RECENT PROGRESS OF HYBRID PELLETIZED SINTER PROCESS AT FUKUYAMA WORKS, NKK

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Summary

In order to produce high quality sinter having low slag volume and to use a large amount of pellet feeds containing high iron and low gangue minerals, NKK has developed an advanced agglomeration process called HPS process. This process which was constructed by remodeling Fukuyama No.5 sintering machine started the commercial operation since November 1988. Productivity and qualities of HPS products improved after starting the operation, due to introducing various new technologies. A new charging equipment gave the suitable segregation along the bed height both in size distribution of quasi-particles and distribution of coke breeze concentration. This contributed to improve the yield and the productivity. Decreasing SiO_2 content in HPS products, which was achieved by complete granulation, was effective for high PCI operation of blast furnace and also for increasing Fe production of products. Enlarging the coke breeze coating mixer in diameter contributed to increase the productivity more than the target value 1.85T/m²/H. As a result of these improvements, the productivity expanded from 1.38 T/m²/H at the beginning to 1.88 T/m²/H now.

Key Words

hybrid pelletized sinter | segregating slit wire | charging equipment
low SiO_2 content | coating mixer

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1. Introduction

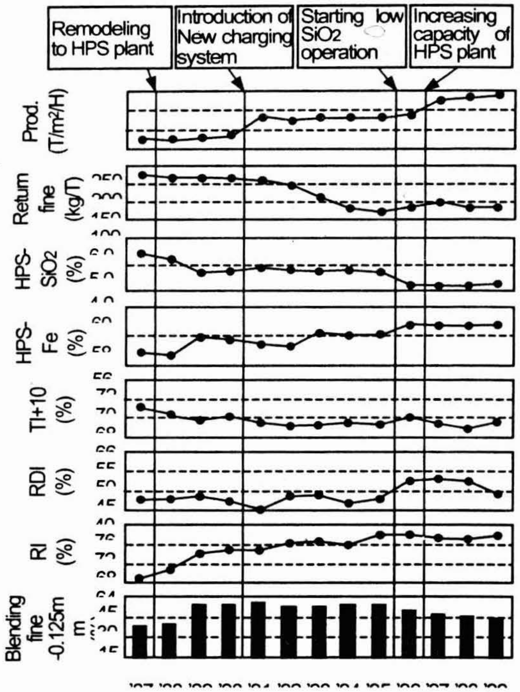


Fig. 1 Operational trend at Fukuyama HPS plant.

The HPS (Hybrid Pelletized Sinter) process, originally developed by NKK, can use a large amount of cheap, high-quality pellet feeds which are difficult to use at the conventional sintering process. It can also produce high quality sinter products with high reducibility and low slag volume. Fukuyama No.5 sintering machine (effective suction area : 530m^2) was remodeled to the HPS process in November 1988. Since then, to expand the production, various new technological improvements have been developed and introduced to the process (Fig.1) . Simultaneously it has been improved the quality corresponding to the varieties of raw materials and changes of blast furnace operation. The productivity 1.38 T/m^2/H at the beginning of commercial operation expanded to 1.88 T/m^2/H in 1999 through these improvements. This report presents the outline of the improvements and the increasing capacity of HPS plant that has been contributed to attain the higher productivity.

2. Concept and Measures for Attaining High Productivity

In HPS process to increase in production under the constant suction condition, it is necessary to take measures shown in Table 1[1]. The concept which is the same as the ordinary sintering process is basically applicable to HPS process. Improvement of permeability in sinter bed is required to raise the sintering speed. To achieve higher yield, it is important to compose the suitable bed structure to keep heat supply uniformly from top to bottom through the bed. To attain this uniformity over the pallet width direction is also important. Though the decrease in SiO_2 content level does not directly improve the productivity, iron production increases with increase in higher iron content in products under the constant productivity. Table 1 also shows the technological improvements developed by Fukuyama Works, NKK to attain the high productivity of HPS process. The outline and the effect of each improvement are described below.

Table 1 Concept and measures for increasing HPS production.

Purpose		Item should be improved	Measures	Technological improvement developed by NKK
Higher production	Increase in sintering speed	Improvement of permeability in sinter bed	Prevention quasi-particle from disintegration	Improvement of coating mixer
			Reduction of raw materials interfere with sintering reaction	Development of segregation charging equipment
			Production of coarse sized quasi-particle by adding burnt lime	
			Decrease in charging density of sinter bed	
	Increase in yield	Improvement of upper layer's yield	Enhancing segregation of quasi-particle and coke breeze	
		Uniform sintering along longitudinal and width direction of pallet	Uniform charging of raw material	
		Prevention against over-crushing	Enlargement gap and pitch of crusher Decrease in gap of conveyer connection part	
	Increase in Fe content	Decrease in slag content	Decrease in SiO_2 content	Low SiO_2 content sinter ore

3. Development of Segregation Charging System

One of the important technology in HPS process is how to transport quasi-particles granulated by DP (Disc Pelletizer) to sintering machine without the disintegration. Ordinary sintering machines adopt generally charging system with the surge hopper and roll feeder. To keep the granulated materials from the disintegration, a new charging equipment with reciprocation conveyer and wide conveyer, which had been adopted in pelletizing plant, was introduced. Figure 2 shows the schematic drawing of the original charging equipment in HPS process at

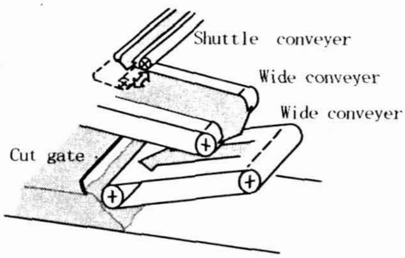


Fig. 2 Schematic drawing of the original charging equipment.

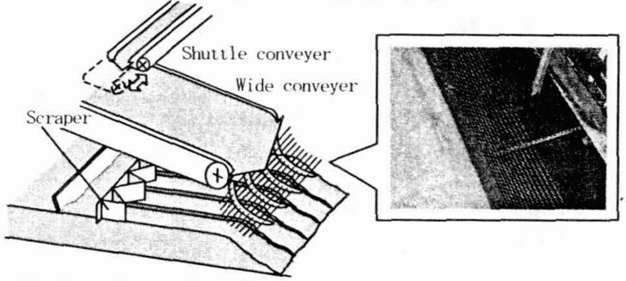


Fig. 3 Schematic drawing of charging system after introducing

the first operation[2]. In this equipment, as the granulated materials were directly charged to the pallet from slightly inclined wide conveyer, no-segregation charging occurred. The sedimentary layer in front of the cut gate sometimes collapsed when the pile exceeds upper limit. Such avalanche phenomenon caused " irregular scorch ". This phenomenon made the yield and the productivity worse. It is necessary to avoid the avalanche phenomenon and to develop the strengthened size-segregation charging equipment for attaining the higher yield. Evaluation by various charging experiments clarified that a charging system composed of the unified wide conveyer and the wire-chute having functions as a sieve is suitable for avoiding the avalanche phenomenon. It was SSW (Segregation Slit Wire), which wires were arranged curvedly as shown in Fig.3 and the photograph.

Figure 4 shows the segregation behaviour of quasi-particle size and concentration of free carbon along the sinter bed height. SSW strengthened the size segregation of quasi-particles, and moreover, raised concentration of coke breeze at the upper part of the bed. It remarkably contributed to increase the productive yield. It was also effective in dispersing the quasi-particles. As the dispersed particles were sized and charged along the bed height, the bulk density of the bed became lower and the permeability increased. By introducing the SSW, the charging density changed from 1.98~1.95T/m^3 to 1.92~1.88 T/m^3.

The SSW was composed of the iron wires covered with urethane resin as the measure for adherent raw materials.

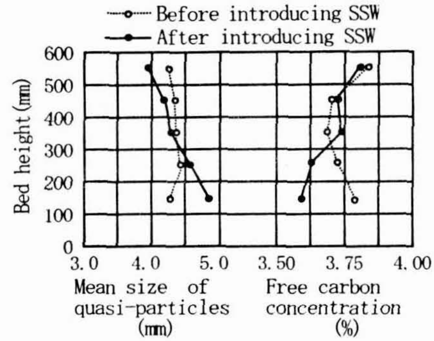


Fig. 4 Comparison of the segregation behaviour before and after introducing SSW.

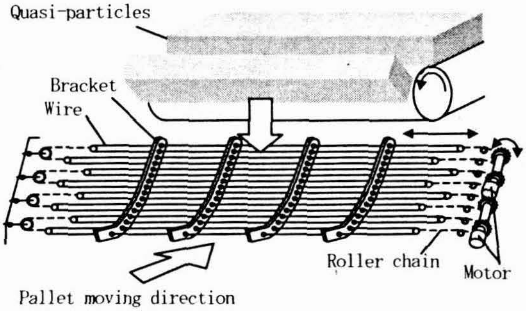


Fig. 5 Schematic diagram of automatic cleaner.

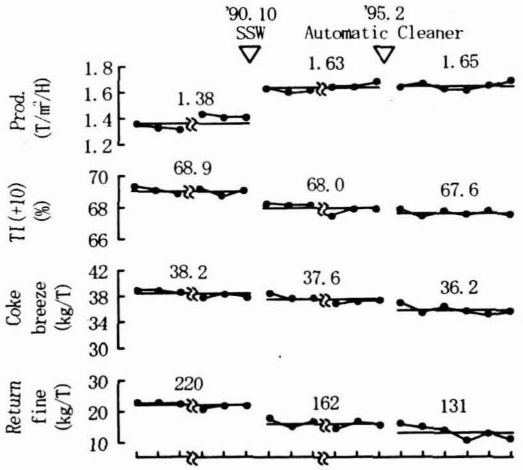


Fig. 6 Effect of introducing SSW and automatic cleaner on the operation of HPS process.

But it was impossible to avoid them completely. Quasi-particles were partially blocked in the wire gap after passing two hours. To avoid the blocking phenomenon, an automatic cleaner which adopted wire sliding method as shown in Fig.5, was designed and installed in July 1995[3]. The blocking phenomenon reduced remarkably by moving the cleaner 10 to 15 minutes interval.

Figure 6 shows the operation results of HPS after introducing a series of the charging equipment. The productivity increased from 1.38T/m^2/H to 1.65T/m^2/H by installation of SSW and the automatic cleaner. Return fines also decreased from 220kg/T to 130kg/T and the yield improved by about 3%. Moreover coke breeze could also decrease 2.0kg/T.

4. Production of Low SiO_2 HPS

Reducing SiO_2 content in sinter products leads iron production to increase because of higher iron content in the products and can reduce the cost of sinter production by cutting down the cost of secondary raw material. Since reduction of slag volume in sinter products causes deterioration of the strength (TI+10:Tambler Index +10) , yield and RDI (Reduction Degradation Index) , the SiO_2 content in the ordinary sinter products has been controlled for 5.0~7.0%. Figure 7 shows the effect of the SiO_2 content on RDI and strength of HPS products.

However, increase in the amount of PCI (Pulverized Coal Injection) at the blast furnace in recent years tends to relax the value of RDI because the retention time of the products at 500~600 ℃ zone in a blast furnace becomes shorter. Figure 8 indicates a summary of the effect of the low SiO_2 sinter products on the in-furnace condition under the high PCI

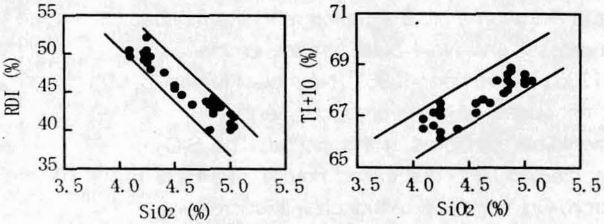


Fig. 7 Influence of SiO_2 content on HPS qualities.

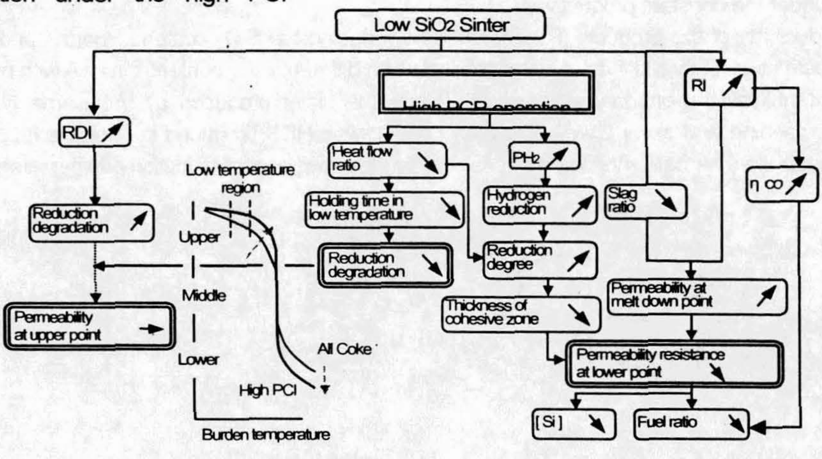


Fig. 8 Concept of an effect of low SiO_2 sinter on in-furnace condition at high PCI operation.

operation[4]. Using the low SiO_2 sinter is an effective method for decreasing slag volume of blast furnace and improving permeability at lower part of blast furnace.

Because the HPS process completes the granulation with DP under blending a large amount of pellet feed and reinforces the diffusion bonding structure during sintering process, low SiO_2 products could be achieved easily compared with the ordinary sinter. Since introducing the SSW in 1995, the strength and yield of HPS improved and the quality was also greatly improved. As the measure for lowering SiO_2 content, the method which decreasing serpentine in the blending fine was adopted because of the inferior assimilation of the serpentine.

Figure 9 shows the operation results of the Fukuyama No.5 sintering machine (HPS process) and No.4 blast furnace in January 1995 ~ November 1996[4]. No.4 blast furnace has used HPS products entirely as agglomerated ores in this period. The SiO_2 content in HPS decreased from 4.8 to 4.2% from October 1995. Although with decreasing the SiO_2 content, RDI became worse, the strength (TI+10), the return fine, and the productivity were kept constantly. Figure 9 indicates that net iron production increased by lowering the SiO_2 content under the constant productivity.

* Reduction Index under the condition of Japan Industrial Standard.

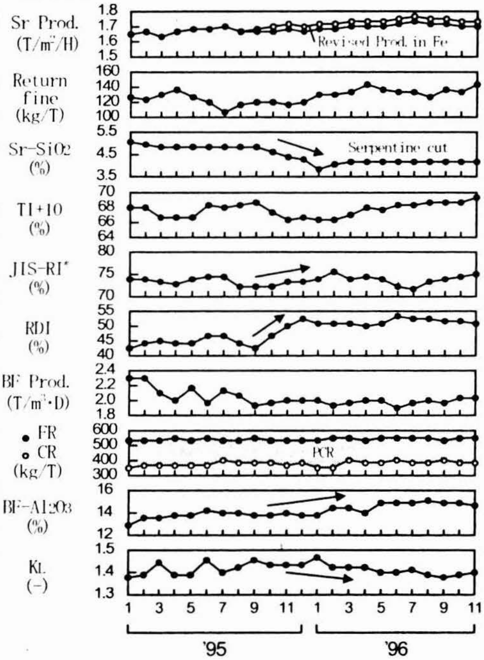


Fig. 9 Operational results for producing low SiO_2 HPS.

Reducibility of the products (RI) improved by reducing the SiO_2 content. Photo 1 shows the microstructure of three kinds of sinter products with different SiO_2 content, sinter A with high SiO_2 content was the ordinary sinter, sinter B was the sinter produced by Fukuyama No.4 sintering machine and sinter C with low SiO_2 content was HPS produced in January 1996[4]. Neither secondary hematite nor columner calcium ferrite which control reduction gas penetration

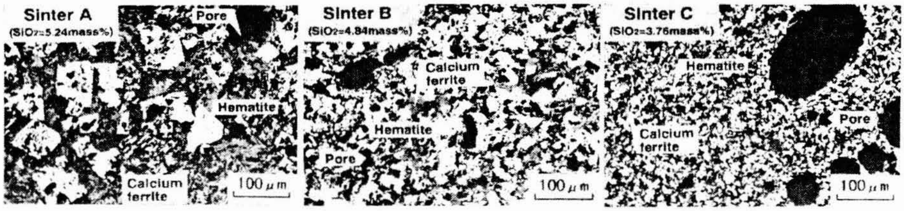


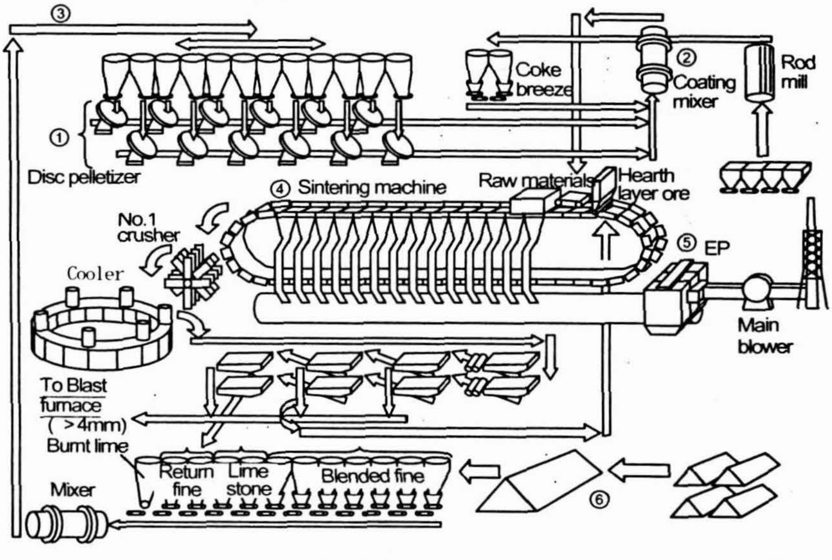
Photo 1 Microstructure of sinter products (Sinter A: Ordinary sinter ore, SiO_2=5.24% Sinter B: Fukuyama No.4 sinter ore, SiO_2=4.84% / Sinter C: HPS, SiO_2=3.76%).

due to the dense structures are seen by decreasing SiO_2 content, and the majority of the structures are composed of porous hematite, porous calcium ferrite, and micro pores. It contributed the high reducibility, high RI.

As shown in Fig.9, No.4 blast furnace could continue to maintain constant operation (productivity : 2.0T/m^3/D, PCI : 170 kg/T) during these periods[4]. Though Al_2O_3 content in slag rose near 15% by lowering slag volume, gas flow characteristics in the blast furnace tend to improve because of improvement of permeability resistance at lower part of blast furnace(K_L). This means that decreasing SiO_2 content in HPS is very effective for high PCI operation

5. Increasing Capacity of HPS Plant

With increase of a worldwide steel production ,especially direct reduction iron ,since middle



	Equipment	Item & Content
Sintering plant	① Pelletizer	Added disc pelletizer×2 ϕ7.5m×H0.8m
	② Coating mixer	Enlarged coating mixer ϕ4.4m×L17.5m→ϕ5.5m×L15.0m
	③ Belt conveyer	Increased capacity of belt conveyer
	④ Sinter pallet	Rose side-wall 620mm→690mm, Remodeled lower part of ignition furnace
	⑤ Measure for environment	Built a new EP
	Incidental construction	Remodeled controlling systems, Built a new electric source
Raw material treating plant	⑥ Piling line (Sinter feed)	Built new piling conveyers : 3→4series Built new surge hopper & new CFW

Fig. 10 Outline of the increasing capacity construction of the HPS process.

of 1990 's pellet price has been rised by shortage of the supply. Since sinter production is lower than pig iron production in Fukuyama Works, the ratio of the pellets in blast furnace burdens was higher than that of other works in Japan. A further increase in production of the sinter was demanded because of the pig iron cost reduction. The increase of production capacity of HPS was planned from 1.65T/m^2/H (21000 T/D) to 1.85T/m^2/H (23500 T/D). The construction for increasing capacity was carried out from 1995 to 1997 to meet the demand. The items and the contents of the construction are shown in Fig.10.

As for the fine coke coating mixer , the hold-up ratio in the mixer became too high by increasing the productivity. This result caused quasi-particles were lifted up in the mixer and disintegrated by the collision when falling. To prevent quasi-particles from disintegrating, enlarging diameter of the coating mixer was the most prior item in the construction. And as the method of increase in production, in order to avoid reducing the yield increasing the pallet speed was suppressed as much as possible and the sinter bed thickness was raised. Two unit of DP were introduced newly to maintain permeability in the thickened bed.

For enlarging of the coating mixer, the tests changing the amount of raw material were carried out by using the operating coating mixer to investigate the hold-up ratio and the disintegration of quasi-particles. Figure 11 shows the results of reducing the mean diameter, the disintegration ratio of the quasi-particles, and hold-up ratio at each position in the coating mixer. This result indicates that the disintegration ratio of the quasi-particles were greatly improved when decreasing hold-up ratio to 7% or less compared with hold-up ratio 12%. The result also

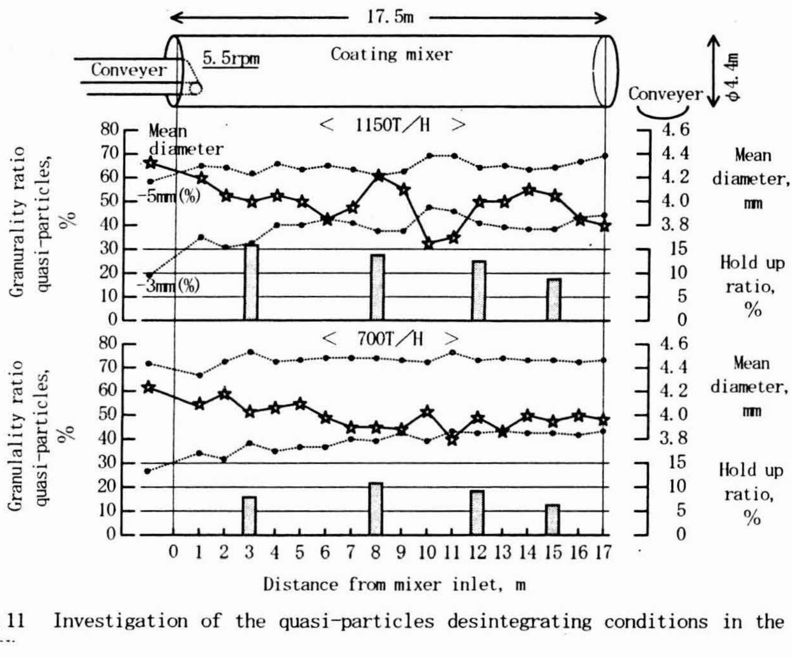


Fig. 11 Investigation of the quasi-particles desintegrating conditions in the coating mixer

clarified that decreasing the mean diameter was able to be small.

On the basis of the tests, the secondary mixer of ordinary No.5 sintering machine having large inner volume was replaced as the new coating mixer in which the hold-up ratio was decided to about 5%. Average retention time of the quasi-particles in the mixer estimated to 1.5min from past investigations. Rotating speed and the inclination angle was decided from W. C. Saeman equation.

Table2 Comparision of the new coating mixer specifications with the former's.

	Former mixer	New mixer
Transporting material weight (T/H)	1100	1350
Length (m)	16.0	13.5
Diameter (m)	4.4	5.5
Inclination angle (-)	4/100	7/100
Revolution (rpm)	5.5	4.6
Hold up rate (%)	12	5
Retention time (min)	3.0	1.5

W. C. Saeman equation

$T = L\sin\theta / \pi DNS$ $\quad\quad f = 4QT/\pi D^2 L\rho$

T : Retention time (min) f : Hold-up ratio (%) ρ : Bulk density of quasi-particles (T/m^3)

θ : Repose angle of quasi-particles (degree) L : Length (m)

Q :Transporting material weight (T/H) D : Diameter (m) N : Revolution (r.p.m.)
S : Inclination angle (degree)

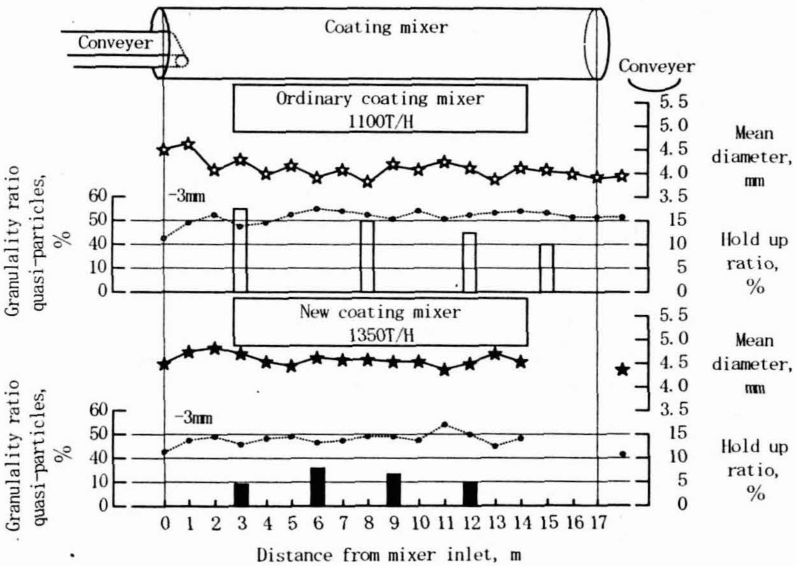


Fig. 12 Comparision of quazi-particles disintegration behavior in the new coating mixer with the former's.

Figure 12 shows the disintegration behavior of quasi-particles in the coating mixer before and after enlarging. The disintegration ratio of the new coating mixer was greatly improved compared with the former's. This enlargement contributed to improve the productivity greatly by decreasing the amount of fine particles.

Figure 13 shows that the productivity increased satisfactorily and attained the planning value 1.85T/m^2/H under maintaining low SiO_2 content level. But the strength (TI+10) and the yield had a tendency to reduce because the segregation of quasi-particles became weak with increasing the amount of charging materials. To enhance the segregation, the arrangement of the wires changed so that radius of curvature should increased on the lower part. It leads to strengthen the sieving efficiency of quasi-particles. This strengthening recoverd both strength (TI+10) and productive yield. By these modifications the productivity achieved 1.88T/m^2/H more than the target value.

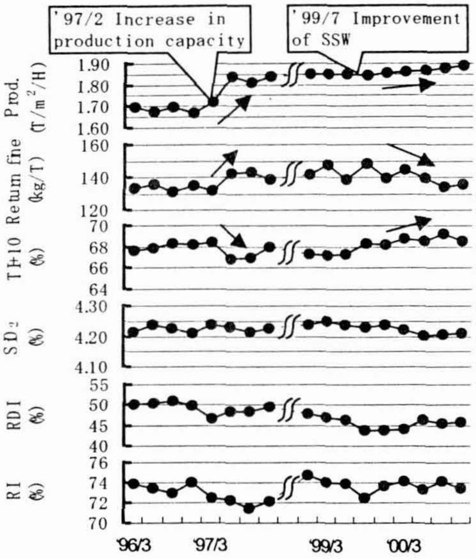


Fig. 13 Operational results after increasing production capacity of HPS process.

6. Conclusion

HPS plant remodeled by Fukuyama No.5 sintering machine introduced various technological improvements developed by NKK. This plant now operates favorably at high productivity 1.88 T/m^2/H. To attain the productivity 1.88 T/m^2/H, main countermeasures are summarized as follows:

(1) Introduction of SSW and automatic cleaner as the new charging equipment gave the suitable segregation condition of quasi-particles and the coke breeze. It contributed to improve the yield and the productivity.

(2) By decreasing the serpentine, the SiO_2 content in HPS could decrease without decrease in strength and productivity. Lowering SiO_2 content in HPS was effective for high PCI operation of blast furnace and also for increasing Fe production in HPS at constant productivity.

(3) Enlarging the coating mixer prevented the quasi-particles from disintegrating and improved the permeability in the sinter bed. This enlargement increased the productivity up to 1.88T/m^2/H which exceeds target value of 1.85T/m^2/H.

Reference

1) H.Sato et al. : CORAS 97 PROCEEDINGS VOLUME-1 (1997) p.21
2) Y. Niwa et.al. : NKK Technical Report No.133(1990) p.18
3) H. Sato et.al. : NKK Technical Report No.158(1997) p.67
4) H. Noda et.al. : CAMP-ISIJ Vol.10 (1997) p.948
5) W. C. Saeman : Chem. Eng. Progr. Vol 47 (1951) p. 508