Nm³/h is admitted into both the charge mix bunkers through a mild steel pipe of 100 mm dia. The opening of the pipe is positioned at 200 mm above the roll feeder at equidistant from the sides of the bunker wall. A new pipe line is laid from the existing compressed air station at SP-I for this purpose. This is bifurcated through a header. Each line has a pressure transmitter for measuring the back pressure and an orifice plate assembly. The differential pressure across the orifice is measured through a differential pressure transmitter. The pressure signals and differential pressure signals are fed into the computer (Fig.2). The feed rate, bunker weight, % moisture, water flow rate, machine running position, balling drum running position and conveyor running position signals are taken from the existing instrumentation / electrical panel through suitable isolators and fed in to the computer. Water control signal is taken through a selector switch. This is to facilitate control of water addition either through the operator or through the permeability optimisation software. By controlled addition of raw mix in to the bunker an equation was generated to arrive at the height of the material in the charge mix bunker and the area at that height. These data are utilised for the calculation of the permeability using Eq. 2. This permeability data is utilised through the permeability optimisation software to evaluate and assess the present position in the permeability versus charge mix moisture curve.

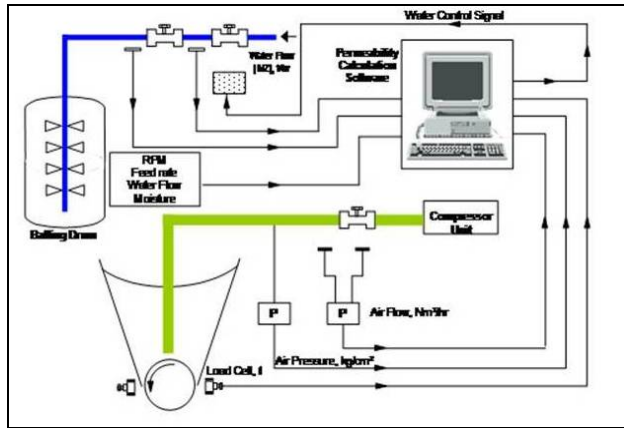


Fig.3: General arrangement of permeability measurement and water control system

Accordingly a set point is generated and down loaded to the water controller either to reduce or increase the water addition in small increments to achieve the optimum moisture and thereby increased permeability. The increased permeability directly contributes to the increased productivity. Water is added in the balling drum.

C. The Mathematical Model

There are two sinter machines in Sinter Plant-1. Both the machines receive the base mix from the same source. Apparently it is logical to expect both the sinter machines operate at the same moisture percentage and permeability. But it may be seen at a given instance both the sinter machines operate at different moisture percentage and permeability. This is due to differing balling efficiency, return sinter percentage addition, segregation and loading characteristics. Moreover the variation in input materials and other conditions also results in change in permeability of the base mix. It is impossible for the operator to control the water flow based on the input quality of the sinter mix resulting in loss in productivity.

In order to achieve the optimum moisture in sinter mix it is desirable that the bed permeability be predicted mathematically to ensure close control on the sinter quality. Based on the real-time conditions the bed permeability of the sinter mix has been calculated using the widely accepted Equation.2, but the real challenge was to determine the exact position of bed permeability in permeability-charge mix moisture curve. The input materials as well as the surrounding conditions are so dynamic that lead to frequent shifting of the optimum point of moisture in the permeability-moisture curve. In order to take care of the issue, relative permeability is determined at regular intervals and is compared with previous permeability value to determine the optimum moisture level. For example, after increasing the water flow, if it was found that permeability value of a given sinter mix has shown an improvement, the model will keep on increasing the water flow with each iteration until any further increase results in decrease in

permeability value of that sinter mix. In this way the maximum permeability is reached. The system will control the water flow accordingly to maintain the permeability of sinter mix in the maximum point for the given type of sinter mix. As soon as the permeability-moisture curve changes because of change in input material or other conditions, the model again compare the new values with old and repeat the same exercise to attain the new optimum point. This enables the system to take corrective actions dynamically based on real-time conditions which was earlier impossible to be done manually.

IV. RESULTS & DISCUSSION

A. Air Filtration Velocity

The permeability measurement system was installed in both the sinter machines in 2009. Air filtration velocity measurements were carried out during the operation of the sinter machines using the permeability optimisation system and without using the system. The results are shown in Fig. 4. From these it is evident that the use of the permeability optimisation system resulted in increase in air filtration velocity from 0.3 to 0.36 m/s. This directly translates in to increase of sinter productivity.

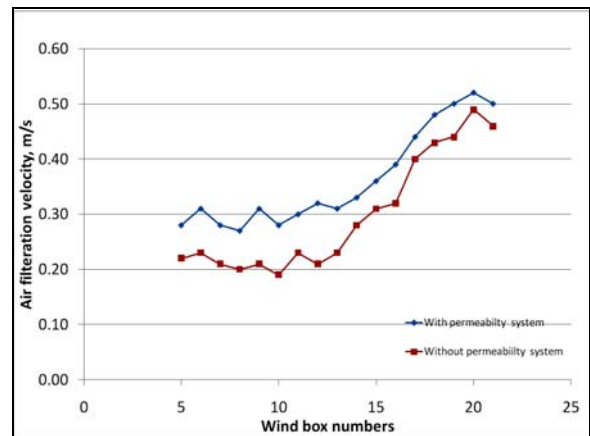


Fig.4: Air filtration velocity with and without permeability contro

B. Burn-Through-Point

Burn Through Point (BTP) is an important indicator that signifies whether the sintering process is complete or not. It is the maximum temperature of flue gas in the wind box during sintering. BTP data with and without the permeability measurement system is given in Fig.5. The BTP has shown an advancement by 2 wind boxes (from 20th to 18th wind box) when the permeability measurement system was operational. This further confirms that the air filtration velocity through sinter bed has improved because of improvement in permeability of sinter charge when the system is under use. Since the sintering process completes in advance, it gives sufficient room to the operator to increase the line speed which in turn increase the productivity of the machines.

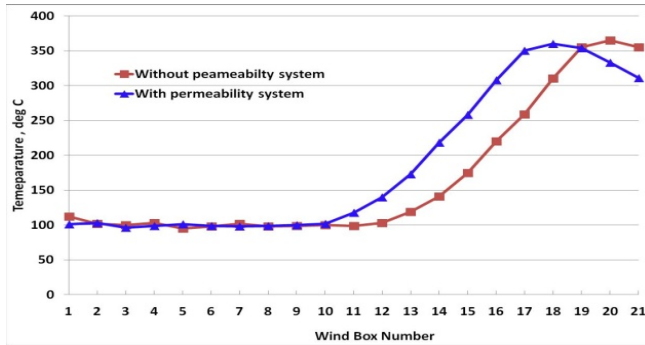


Fig.5: BTP curve with & without permeability optimisation system.

V. CONCLUSION

The mathematical model based control system not only provides a better way of controlling the process but it controls the system in a scientific way. The system makes the process less dependent on the expertise of the operator. The PLC based system ensures the control more accurate which results in continuous monitoring of the bed permeability and accordingly control the water flow to

achieve the optimum permeability. The system was patented on 7th July 2006.⁶

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