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IMPROVEMENT OF SINTER PRODUCTIVITY AND QUALITY[1]

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Abstract

West Japan Works (Fukuyama) of JFE steel have two sinter plants. Fukuyama #4 sinter plant (Suction area: 454 m^2) is normal plants. It means that #4 sinter plant don't have HPS plant. And Fukuyama #5 sinter plant (Suction area: 605 m^2) have HPS(Hybrid Pelletized Sinter) plant. We make always improvement of sinter productivity and quality. This paper reports several contents of our improvement. Summary is follows. i) JFE has developed an advanced granulation process for the treatment of raw mixtures, named "Clear (Coke breeze and Limestone External Addition for Reactivity) Process". We introduced Clear process in Fukuyama #5 sinter plant. Probably, combination of HPS and Clear process is the first time. As the results, productivity increase about 3% with the improvement of granulation size; ii) we are making improvement of the operation precision. We try to improve the BTP (Burn trough point) control again. As the results, productivity increase about 2% with the improvement of quality deviation.

Key words: Sinter productivity; Sinter quality; HPS; BTP.

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1 INTRODUCTION

In recent years, iron ore supply and demand has shifted to a seller's market due to increased world crude steel production and oligopolization by resource majors. This has resulted in a remarkable collapse of the existing supply system, in which stable quantity and quality were secured under long-term contracts and resource consumers played the leading role. At the same time, the quality of iron ore resources is steadily deteriorating, with Fe% decreasing and SiO_2 and Al_2O_3 % increasing by the year, as shown in Figure 1. From the viewpoint of environmental protection, there are also increasing demands to expand recycling of hard-to-sinter raw materials such as steelmaking slag.
In spite of this diversifying raw material situation, there has been no change in the fundamental requirements placed on the sintering process, namely, improved sintered ore quality and increased productivity. Further it is known that control of the granulated particle structure of the sintered product is an effective means of meeting these requirements, and several previous reports have examined this subject.[1-4] JFE Steel Corporation also developed and introduced a "New Coating Granulation Technology of Limestone and Coke Breeze,"[5,6] which contributes to improved sinter quality and higher productivity. This paper reports examples of activities carried out at JFE Steel with the aim of further improving sinter quality and productivity.

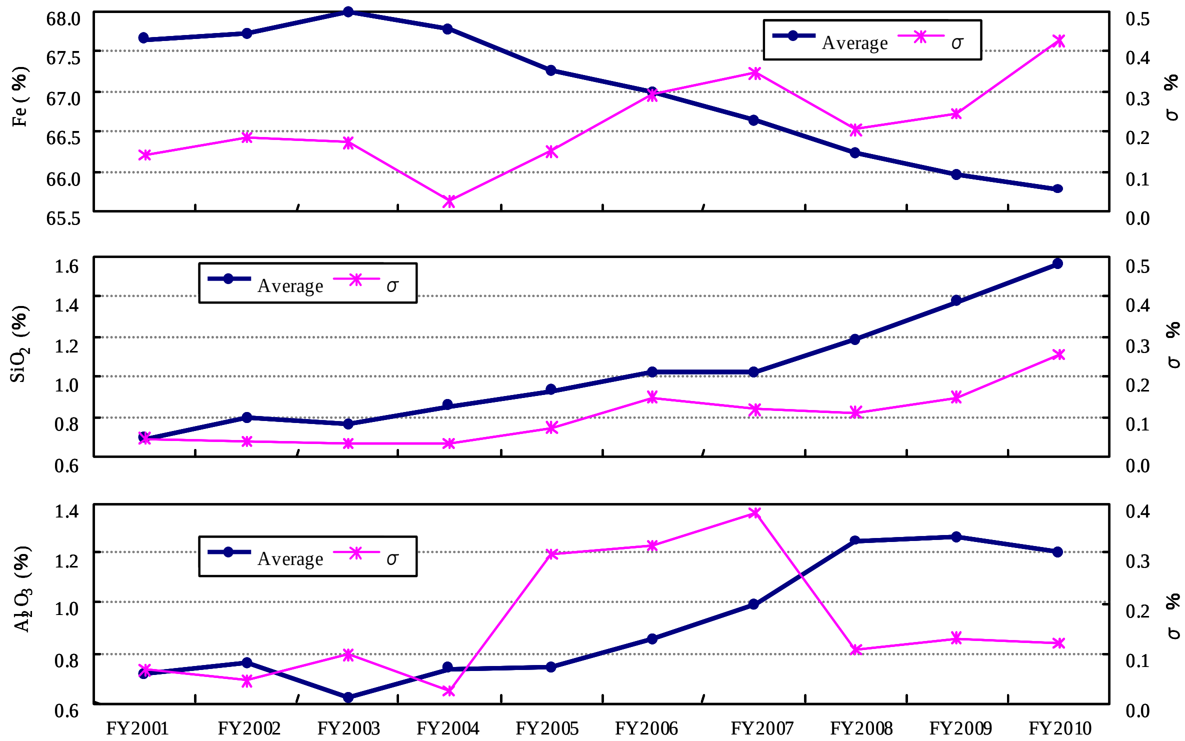

Figure 1 Transition of quality of A ore (FY 2001-2010, Fukuyama).

2 CONCEPT OF IMPROVEMENT OF SINTER QUALITY AND PRODUCTIVITY

Figure 2 shows the technical issues for improvement of sinter quality and productivity from the viewpoint of sintering burning technology. Use of porous iron ore is increasing due to depletion of high quality, dense ores, as represented by hematite. Under these new raw material conditions, the suitable range of heating values in the melting zone is reduced.[7] As a result, deterioration of yield (reduced productivity)

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accompanying reduced sintered ore strength has become apparent in the conventional sintering process, in which priority is given to melting using a large heat source. To overcome this problem, JFE Steel West Japan Works (Fukuyama) introduced the HPS (Hybrid Pelletized Sinter) process at Fukuyama No. 5 sinter machine, which began operation in 1988. This was followed by introduction of the limestone/coke breeze coating granulation technology at Fukuyama No. 4 sintering machine in 2003, as shown in the transition in improvements of the sintering equipment at Fukuyama in Table 1. This process promotes melt formation when using pisolite ore, and achieves improvement in sinter strength and productivity. In addition, the widths of Fukuyama No. 4 and No. 5 sintering machines were expanded successively in 2004 with the aim of improving productivity.
As described in this paper, coke breeze coating granulation in the HPS Process at Fukuyama No. 5 sintering machine was optimized for further improvement of sinter quality and productivity. Simultaneously with obtaining a productivity improvement effect, sinter quality was also stabilized by realizing uniform sintering in the sintering bed height direction. To achieve uniform sintering in the machine width and length directions, burn-through point (BTP) control and the action flow were reviewed, resulting in reduced deviations in sinter strength and increased productivity. This report describes the history of development of these respective technologies.

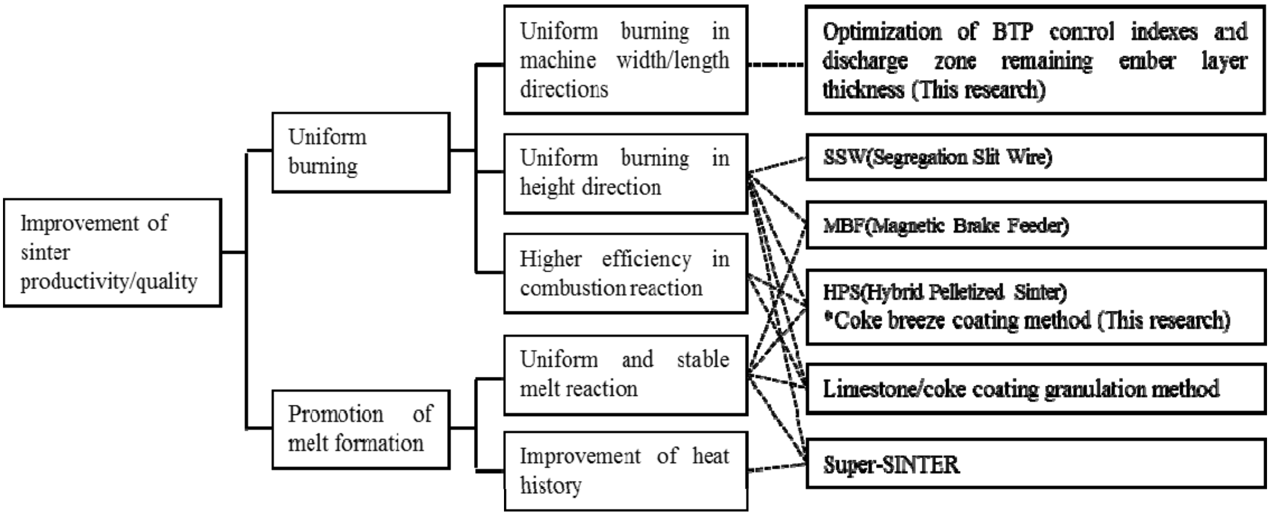

Figure 2 Technical issues for improvement of sinter quality and productivity from viewpoint of sintering burning technology.

Table 1 Transition of equipment at Fukuyama sintering machines (10-year period)

		Year									
		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
No.4DL	Width expansion, extension of machine length		400m2		*	453.75m2					
	Introduction of limestone/coke breeze coating			*							
No.5DL	Width expansion, extension of machine length		530m2		*	605m2					
	Change of coke breeze coating time										*

3 IMPROVEMENT OF COKE BREEZE COATING GRANULATION METHOD AT FUKUYAMA NO.5 SINTERING MACHINE

3.1 Laboratory Verification of Optimization of Coke Breeze Coating Time

The aims of coke breeze coating granulation are: 1) to increase the granulated particle size, and thereby improve the permeability of the sintering bed, by post-addition of hydrophobic coke breeze, and 2) to improve combustibility by exposing the coke breeze on the particle surface, and prevent strength drop and yield deterioration by using the excess heat to form calcium silicate. At Fukuyama No. 5 sintering machine HPS, coke breeze coating was performed in a coating mixer after granulation of the ore by a disk pelletizer. A coating time of 90 s had been used since the beginning of development. However, with changes in raw material conditions, changes in the relationship between the granulated particle size of the ore and the optimum coke breeze coating time are conceivable. Therefore, laboratory sintering tests were performed under the current raw material blending conditions, and the optimum coke breeze coating time was studied.

Figure 3 shows the relationship between the coke breeze coating time and the granulated particle size (harmonic mean diameter) and effect on the production rate in a pot test. The granulated particle size was measured by sieve analysis after drying the granulated sample for 1 day at 110°C and tapping for 5 s by the ro-tap method. From Figure 3, as the coating time is shortened from the conventional 90 s, the granulated particle size increases and productivity increases due to improved permeability. However, at coating times of less than 30 s, the coke breeze coating becomes non-uniform, and productivity decreases due to yield deterioration. From this, it was understood that the optimum coating time is 30 s.

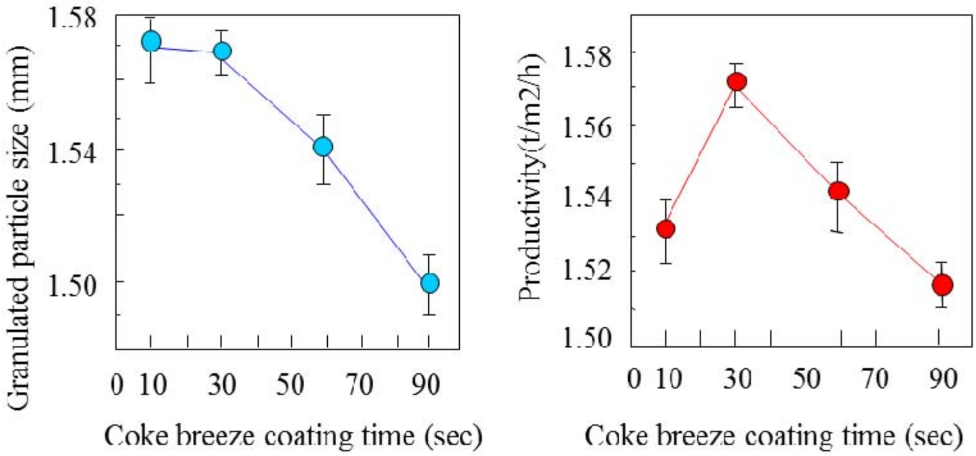

Figure 3 Effect of coke breeze coating time on production (results of pot test).

Based on the results of the pot test described above, the conventional coke breeze coating flow was changed in November 2010, and the equipment was revamped to enable adjustment of the coating time. Figure 4 shows a schematic diagram of the improved coke breeze coating flow. A new bypass conveyor for use in coating was installed at the existing coating line, and it is now possible to control the coating time by controlling the position of charging in the mixer by the high speed projection conveyor (belt speed: 60-300 m/min.)

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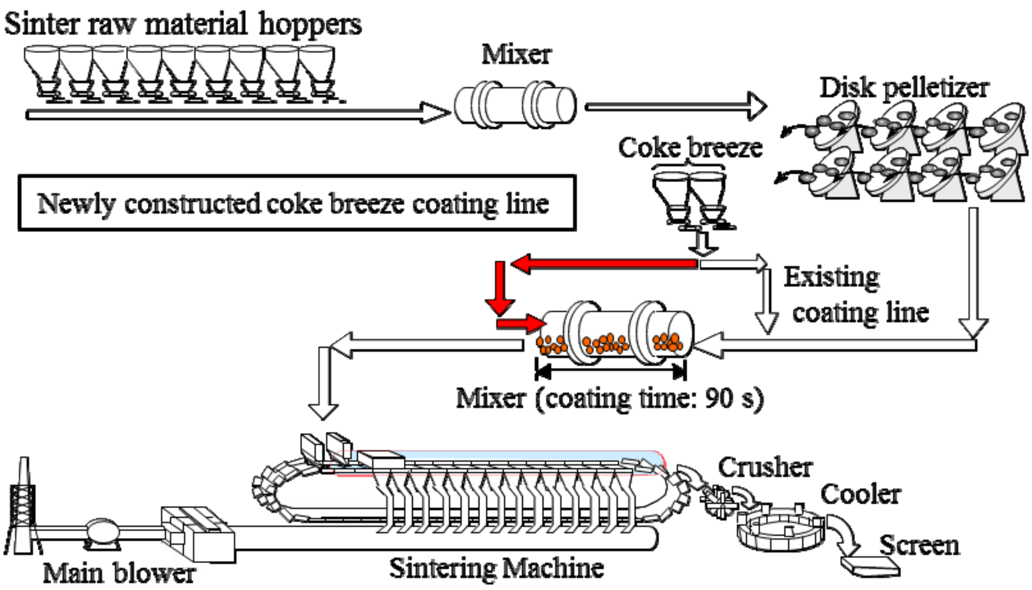

Figure 4 Schematic diagram of coke breeze coating flow at Fukuyama No. 4 sintering machine HPS.

3.2 Verification of Optimization of Coke Breeze Coating Time with Actual Equipment

Figure 5 shows the relationship between the coke breeze coating time in the actual machine and the granulated particle size (harmonic mean diameter). The maximum granulated particle size is obtained with coating times around 20-30 s, but at coating times of less than 20 s, the granulated particle size decreases. From the results of measurement of the free-carbon distribution in each granulated particle, in the region where the coating time is short, deposition of coke breeze on the granulated particle does not progress, and uncoated powder originating from the coke breeze remains. One conceivable cause of this is the difference in the sizes of the laboratory and actual mixers; that is, it is thought that a longer time is necessary to achieve uniform coating with the actual mixer.

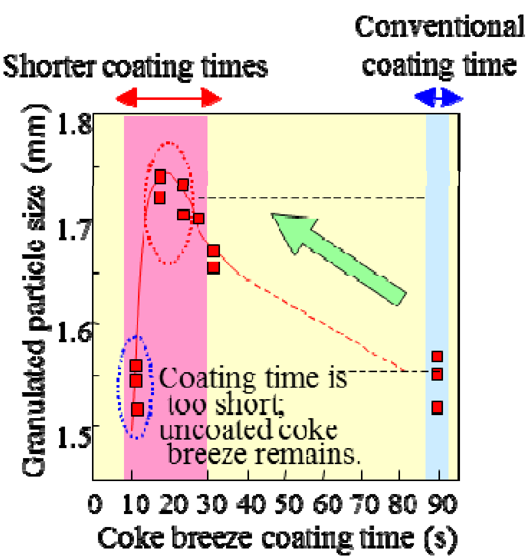

Figure 5 Relationship of coating time and granulated particle size.

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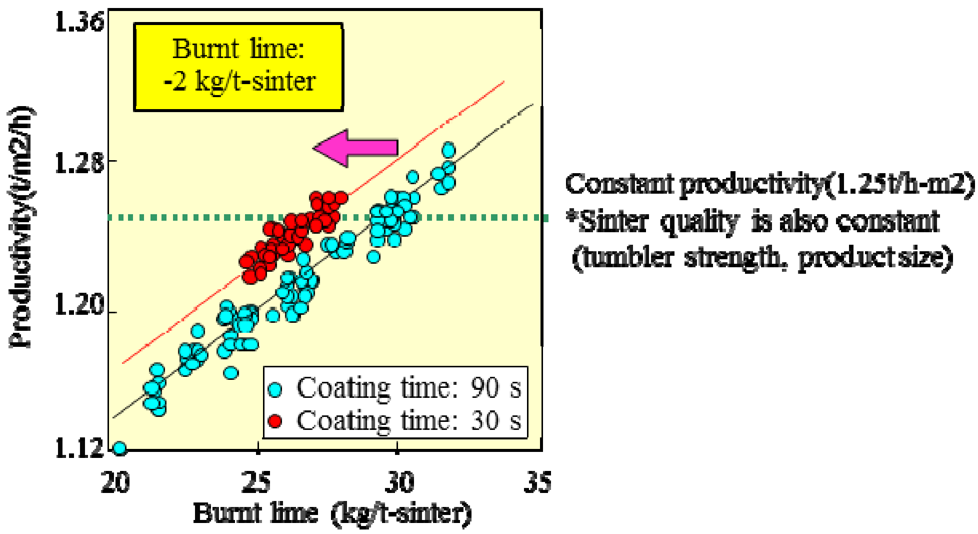

Figure 6 Effect of shortening coating time (Reduction of quick lime consumption).

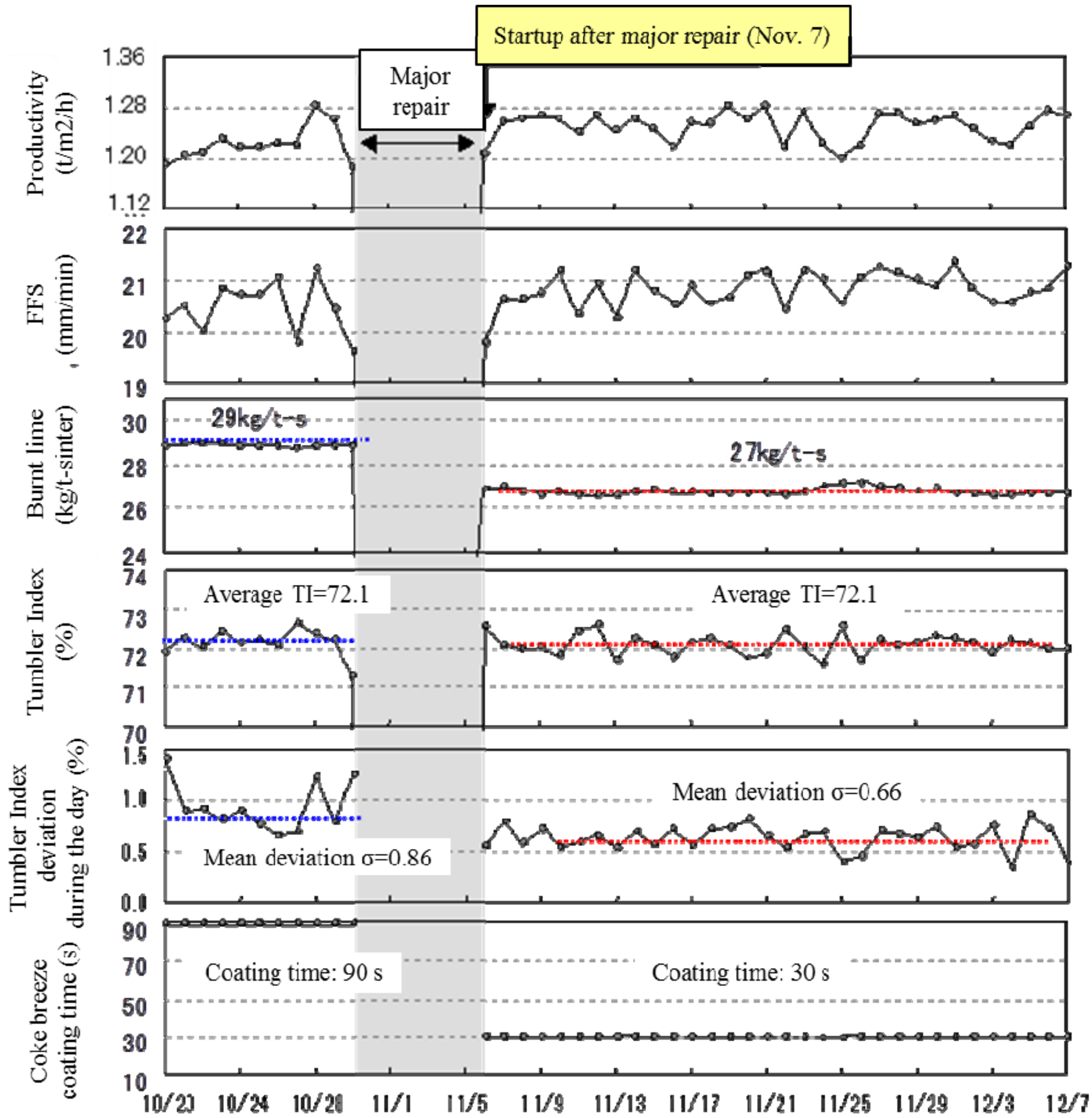

Figure 7 Transition of operation before/after improvement.

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Figure 6 and 7 show the results of shortening the coke breeze coking time and the transition of operation before/after improvement. Based on a sinter production rate of 1.25 t/h-m^2, sinter tumbler (TI) strength of 72.1%, and a constant product particle size, it was possible to reduce unit consumption of quick lime by 2 kg/t-s by substituting reduced quick lime consumption for the granulation property improvement effect. Where sinter quality is concerned, although the daily average tumbler strength is on the same level before and after equipment improvement, deviation during the day (variation in the measured tumbler strength within a period of 1 day) improved from 0.86% to 0.66%.

3.3 Effect of Coke Breeze Coating Conditions on Stabilization of Sinter Quality

Regarding the effect of coke breeze coating conditions on stabilization of sinter quality, the ability to control the state of existence of coke breeze uniformly in granulated particles is considered important. Figure 8 shows the relationship between the speed of the projection conveyor used in coke breeze coating in the actual line and the coating time calculated from the raw material dropping point in the mixer. The target coke breeze coating time is 20-30 s, and the conveyor speed under these conditions is 150 m/min to 250 m/min. As the speed of the charging conveyor is reduced, the dropping range decreases, and it is considered possible to obtain a larger number of granulated particles with the aimed coating time.

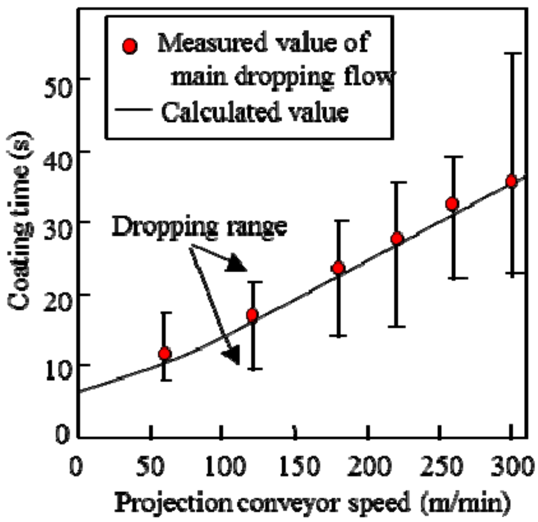

Figure 8 Relationship between projection conveyor speed and coating breeze coating time.

The condition of coke breeze coating on the granulated particles was investigated by carbon analysis of the individual particles. Figure 9 shows the results of the dry particle size distribution of granulated particles for coating times of 30 s and 90 s and the carbon distribution of all granulated particles calculated based on the analysis values of free-carbon for each particle size. From these results, the mass of fine-sized particles in the granulated particles decreases and the mass of coarse particles increases when the coating time is shortened to 30 s. Furthermore, it was found that the carbon content in particles with sizes of 2.8-4.75 mm and 4.75-8 mm increased, and deposition of coke breeze on the coarse particles among granulated particles was promoted. At Fukuyama No. 5 sintering machine, an SSW type charging device has been adopted in order to strengthen particle size segregation in

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the sintering bed height direction, and as a result, these high carbon coarse particles are easily supplied to the bottom layer of the sintering bed. Accompanying the use of large amounts of coarse pisolite ore in recent years, it is considered necessary to strengthen segregation of carbon to the bottom layer of the sintering bed.(8) It is thought that the shortening of the coke breeze coating time in this research simultaneously achieves improved permeability of the sintering bed and optimization of carbon segregation in the height direction, and therefore can reduce deviations in sinter strength by realizing uniform sintering in the height direction.

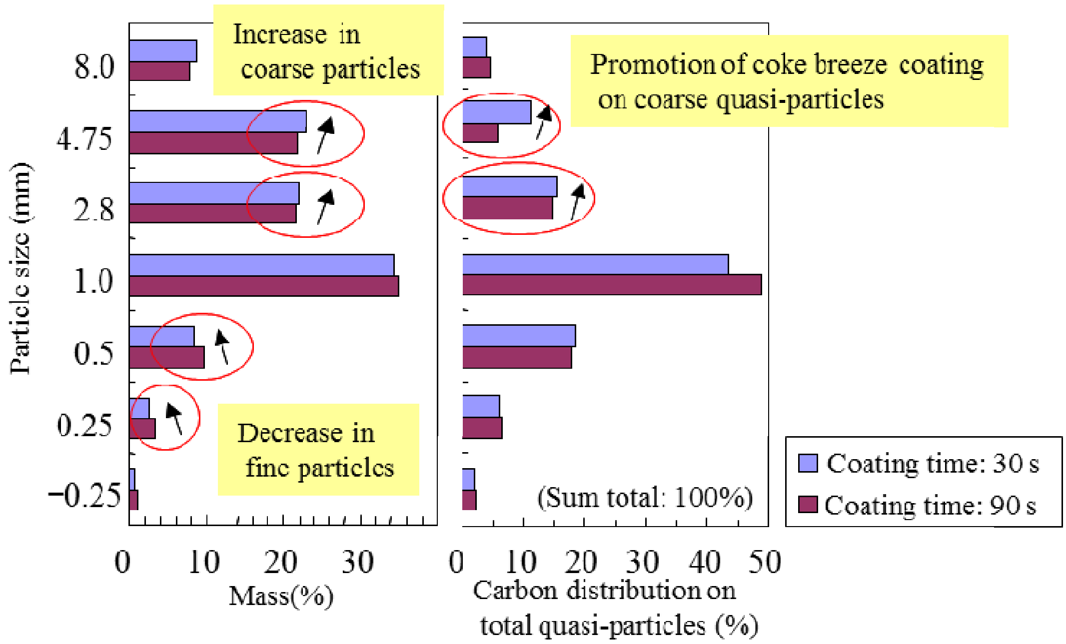

Figure 9 Investigation of particle size and C segregation in granulated particles.

4 IMPROVEMENT OF OPERATION BY IMPROVED OPERATIONAL CONTROL ACCURACY

4.1 Aim and Examples of Implementation of Improved Operation Control Accuracy

Next, this chapter describes operation to maximize quality/productivity improvement effects by improved operational control accuracy. The aim of improved operational control accuracy (raw materials, charging, burning) is to improve productivity by avoiding actions to reduce production during periods of quality deterioration by reducing fluctuations in sinter quality.
Figure 10 shows an example of the factors in sintering operation control. In this research, the content of the underlined items in the figure was reviewed, and new operational control was implemented. Table 2 shows examples of implementation of these items.

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4.2 Quality/Productivity Improvement Effects of Improved Operational Control Accuracy

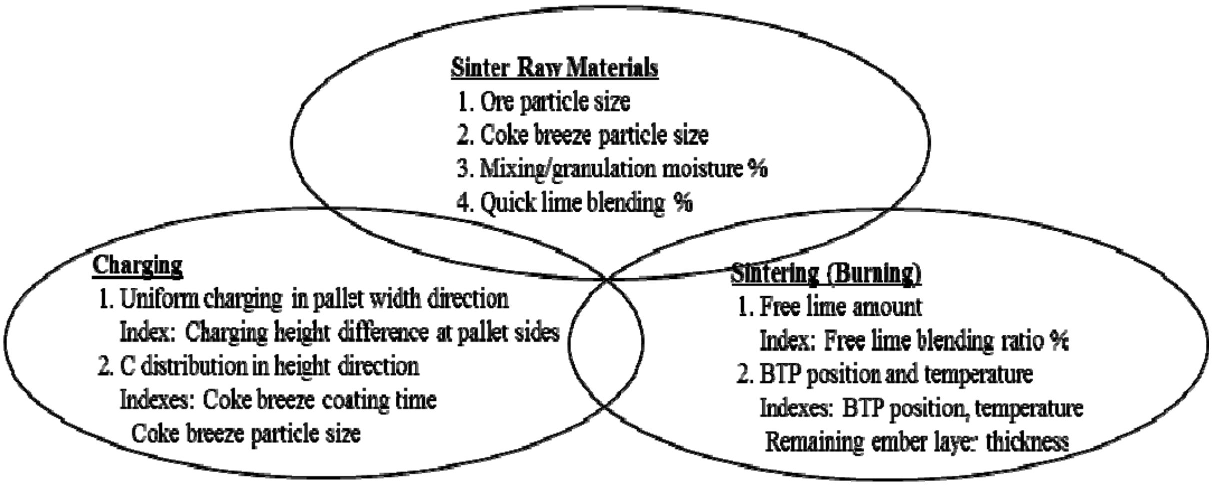

Figure 10 Control factors in sintering operation.

Table 2 Control factors in sinter operation and examples of implementation

Control factors		Examples of review/implementation
Raw materials	Ore, coke breeze size	Sintering bed permeability is evaluated from the size of the blended ore/coke breeze, and is linked to action on mixing/granulation moisture and the quick lime blending ratio. Results are recorded in the operation graph, and check and follow-up on each action are performed (human resources training).
	Mixing/granulation moisture	
	Quick lime blending ratio	
Charging	Pallet side charging height difference	Target value settings and actual results are recorded in the operation graph, and check and follow-up on charging rate adjustment actions are performed.
	Coke breeze coating time	Based on sintering bed permeability and yield, actions are taken for coke breeze coating time and coke breeze size.
	Coke breeze size	
Sintering (Burning)	BTP position, temperature Remaining ember thickness at discharge zone	The target BTP position and temperature are set, and are linked to charging rate adjustment actions. The actual BTP position and temperature and remaining ember layer thickness are recorded in the operation graph, and the achievement rate for each value relative to the target BTP position and temperature is evaluated (human resources training).

Figure 11 shows the flow of operational actions. In the conventional flow, raw material actions and charging/sintering actions were taken based on the wind box temperature and total negative pressure. The following two points were added to the improved flow in this research.

- An action index for pallet side BTP (north and south BTP) was added.
- the both pallet side-BTPs are entered in the operation graph, the degree of achievement in each shift is evaluated, and a database of examples is prepared.

Based on the above, non-uniformity in the pallet width direction was evaluated by the position and temperature of the north and south BTPs, and the result was used as an

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index for improvement of pallet width-direction uniformity. Furthermore, the results of the north and south BTP positions and temperatures were evaluated and reflected in charging actions (adjustment of charging height). From the viewpoint of improvement of operator skills/human resources training, visualization of evaluations also contributed to improvement of action accuracy.

Figure 12 shows the results of the review of the action flow. After the review, quality deviations (deviation during the day of σ of TI strength, deviation during the day of product particle size ▲5 mm) were reduced.

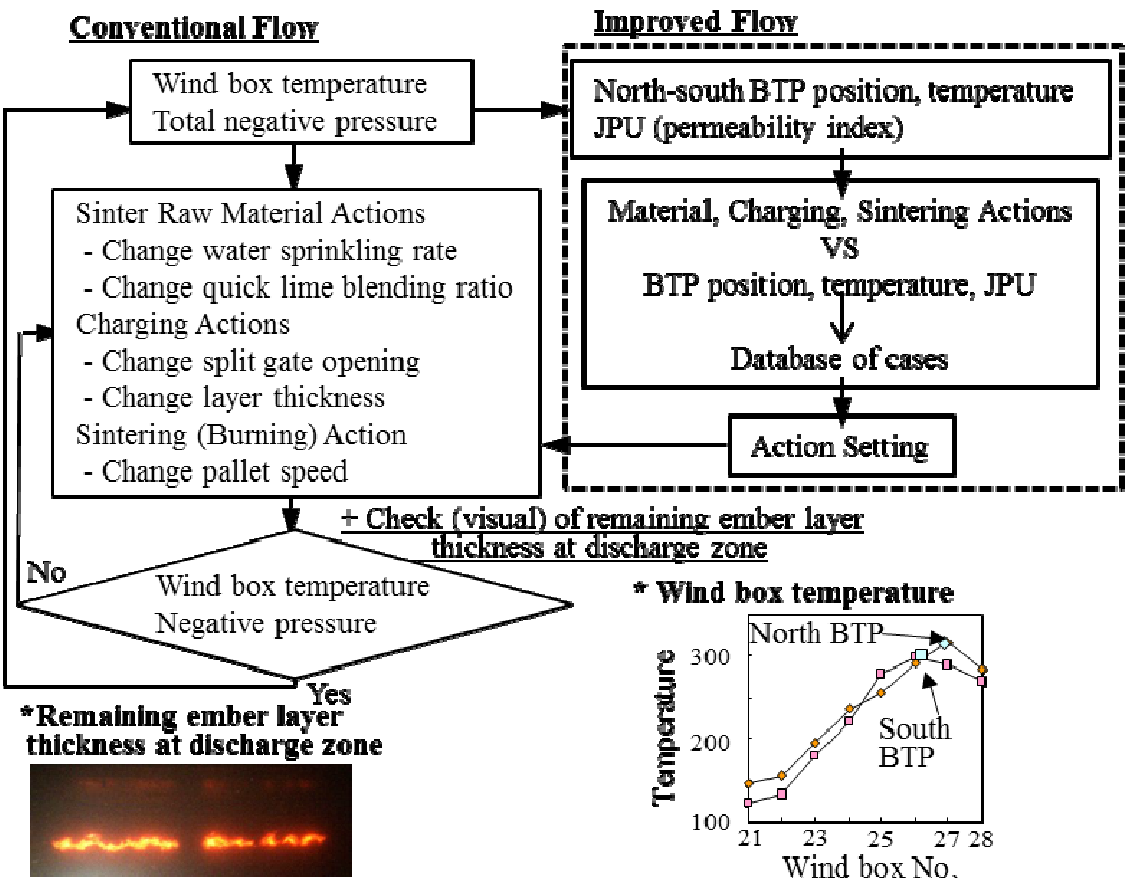

Figure 11 Flow of operational actions.

As a future aim, checks of the sinter discharge zone, which are now performed visually, will be digitalized by camera + image analysis of the discharge zone in order to further improve operational accuracy for more uniform sintering.

Figure 13 shows the effects of the review of the action flow on quality and productivity. At constant quality (TI strength), productivity improved from 1.21 t/h-m^2 before implementation to 1.23 t/h-m^2 (+0.02) after implementation.

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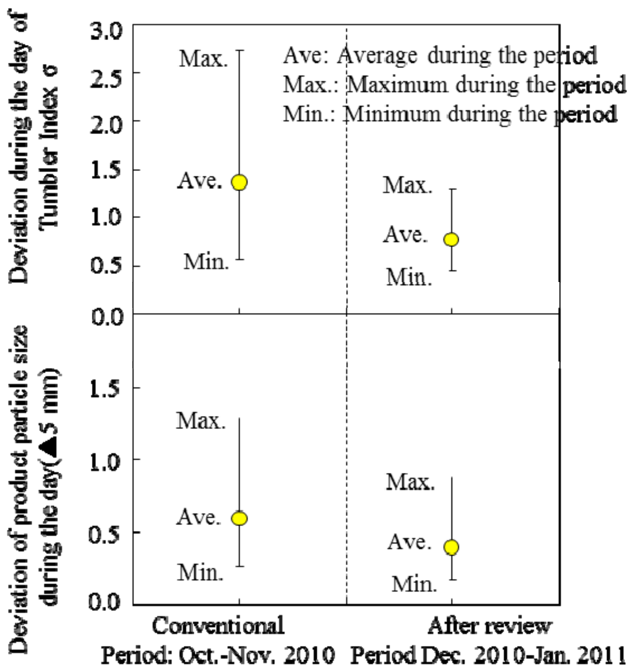

Figure 12 Results of review of action flow.

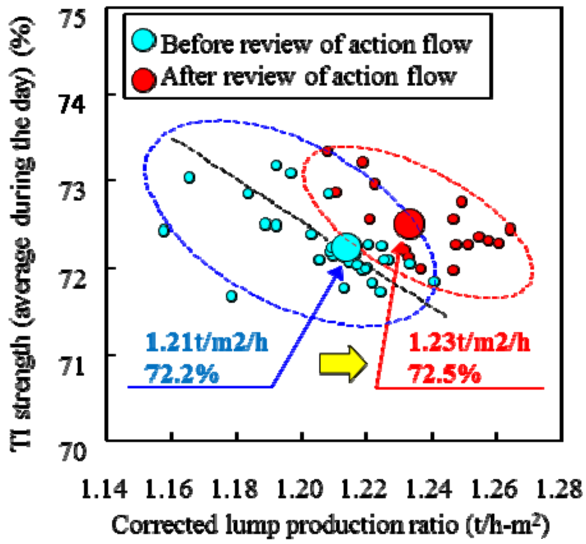

Figure 13 Effects of review of action flow.

4.3 Future Improvement Activities

At present, non-uniform sintering conditions in the width direction are corrected based on visual inspection of the remaining ember layer at the discharge zone. For further improvement of operational accuracy in the future, efforts are now being made to digitalize the ember layer thickness in order to evaluate the thickness of the ember layer at the discharge zone and link this to actions for achieving uniform sintering in the width direction.

As the method of digitalization now under study, in addition to the thickness of the ember layer at discharge, the pallet width direction is divided into three blocks (north, middle, south), and the ratios of the thickness of the remaining ember layer in the center block to thicknesses of the north and south blocks (average values of

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measurement points in each block) is used as an index for evaluation of the thickness of the ember layer at the discharge zone. Figure 14 shows an example in which the ratios of the thickness of the ember layer at discharge (average thickness at center/average thickness at north side, average thickness at center/average thickness at south side) are used as indexes.
In the future, this will be evaluated as an operational index while confirming the effect on quality and productivity. If this approach proves effective for improving operational control accuracy, a review of the operation action flow is planned.

5 CONCLUSION

Efforts were made to improve sinter quality and productivity at Fukuyama No. 5 sinter machine. The following effects were obtained.

- The coke breeze coating time was optimized from the conventional 90 s to 30 s. As a result, the granulated particle size increased and permeability in the sintering bed improved. Uniform sintering in the sintering bed height direction was also achieved by optimization of the condition of existence of coke breeze in the granulated particles.
- The operation action flow was reviewed in order to improve operational control accuracy, resulting in improved productivity at a constant sinter quality. With a full-scale change to a new generation of operators now in progress, improvement of operational control accuracy is also considered an effective means of avoiding a
  - Indexing of ember layer thickness at discharge zone
  - Example of application decline in the level of site skills and will be carried out on a continuing basis.
  - In the future, development of granulation, charging, and sintering technologies and effective equipment improvements will be undertaken in order to further improve sinter quality and productivity under deteriorating raw material conditions.

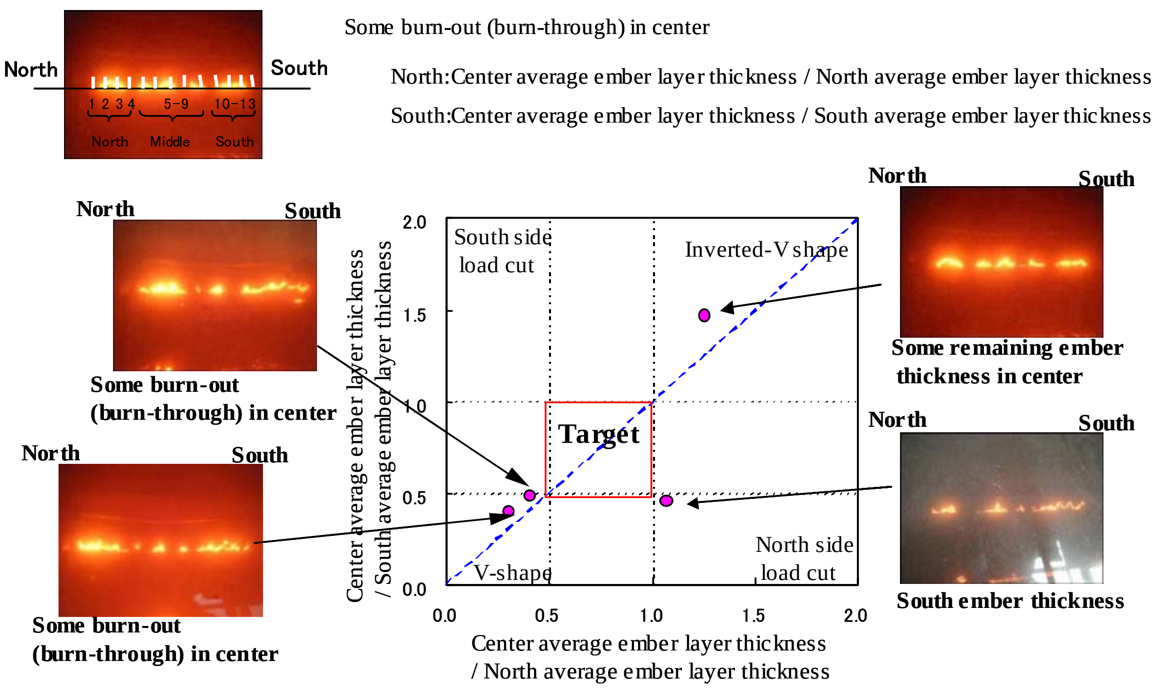

Figure 14 Concept of indexing remaining ember layer thickness at discharge zone and example of application.


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