Visualization and control of the entire foundry for Better Casting Manufacturing

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ABSTRACT

Green sand molding is one of the most common processes since this is suitable for mass production such as automotive parts. Typical casting defects in green sand molding are usually caused by abnormal sand properties. Sand properties correlated to casting defects are classified following two groups; one group is those which changes drastically in a short term such as sand temperature or moisture, and the other group is those which changes moderately in long term such as clay content. For the first group, in order to keep sand properties stable to feed, automatically measure the properties at short intervals such as several minutes and control accurately are required. On the other hand, for second group, analyze statistically about sand properties, estimate the trend of transition and then adjust them in long term according to the estimation is required. The concept of such sand management is incorporated in a sand treatment total system. It is the first step for making a high quality casting to adjust sand properties aggressively from cooling and keeping moisture of the return sand to the final adjustment in the mixer. To realize above mentioned concept, various developments are advancing for sand treatment system and these developments evolves advanced and IT utilized sand control. This paper describes the trends of state-of-the-art sand treatment system.

Keywords: Green Sand Molding, Sand Treatment System, Advanced Sand Control, IT Utilized Sand Control, The integrated manufacturing system,

1. Introduction

Fig.1 illustrates a flowchart of the standard green sand treatment system. Sand treatment system is classified to sand recovery process, sand cooling process, and mixing process. These processes are configured by following devices; 1) sand recovery process: magnetic separator and screen, 2) cooling process: water spraying device, sand cooler and sand bin, 3) mixing process: water feeding device and Compactability controller. Sand cooling and mixing process strongly contribute to stabilization of green sand properties among above mentioned processes. Sand cooling process utilizes vaporization heat of water in sand cooler by spraying water to hot return sand after pouring[1)]. Evolution of production system requires further improvement for sand cooling ability. Mixing process takes part of final adjustment of sand properties with adding water and

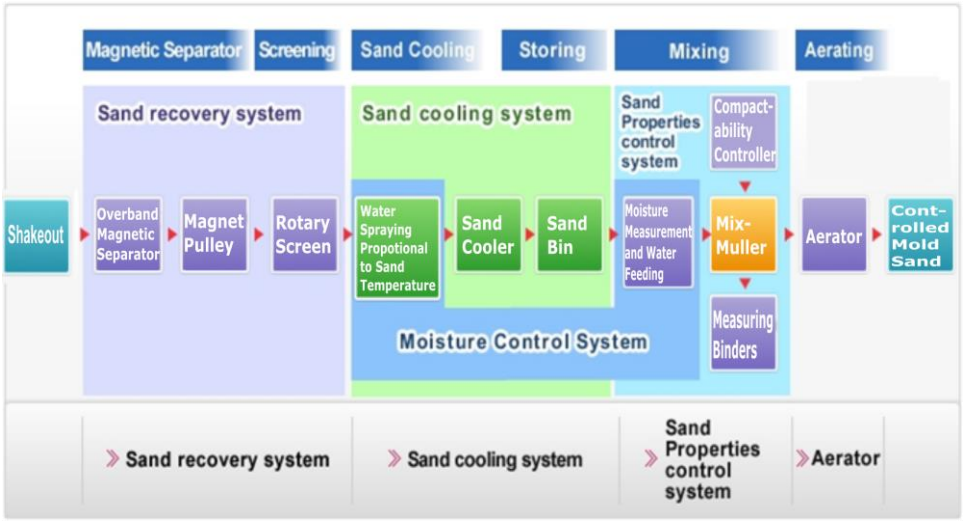

Fig.1 Flowchart of the Standard Green Sand Treatment System

additives. Accuracy of properties and quality improvement for mold sand is also required for quality improvement of castings. To satisfy on-site needs, following developments are conducted such as improvement of sand cooling ability, improvement of sand property control accuracy, and monitoring mold sand quality in order to prepare quality mold sand.

2.Improvement of accuracy in Sand Cooling System

Fig. 2 shows configuration of conventional sand cooler[2].

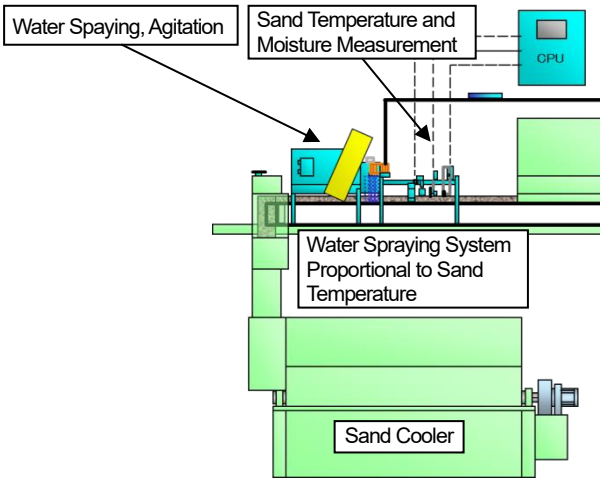

Fig. 2 Configuration of Conventional Sand Cooler

At first, a sensor mounted on the belt conveyor measures return sand temperature and moisture. Next, the water spraying system calculates moisture vaporized on cooling and moisture shortage against target moisture after cooling based on measured moisture value, and then sprays water. Next, an agitator mounted on the belt conveyor agitates water sprayed on hot sand, and then drum type and cooler agitates it again. Contacting air during agitation vaporizes moisture in hot

mold sand and cools down sand temperature. To improve cooling efficiency, much more moisture should be vaporized in the sand cooler. Therefore, moisture in mold sand should be dispersed uniformly prior to the sand cooler. Conventional agitators tend to cause non-uniform moisture dispersion and also non-uniform sand property due to wear of agitator blades. To solve these problems, ability of the agitator prior to the sand cooler is improved[3]. Fig. 3 shows the outside view of developed agitator. This device is mounted between the belt conveyor and the sand cooler. The agitator first feeds water to sand come from the belt conveyor, agitates it inside the device and then continuously discharges it to the sand cooler. This device enables to agitate all of sand pass thorough it uniformly and this results to disperse water good enough and finally water is vaporized more efficiently.

Fig. 4 shows cooling ability comparison between conventional model and developed model. When sand temperature becomes 80 deg. C or hotter, developed model clearly shows that cooling ability is drastically improved since sand temperature after cooling becomes much cooler than conventional model. By this result, this device is particularly beneficial for foundry plants those which return sand temperature becomes hot. And as mentioned below, this device contributes to stabilization of sand properties at mixing process.

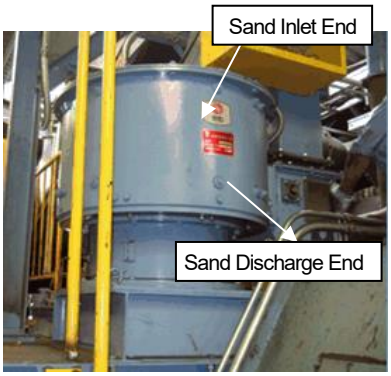

Fig. 3 Developed Agitator

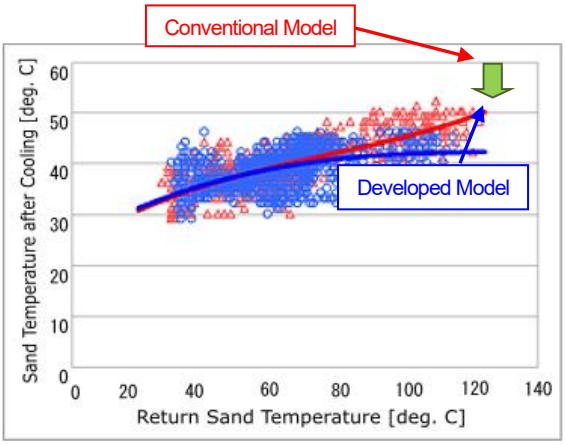

Fig.4 Cooling Ability Comparison

3. Sand Mixture Control System

In recent years, batch type mixers are the mainstream for final mixing process. Particularly, high-speed mixing type becomes popular since foundries prefer high throughput mixers. The advantage for our mixing system is to provide greater bonding with less bentonite by transmitting pressing force of rollers good enough to sand grains with using wide-roller type mix-muller. Moreover, moisture and Compactability are measured and adjusted at the mixer to control sand properties in one batch. Fig.5 shows the schematic diagram of the system. At first, an electrode type sensor in moisture measurement and water feeding system measures moisture and sand

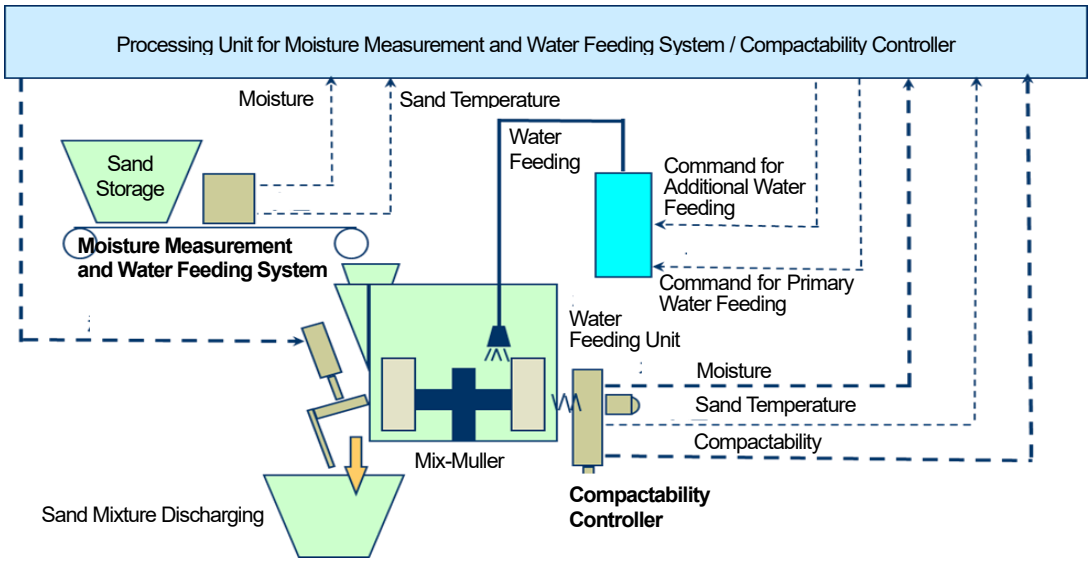

Fig. 5 Sand Mixture Control System

temperature of return sand between the sand feeding storage to the molding machine. Concurrently, a load cell weighs sand for one batch. The system determines primary water feed amount to the mixer in order to control moisture for target value based on the measured data. Next, the sand feeding storage feeds sand to the mixer; after then, primary water is fed and mixing begins. After a period, the Compactability controller samples sand from the mixer automatically and measures Compactability and moisture. If measured Compactability is not within the target range, water added and then the controller measures it again. The controller repeats this process until Compactability is within the range. When the controller confirms that Compactability is within the range, mixing process is completed and the mixer discharges sand mixture. Now, sand properties change day by day since fines content or core sand content also change day by day. Therefore, periodical preparation of the calibration curve is required to maintain accuracy of water amount for primary feeding. The calibration curve is defined by the relationship between voltage at electrode and moisture; consequently required water amount is calculated by using this relationship. Decrease of water amount accuracy has the risk for over feeding of water. To avoid this risk, primary water amount is set to the value less than the target and additional water feedings approach Compactability to target value during mixing (see Fig. 6). If much water is added in additional feedings, water cannot be dispersed to whole sand mixture in short time and this trouble causes moisture segregation. On the other hand, perfect mixing is to feed appropriate amount of water in primary feeding and to reach target Compactability range in the shortest time as shown in Fig. 7.

Fig. 8 shows the calibration curve for conventional system, and Fig.9 shows that for developed

system. The biggest difference between both curves is calibration curve for conventional system is defined the relationship between electrode voltage and “current” sand moisture; on the other hand, that for developed system is defined the relationship between electrode voltage and “required” moisture to achieve the target. The developed system[4] feedbacks required water amount for next mixing cycle according to actual total water amount at present mixing, water amount calculated by electrode voltage at the sensor on moisture measurement and water feeding system, and the calibration curve. This mechanism enables to calibrate relationship between electrode voltage and water amount to feed automatically and eliminates periodical preparation of the calibration curve.

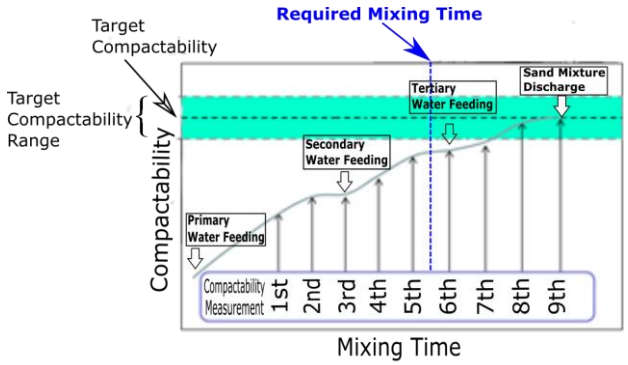

Fig. 6 Compactability Transition in Conventional System

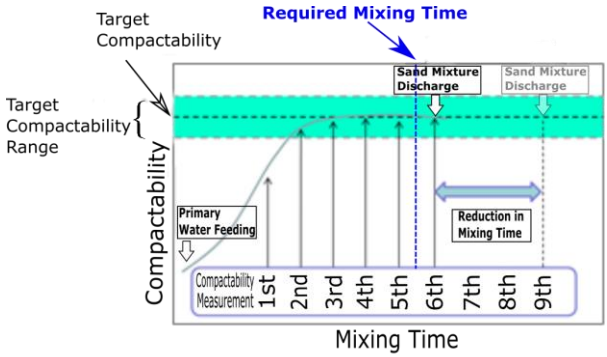

Fig. 7 Compactability Transition in Developed System

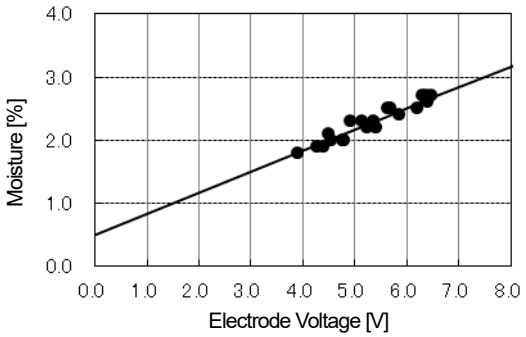

Fig. 8 Calibration curve for Conventional System

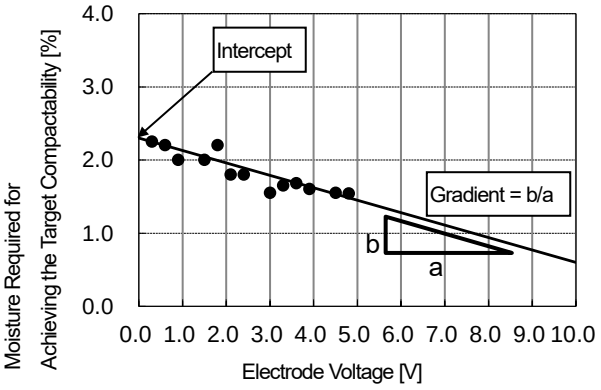

Fig. 9 Function for Determining Required Water Amount on Primary Water Feeding in the Developed System

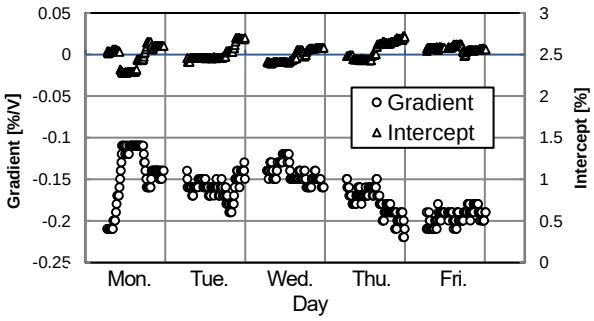

Fig. 10 Transition of Calibration Curve When New Algorithm Valid

Fig. 10 shows the transition of calibration curve with new algorithm in an actual plant. Calibration curve was believed to prepare once in several months to maintain measurement accuracy. The transition result measured in a plant which stops weekend shows that relationship between voltage and water feed amount varies widely immediately after the plant starts operation in Monday morning. In the other days, the result shows that this relationship also varies in one day.

The developed system enables to improve water feed accuracy and to keep accuracy automatically by improvement of calculation algorithm and water feeding unit as mentioned above. Capable of measuring Compactability in one batch and monitoring data such as actual water amount, sand weight in one batch, weight of additives, etc., which are necessary to determine required water amount accurately, achieves this system. Fig. 11 shows the Compactability measurement result in conventional system, and Fig. 12 shows that in developed system. These graphs show the status of Compactability after primary water feeding; the lateral axis indicates the difference between target Compactability and Compactability after primary water feeding, and vertical axis indicates the frequency. In conventional system, probability being within target Compactability +/- 3% was 64.0% and this probability indicates that further adjustment is often required in secondary water feeding. However in developed system, the probability is greatly improved to 95.8%. This result shows developed system enables to increase the probability to be within target Compactability range. Consequently, this system enables to reduce total mixing time by reducing frequency of additional water feeding. Table 1 summarizes effects of the developed system. The developed system greatly improves water feeding accuracy, eliminates delay in mixing time, and increases throughput 24%. Moreover, the system supplies more stable and accurately controlled Compactability sand since standard deviation σ of Compactability discharged from the mixer for target Compactability is decreased.

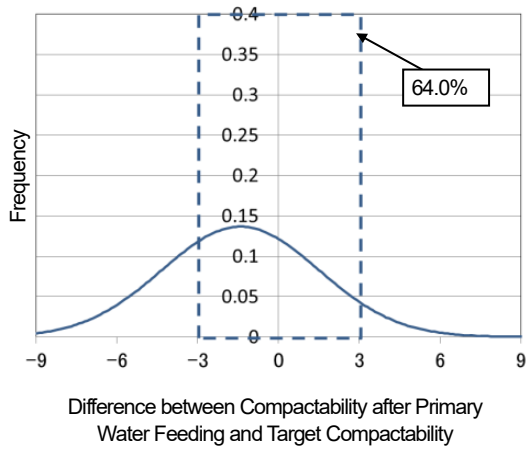

Fig. 11 Compactability Measurement Result in Conventional System

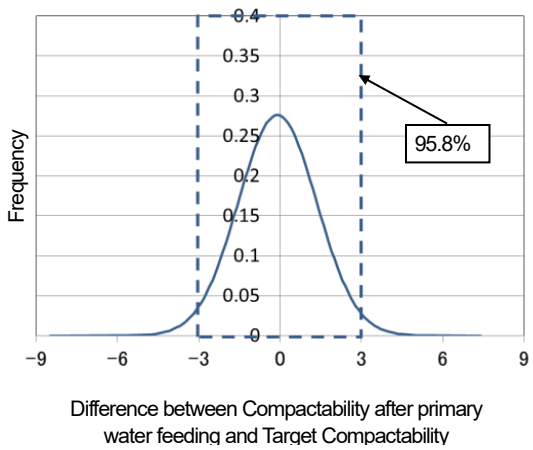

Fig. 12 Compactability Measurement Result in Developed System

Table 1. Comparison between Conventional System and Developed System

Items	Developed	Conventional
Probability to Achieve within Target Range by Only Primary Water Feeding	95.8%	64.0%
Increased Throughput (Set Conventional as 100)	124	100
Standard Deviation for Compactability in Sand Mixture (σ)	1.07	1.32

4. Mold and Property Monitoring System

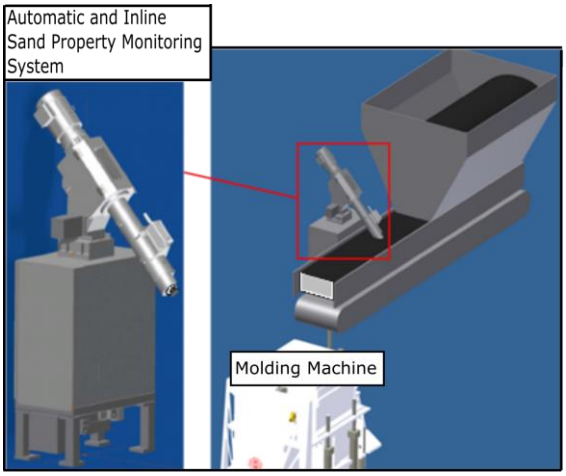

Fig.13 Outside View of Automatic and Inline Sand Property Monitoring system and Situation to be Built Inline

During to send sand mixture from mixers to molding machines, sand properties changes by external factors such as change in room temperature and humidity or line stops. However, inconstant sand property variation enables to be difficult to figure out the actual sand properties of mold sand. Actually, operators sample mold sand periodically on molding machines, and then test engineers confirm sand properties in the laboratory with using many manual test devices. Consequently, it is very difficult to investigate casting defects caused by abnormal sand properties and solve them correctly. Therefore, the automatic and inline sand property monitoring device is developed in order to monitor mold sand properties prior to molding machines automatically and utilize them for investigating casting defects or indexes for stabilizing mold sand. Fig. 13 shows the outside view and the situation how the system to be built inline. This system samples mold sand from the sand supply conveyor to the molding machine, and then measures sand temperature, moisture, Compactability, permeability and compressive strength automatically. Especially, compactability influences moldability. However, influence of sand temperature and ambient temperature varies compactability on molding

machine and cannot always satisfy the target on molding machine. Developed sand tester controls compactability of sand mixture to meet target value of compactability on molding machine by feedback control based on measured compactability on molding machine. Fig.14 shows the comparison with/without feedback control. Result of without feedback shows higher compactability in the morning and compactability is descending forward evening time. On the other hand, feedback control enables to supply steady compactability molding sand to molding machine all day.

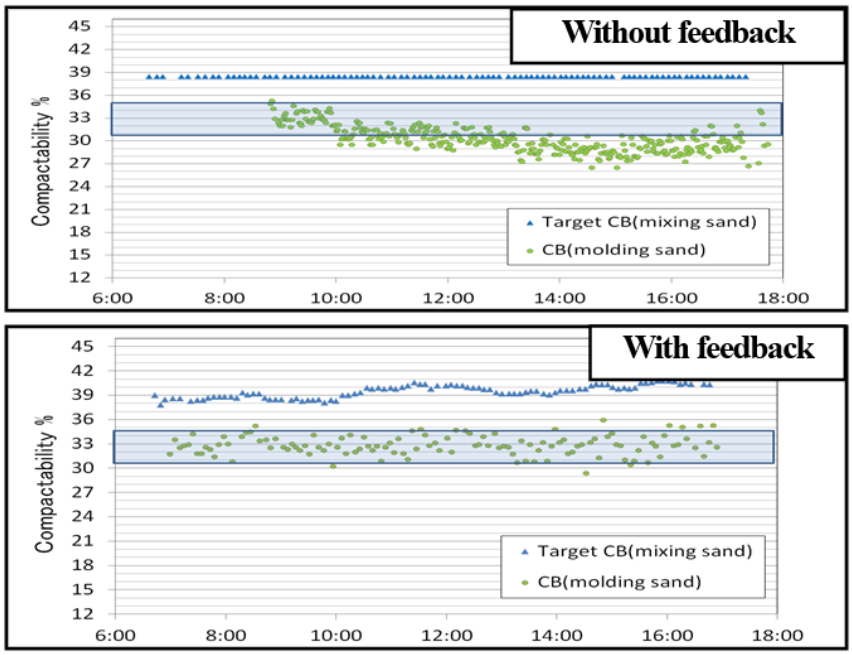

Fig.14 Compactability on Molding Machine With/Without Feedback Control

5. Conclusion

In green sand plants, development of molding machines has been carrying on in order to improve quality of castings. Concurrently, development of sand treatment plant controllable sand properties accurately has also been carrying on. Technical innovations on each stage of foundry plant have improved casting quality greatly. However, skilled workers are anticipated to be decreased in the future. Foundry plants are required to achieve further higher performance and fully automated control with utilizing IT in this difficult situation. We will continue to develop foundry plants as the integrated manufacturing system in order to achieve further higher quality castings.

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