Energy Saving Technology for Lowering Air Leakage of Sintering Pallets in Sinter Plant

JIA-SHYAN SHIAU*, SHIH-HSIEN LIU*, CHIA-MING HSIEH, PO-YI YEH** and KUN-HSIANG HUANG****

** Iron & Steel Research & Development Department,.*
*** Iron Making Department,*
China Steel Corporation.

In operational practice of the iron ore sintering machine, the increasing air leakage ratio will result in higher electricity consumption of the suction fan, higher solid fuel rate consumption, and lower sintering productivity. In general, more than 50% of the leakage occurs at the pallets themselves and the interfaces between the pallets and the wind boxes. Basically, the sintering strand is comprised of a large number of pallets. And, this leads to a larger number of sealing parts. Consequently, the routine examination of the sealing condition of the pallets for detecting any abnormal air leakage is quite a heavy load for the maintenance staff. Hence, an on-line continuous measurement technology for the air leakage ratio of the sintering machine has been developed in China Steel Corporation (CSC). It has been applied to help the maintenance staff easily find any abnormal air leakage efficiently, then to repair or replace the pallets in short time.

In this technology, the hot-wire type anemometers are fixed on a moving rack for scanning the velocity of the effective air flowing through the sinter bed. Meanwhile, the microphones are installed beside the pathway and close to the outer sidewall of the travelling pallets for monitoring the sound pressure generated by the abnormal air leakage. For identifying the passing pallet, the thermal-resistant type RFID technology is adopted. Based on the data measured from the hardware system mentioned above, the air leakage ratio of the sintering machine can be calculated with the mass balance method and total gas flow rate drawn by the suction fan. And, the pallets with abnormal leakage can be detected and ranked in the severity of leakage according to the measured sound pressure with the relevant criteria.

The technology had been implemented in the sintering plants of CSC, and the operation result indicates that it can effectively reduce the air leakage ratio by 5% and further decrease the electricity consumption of the suction fan for the sintering machine. In fact, this technology is very helpful to maintain a low air leakage ratio during the long-term operation of the sintering machine.

Keywords: Sintering Machine, Air Leakage Ratio, Pallets, On-line Detection

1. INTRODUCTION

The air leakage from the sintering machine means that the air flows through the leakage points into the main exhaust pipe of the sintering machine without participating in the sintering reaction of the sinter raw mix. Basically, the leakage will lower the effective air volume flowing through the sintering bed under a fixed suction force of the fan, illustrated in Fig.1. Currently, the air leakage rate for a world-class sinter plant is about

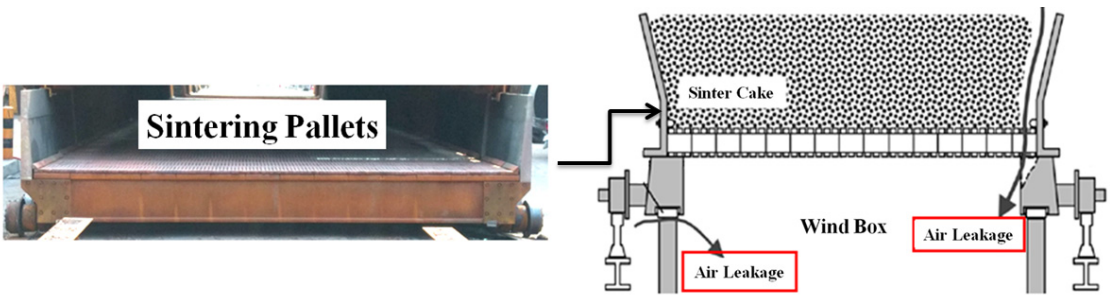

Fig.1. Schematic diagram of air leakage occurred in a sintering pallet.

30-35%[1,2]. In general, more than 50% of the air-leakage occurs at the pallets themselves and the interfaces between the pallets and the wind boxes. In fact, the air leakage in the iron ore sintering process is an inherent problem which can not be diminished completely. In the past, relying on inspection by maintenance staff, made it difficult to quickly and accurately identify the pallets with severe air leakage. At present, the technology for measuring the air leakage via the flue gas analysis has been widely adopted in steel plants. However, there were some application problems such as heavy workload of gas sampling and complicated operational processes, long-term continuous detection is needed with the ability to identify specific air leakage locations.[3]

In this study, an on-line technology for measuring the air leakage ratio of the sintering machine has been developed to effectively and timely monitor the change of the air leakage. It enabled the maintenance staffs to repair or to replace the equipment for minimizing the air-leakage in time. Since the technology applied in CSC sintering plant, the air leakage and the electricity consumption was decreased by about 1% and about 0.15 kWh/ton-sinter, respectively.

2. RESEARCH METHOD

2.1 Measurement of superficial velocity of air sucked into sinter bed

In this study, a device was designed and assembled for measuring the superficial velocity of air sucked into the sinter bed surface. In the device, six hot-wire anemometers with protective sleeves are fixed on a movable supporting rack which stands over and across the sinter strand, shown in Fig.2. For a sintering machine, the total effective air flow rate can be obtained by moving the rack over the entire surface of the sinter bed in short time for scanning the superficial wind velocity.

2.2 Ranking system for the severity of air leakage among the sintering pallets

2.2.1 Air leakage detection system for sintering pallets

In this study, a microphone array was installed beside the pathway and close to the outer sidewall of the travelling pallets for monitoring the sound pressure generated from the abnormal air leakage. And, a thermal-resistant type RFID technology was adopted for identifying which pallet on the sinter strand is passing the detector.

2.2.2 Alarm criteria of the air leakage for sintering pallets

An appropriate threshold value of the sound pressure was pre-set as the baseline for determining whether to turn on the air leakage alarm or not. The alarm number of each pallet is counted once when the average value of the sound pressure received from microphones is greater than the threshold. And, the ranking of the sound pressure of the air leakage among sintering pallets is renewed from time to time.

2.2.3 Verification work for the reliability of ranking system

According to the ranking, the top few pallets would be replaced by the well-maintained pallets sequentially during a short-term downtime of the machine. The new ranking list was closely observed during the beginning operation after the replacement of pallets. It is necessary to examine the damaged condition of the replaced pallets for verifying the correctness of the ranking system.

2.3 Basic theory and test for detecting air leakage of sintering pallets

The basic principle of air leakage detection on the sintering pallets is an application of the sound field analogy equation, shown as Eq. (1), on the sound originated from the gas leakage.

$$P(x,t) = k\,\rho\,u^2MD, \quad f = u/D \quad \text{..... (Eq. 1)}$$

Where, P: total sound pressure (Pascal, N/m^2)

k: weighted constant (-)

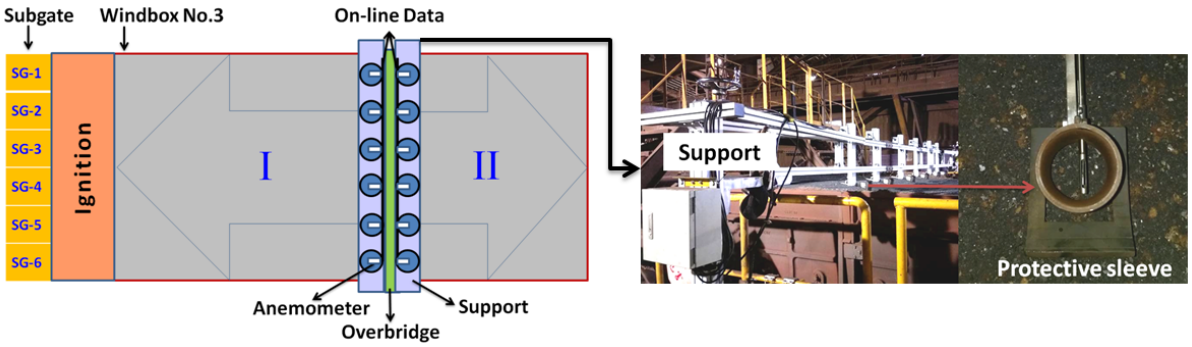

Fig.2. Schematic diagram of the measurement of the effective gas flow into sinter surface.

ρ: gas medium density (kg/m^3)

f: noise frequency (1/sec)

u: leakage rate (m/s)

M: Mach number (-)

D: diameter of leakage (mm)

It could be known from the equation that the sound pressure of air leakage is proportional to the leakage aperture. And, the sound pressure becomes larger when the air leakage becomes higher. In this study, a microphone array was installed near the travelling path of pallets to receive the sound pressure of the pallet. In our testing, it was proven that the pallet with the severer air leakage, compared to well-condition pallets with low air leakage, had obviously higher sound pressure from low to high frequency, as shown in Fig.3. It also was confirmed that the technology applied to monitor the severity level of the air leakage is highly reliable.

3. RESULTS AND DISCUSSION

3.1 Results of the air leakage ratio measurement for sintering machine

Based on the data measured via the technology developed in this study, an illustrated example for the calculation of the air leakage ratio of a sintering machine is shown in Fig.4. The average effective wind velocity measured by the anemometers on the sinter surface was 0.398 m/s. Multiplied by the surface area, the average effective air volume through the sinter bed was 451,650 m^3/hr. During the measuring period, the average temperature and velocity of the flue gas at the stack were 142.5 °C and 12.23 m/s, respectively. And, the cross-sectional area of the gas channel of the stack is 25.44 m^2. Then, the total gas volumetric flow drawn by the main fan of the sintering machine can be calculated, 803609 m^3/hr. Due to the evaporation of water that happens during the iron ore sintering, the steam flow rate should be subtracted from the total gas flow rate on the calculation of the air leakage ratio. In this example, the steam flow rate was, 65116 m^3/hr. estimated on the condition of the free water content (7.2%), the crystal water ratio (7.92%), bulk density (1920 kg/m^3) of the raw material, the width (4.5m), bed height (0.7m), the travelling velocity (0.031 m/s) of the pallets, and with an assumption that 50% the mixture on the pallets of the sinter strand is in a wet state. Finally, 38.84 % for the air leakage ratio of the sintering system was obtained via the mass balance calculation based on the condition mentioned above.

3.2 Verification and Application of the automatic ranking system

The air leakage ranking system for the sintering pallets was developed and verified in this study, three (No.137, 130, and 28) of the top few pallets in ranking list were replaced with the well-condition three pallets (No.71, 30, and 84) when the sintering machine was temporarily shut down for the scheduled maintenance. After the machine re-started, the new three pallets did not enter the air leakage ranking list for a long time. From the observation on the exterior appearance of the replaced three pallets, some severe damages were found and recognized as the cause of the air leakage. Generally, the main types of damage were distortion and worn-out grate bars, cracked pallet walls, stuck seal bars, as shown in Fig.5. The high reliability of the air leakage detection system developed in this study was verified many times by the examination mentioned above. To minimize the air leakage, this system was used in CSC sinter plant to

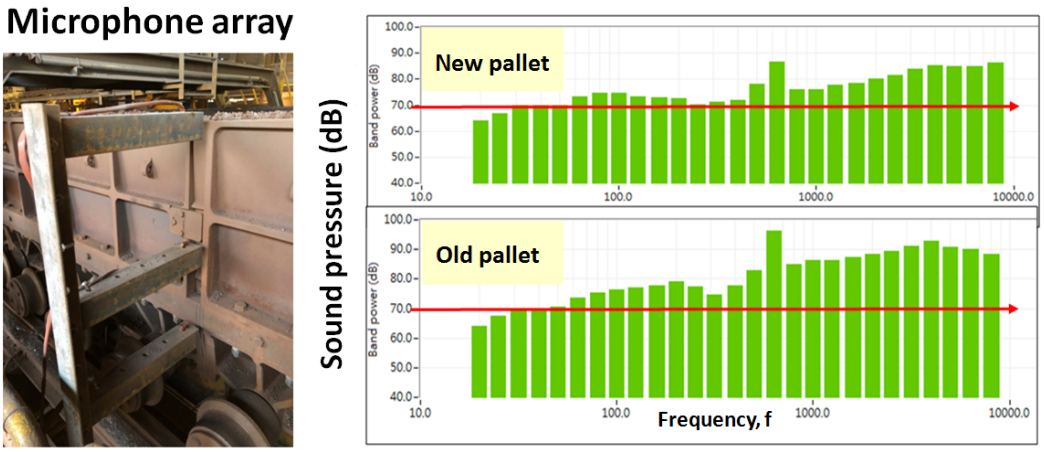

Fig.3. The typical sound pressure received from an old pallet and a new pallet.

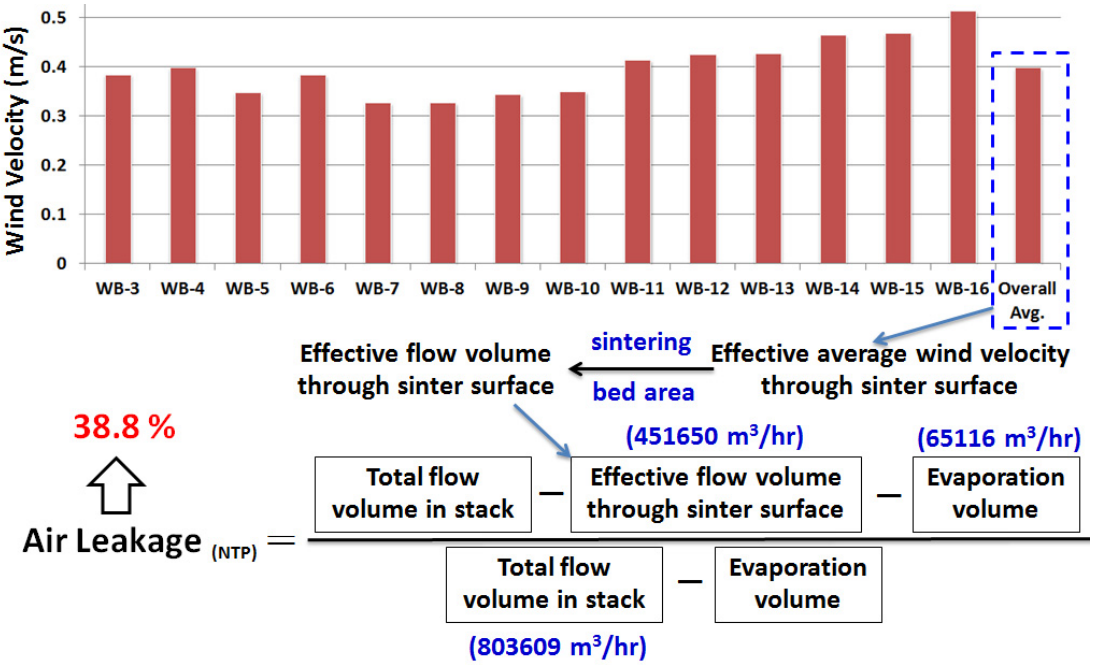

Fig.4. An illustrated calculation of the air leakage ratio in a sintering machine.

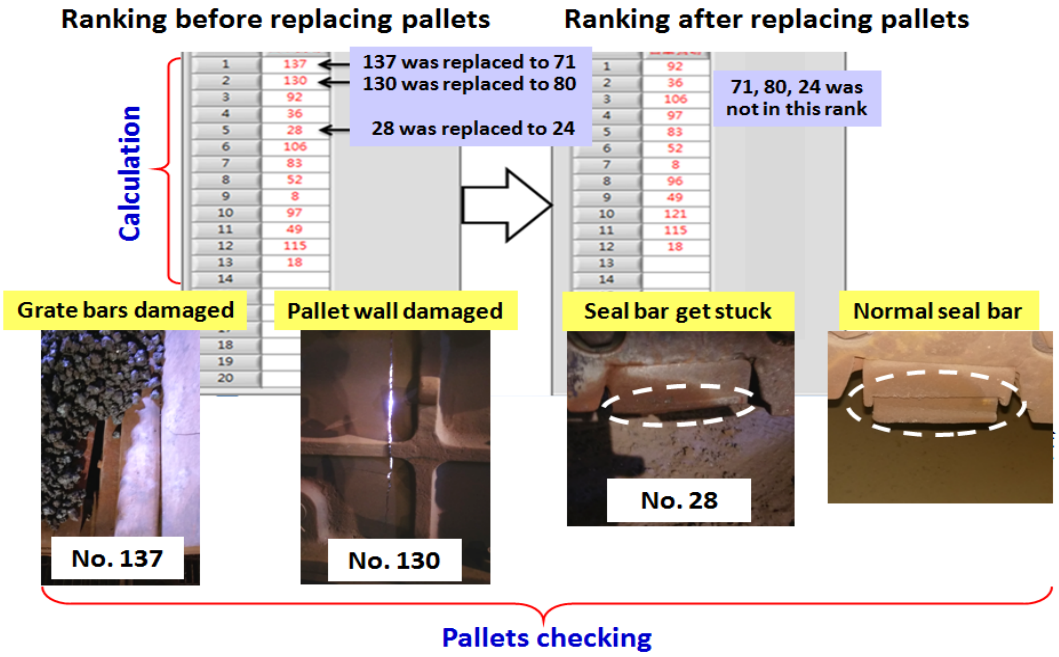

Fig.5. An example of the air leakage ranking list and the various damage that cause air leakage.

assist the maintenance staff for quickly and accurately identifying pallets needed to be replaced. Basically, the higher the air leakage, the less efficient the fan suction, and the lower the productivity of the sintering machine. The benefit of the system application has been revealed in the obvious reduction in the electricity consumption of the suction fan and the increase in the sinter productivity of the sintering machine.

3.3 A system developed to identify the pallet under the measurement of the wind velocity

For the air leakage ranking on the pallets of the sintering machine, it is required for the system to be able to identify which one in the pallet strand is under the wind

velocity measurement and the sound recording. Hence, the RFID (Radio Frequency Identification) technology were applied to develop a positioning system which enable the air leakage detection system to precisely identify which pallet has abnormal air leakage. It can instantly present the effective wind velocity at six positions for each pallet which is travelling by the middle section of the sintering machine, as shown in Fig.6. The threshold value on the low wind velocity was set to be a criterion in the ranking system of the air leakage severity of the pallets in the sintering machine due to the less effective air volume flowing through the sinter bed. Finally, in combination with the criteria of sound pressure and wind speed, the air leakage ranking system for pallets can screen out the pallets which must be replaced as soon as possible, as shown in Fig.7. According to the feedback from the users in the sinter plant operation, it has been appreciated that this technology is very helpful to the staff in charge of the process operation, the equipment inspection and maintenance in the sinter plant. The system had been implemented in No. 2 sintering machine of China Steel Corporation (CSC) firstly and extended to the remaining five sintering machines.

3.4 Achievements and benefits

In this study, the energy saving technology for lowering the air leakage of the sintering machine was developed with the combination of a measurement system for the air leakage ratio of the sintering machine and an air leakage ranking on pallets based on sound pressure and wind velocity. Since the implementation of the technology in No. 2 sintering machine in CSC, the air leakage ratio and the electricity current of the suction fan were reduced by about 5% and about 20 amps, respectively, counted on 14 months operational data. The technology has significantly reduced the sintering energy consumption and achieved the target of energy savings, as shown in Fig.8.

4. CONCLUSIONS

In the development of this technology, the hot-wire type anemometers were used for measuring the velocity of effective air flowing through the sinter bed, and the air leakage ratio of the sintering machine was calculated with the mass balance method. Meanwhile, the microphones were installed beside the pathway and close to the outer sidewall of the travelling pallets for monitoring and recording the sound pressure generated by the abnormal air leakage, and the thermal-resistant type RFID technology was adopted for identifying the travelling pallets. A ranking system was developed to identify pallets with abnormal leakage and ranked in the severity of leakage according to the measured sound pressure and wind velocity with the relevant criteria. This technology had been implemented in the CSC No. 2 sinter plant and it would effectively reduce the air leakage ratio by 5%

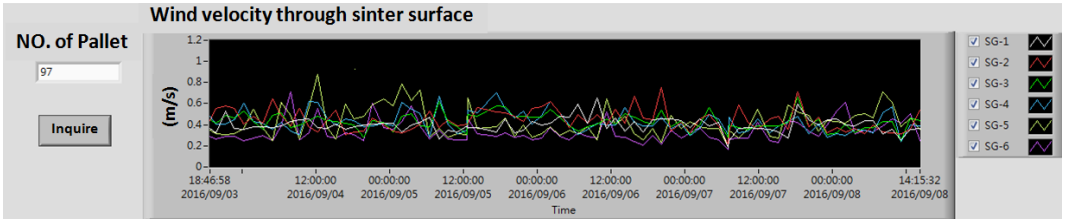

Fig.6. An example of the display of the wind velocity measured during a period for each pallet

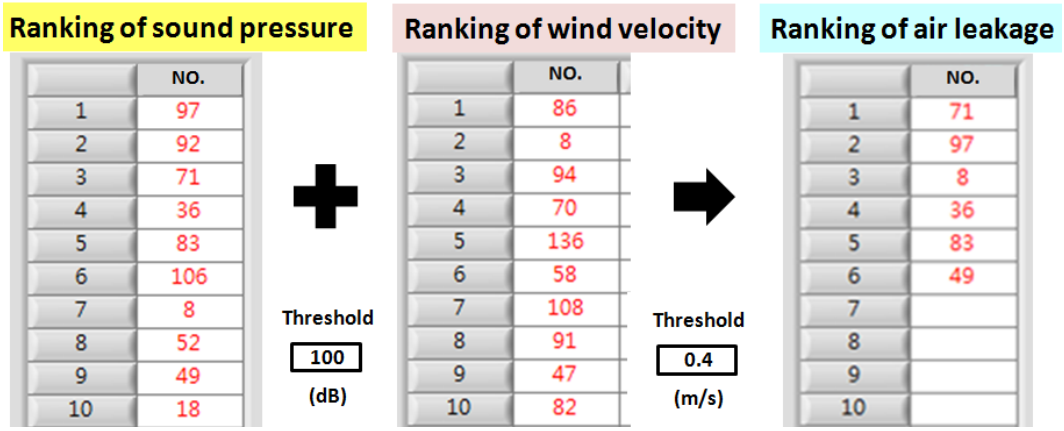

Fig.7. The air leakage ranking on pallets based on sound pressure and wind velocity.

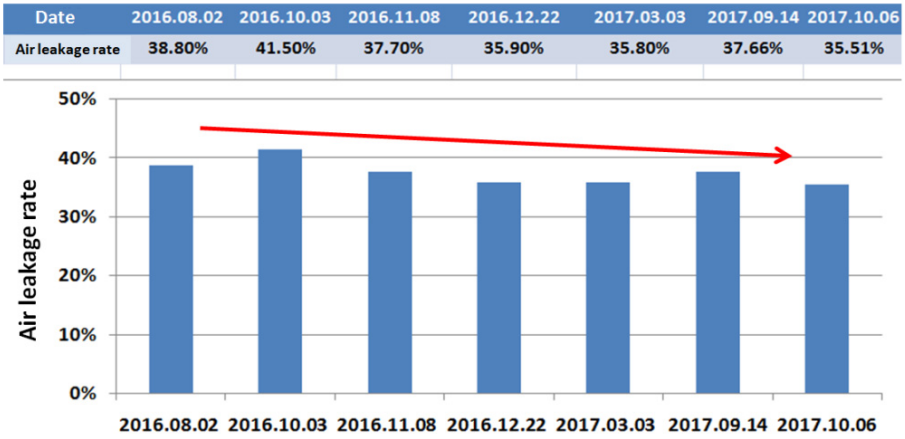

Fig.8. The reduction of the air leakage ratio after the implementation of the energy saving technology in No.2 sintering machine of CSC.

and further decrease the electricity consumption of the suction fan for the sintering machine.

REFERENCES

1. H. L. He, "The technical methods of reducing the flow leakage rate of sinter system", Baosteel BAC (2013), K400-K403.
2. S.A. Liu, T.Y. Xia, Z.W. Li and J.B. Dong, "Analysis and Improvement of Air Leakage of the 360 m^2 Sintering Machine System", Angang Tech., No.2, (2014), pp. 42-44.
3. X.Y. Song and W.H. Li "On the Air Leakage Rate Measurement Technology of Sintering Machine System", Energy and Energy Conservation, No.8, (2013), pp. 51-53.
4. Y.Z. Wang, J. L. Zhang, Z. J. Liu and C. B. Du, "Recent Advances and Research Status in Energy Conservation of Iron Ore Sintering in China", JOM, 69, 11(2017), pp. 2404-2411. □