IMPROVED SLIDING NOZZLE PLATE MATERIAL[1]

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Abstract
Recently, the operating condition of steel casting becomes severe, ex. increasing high grade steel, special grade steel and long sequences. It requires that the sliding plate (SN PLATE) should be improved to adapt such operating condition and longer life. The typical damage of SN plate is cracks, roughed surface and erosion. The cracks and the chipped bore edge may cause abnormal erosion through air suction. The oxygen from steel or air oxidize the carbon in plate, then makes rough surface. Further the calcium element in steel cause erosion. As result, it can be cause shorter life and unstable operation. In this report, we report the results of controlling of cracks, oxidation, erosion resistance, and good trial results on actual operation.
Key words: SN plate; Nano-carbon technology.

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1 INTRODUCTION

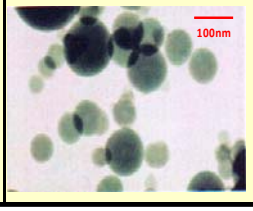
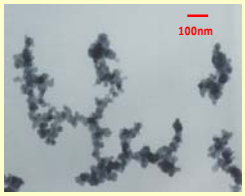
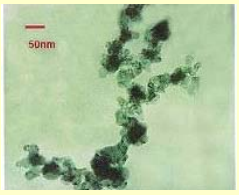
The typical damage of used plates is cracks, chipped edge around bore, enlargement of bore and roughed surface on working surface. For longer life, it is necessary to improve thermal spalling resistance, oxidation and erosion resistance. The application of nano-carbon technology to carbon-containing refractories improves properties, such as thermal spalling and oxidation resistance. This technology can be applied for SN plate material which contains relatively low carbon. Furthermore, it is expected that the base technology with this nano-technology can be applied to increase erosion resistance with lower silica content in plate material which combine with calcium in steel chemically then make low melting material.
We report trial results on actual operation with the application of nano-carbon technology and combination of this and low silica material.

2 IMPROVEMENT OF THERMAL SPALLING RESISTANCE, AND OXIDATION RESISTANCE

2.1 Carbon Material Properties

Carbon examined is the single sphere type and the aggregate type with nano size of grain (Table 1). It is reported that the single sphere type carbon is useful for getting dense matrix, and the aggregate type is contribute to improve spalling resistance due to reduce elastic modulus and increase small pore in matrix. 1) It is expected that HGB, Hybrid Graphite Black, which is synthesized material shows good thermal spalling resistance and high oxidation resistance. We applied this material for AG materials of SN plate.

Table 1. Characteristic of carbon nano particles

Carbon black species	Single sphere type	Aggregate type	HGB
Specific surface area (iodine adsorption:mg/g)	19	60	52
DBP adsorption (ml/100g)	30	130	124
Component particle diameter(nm)	90mm	40nm	40nm
Feature	surface area : small oil adsorption : small	surface area : medium oil adsorption : large	Hybrid graphite black with B4C
TEM Image of Carbon nano pariticles			

2.2 Selection of Carbon Material

Table 2 shows laboratory test sample properties. We have applied some nano-carbon materials to AG material. We used three kinds of nano-carbon material with same content for laboratory test. The carbon material A, single sphere type was replaced by carbon material B, aggregate type carbon or material C, HGB, Hybrid Graphite Black. (Laboratory test 1)

Table 2. Properties of laboratory test 1 samples

Chemical composition/mass%	No.1	No.2	No.3	No.4
Al_2O_3	90	90	90	90
Carbon A(Single sphere type)	2a	1a	-	-
Carbon B(Aggregate type)	-	1a	2a	-
HGB(with B4C)	-	-		2a
Apparent porosity/%	11.0	11.3	11.7	11.7
Modulus of rupture/MPa	25	23	21	23

(a<2.0)

- Thermal spalling resistance test method: cuboids-shaped samples are put into an electric furnace at 1,300°C for 20 minutes. After that, they are cooled by air. This heat represents 1 heat cycle. We carried out 5 “heats”. We evaluate this thermal spalling resistance by deterioration of Young’s modulus and the situation of cracks on cutting surface;
- abrasion test (oxidation test) method: the samples are kept in an electric furnace at 800°C for 2 hours. After that, they are cooled down then shot SiC grain for 30 seconds toward surface. These samples weight loss was measured to evaluate for oxidation resistance by abrasion test.

Spalling index and abrasion index are shown in Figure1. Sample No.3, which includes carbon B, aggregate type carbon, shows improved spalling resistance, but the abrasion index has been worse. sample No.4, which includes HGB, shows better spalling as same abrasion index as conventional sample No.1.

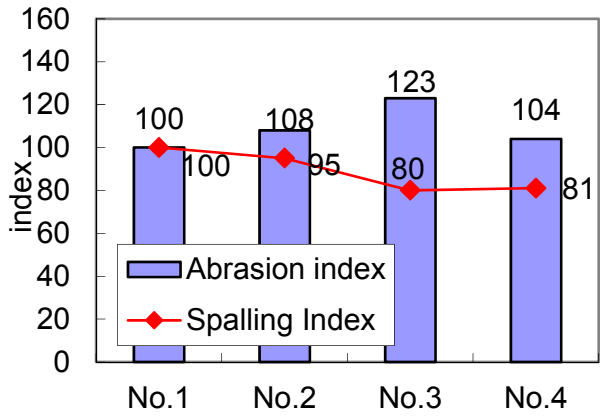


Figure 1. Comparison of abrasion index and spalling index.

2.3 Selection of Antioxidant

In order to prevent oxidization, various quantities of antioxidants are studied. But excess addition of antioxidant may make the plate erosion resistance and spalling resistance worse due to over-sintering.
We have added a fixed quantity of antioxidants A and B to conventional AG material of SN plates, and evaluated their spalling resistance and oxidation resistance. (Laboratory test 2)

Table 3. Characteristics of antioxidant A and B

	antioxidant A	antioxidant B
Grain size/μm	under 45	under 45
Thermal expansion index	1	0.5～0.8

Table 4. Properties of laboratory test 2 samples

	No.5	No.6	No.7	No.8
Content/mass%				
antioxidant A	5a	3a	2a	-
antioxidant B	-	2a	3a	5a
Apparent porosity/%	11.1	10.8	10.7	10.2
Modulus of rupture/MPa	27	28	29	32

(0.1<a<1.0)

The properties of antioxidants are shown in Table 3. The properties of samples are shown in Table 4. The result of spalling and abrasion index and the pictures of the specimens after the test are shown in Figure 2.
From this test, sample No.8, which includes 5a% antioxidant B shows lowest abrasion. The increase of antioxidant B leads better abrasion resistance. We think that antioxidant B is most effective for anti-oxidation.
However, spalling index of sample No.8 get worse because of the influence of excess sintering and increasing brick strength by antioxidant.

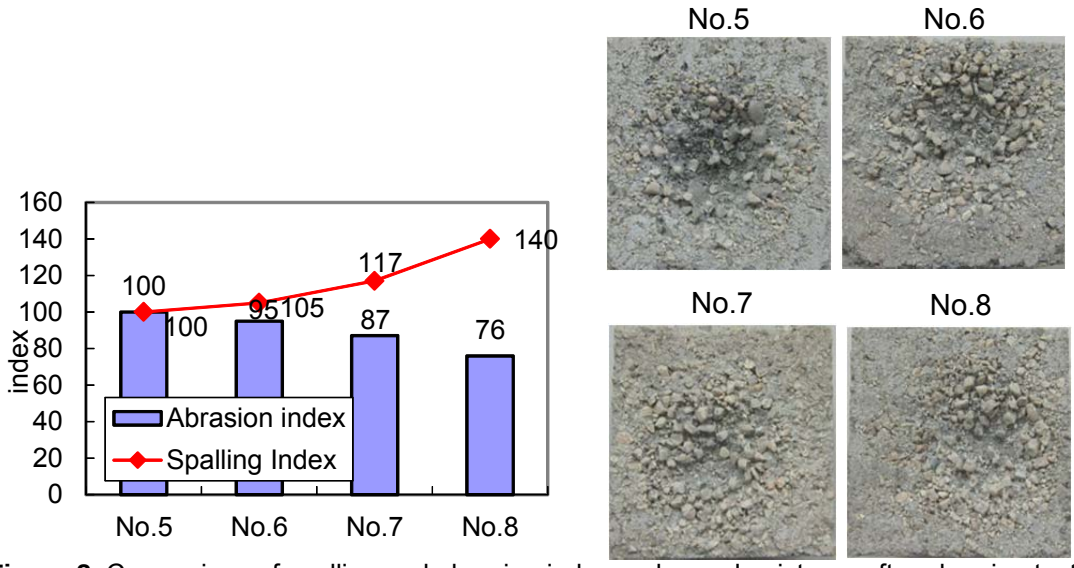


Figure 2. Comparison of spalling and abrasion index and sample pictures after abrasion test.

2.4 Actual Trial at Normal Steel

From the results of laboratory test 1 and 2, we have developed material A and observed the situation of working surface, edge of bore and etc. of used plates after actual trial to compare with conventional material. The properties of this material are shown in Table 5.
Pictures of the materials after trial with 8 heats are shown in Figure 3. Material A has less cracks, chipped edge, damage of working surface, and oxidization, compared with the conventional one. We think that this material A can be used for one more heat.

We had good results of improved plate material A for normal grade steel. However, in the case of Ca-Si steel, we had erosion of edge and working surface. We guessed that this was caused by reaction between calcium in steel and silica in SN plates.

Table 5. Chemical properties of plate for actual trial

Chemical composition/mass%	Conventional material	Material A
Al2O3	78.0	77.0
SiO2	2.0	3.0
ZrO2	10.5	10.5
C	6.5	6.5
Apparent porosity/%	4.5	4.0
Modulus of rupture/MPa	37	40

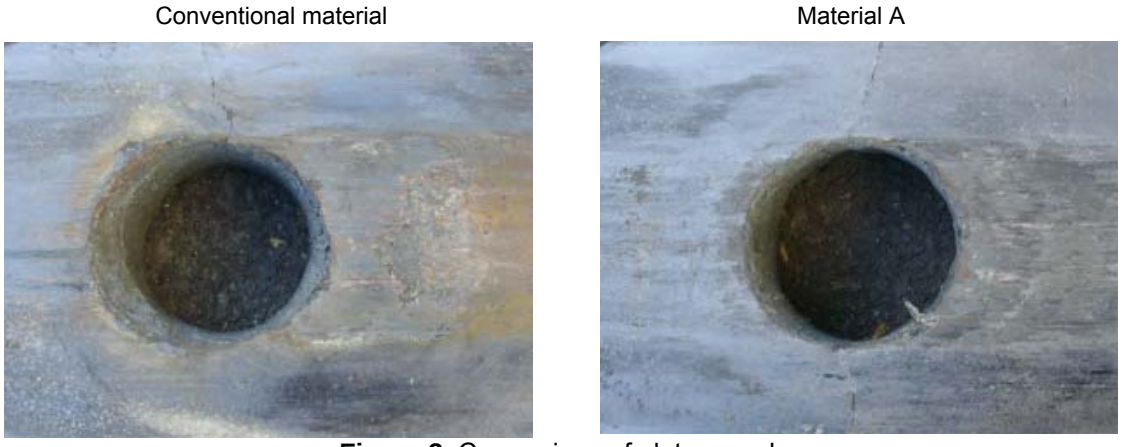


Figure 3. Comparison of plates used.

3 IMPROVEMENT OF EROSION RESISTANCE

3.1 Plate Material for Ca-Si Steel

On the basis of material A, we have developed a new material B, which has high erosion resistance for Ca-Si steel. Material B has lower silica content than Material A as shown in Table 6. We evaluated their spalling, oxidation and erosion index. Also erosion resistance was evaluated by erosion test.

- Erosion test method: samples are put into molten steel including approximately 30 ppm Ca-Si contents in high frequency induction furnace at 1,600°C for 3 hours.

The results of spalling and abrasion index are shown in Figure 4a and the result of erosion index and the pictures of cross section after erosion test are shown in Figure 4b.

As shown in Figure 4a, both spalling and abrasion index of Material B are better than Material A and conventional one because of using low expansion material.

As shown in Figure 4b, material B has less erosion. We think that less silica is effective to reduce erosion.

Table 6. Properties of plate for actual trial

Chemical composition/mass%	Material A	Material B
Al2O3	77.0	78
SiO2	3.0	1.0
ZrO2	10.5	11.5
C	6.5	6.5
Apparent porosity/%	4.0	3.7
Modulus of rupture/MPa	40	43

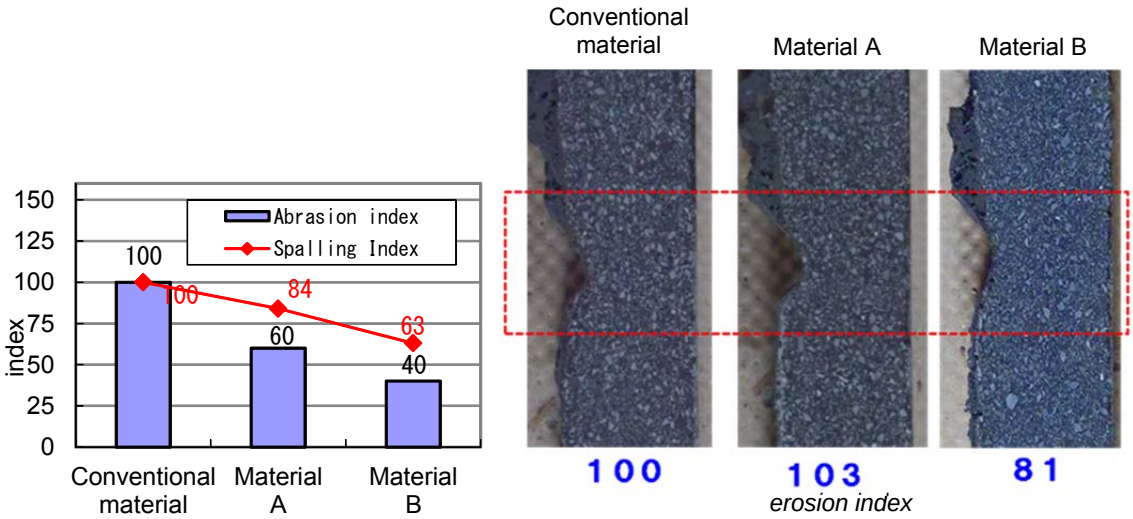


Figure 4. (a) Comparison of spalling and abrasion index; (b) Cross section after steel penetration test.

3.2 Actual Trial Results for Ca-Si Steel

Pictures of the materials after trial with 8 heats (7 heats normal steel and 1 heat Ca-Si steel) are shown in Figure 5. Material B has less erosion of edge and working surface compared with the material A.

Figure 5. Comparison of plates used.

4 CONCLUSION

On this report, for the purpose of improving thermal spalling resistance, oxidation resistance and erosion resistance, we have improved the life of SN plates.

- AG plates with adding HGB has been improved thermal spalling resistance and oxidation resistance;
- AG plates with adding antioxidant B(5a%) showed the advantage on oxidation resistance;
- combination carbon type and antioxidant improved properties of plate material for normal steel;
- to increase erosion resistance for Ca-Si steel, lower silica content in plate material is effective method.

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