

高カーボン樋用流し込み材

High Performance Trough Castable with High Level of Carbon

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Abstract

We focused our research on several different particle sizes of carbon black. As a result, we developed castables using two kinds of carbon black with high corrosion resistance and spalling resistance, while retaining workability. In actual use, the wear rate was significantly reduced. Cracks, which sometimes occurred in the ordinary castables after use, were reduced by using the newly developed castables.

1. 緒言

現在の高炉樋用流し込み材（以下、樋材）はアルミナ、スピネル、炭化珪素、カーボンを主原料とするキャストブルが主流である。その中でもカーボンは、その使い方により樋材の特性を大きく左右する重要な原料である。近年になって、施工水分の増加を伴わずにカーボン添加量を増加させることが可能となり、高耐食性をはじめとした種々の好ましい特性が得られる高カーボン緻密質樋用流し込み材を開発してきた^{1)~3)}。

今回、新たにカーボンの種類に着目し種々検討した結果、粒径の異なる複数のカーボンプラックを使用することによって優れた特性が得られ、実炉使用結果も良好であったことから以下に報告をする。

2. 開発品の特性

実炉使用後のメタルライン用樋材組織を顕微鏡観察すると、稼動面側でマトリックスが優先的に損傷している組織が観察される（Fig. 1）。このためマトリックスの強化を目的に検討を進めた。メタルライン用樋材製品の $-75\mu\text{m}$ のみを抜き出し

1. Introduction

For many years, blast furnace trough castables have been mainly composed of alumina, spinel, silicon carbide and carbon. Above all, carbon is a particularly important raw material.

Recently, some new techniques^{1)~3)} have been proposed for higher performance trough materials. This was achieved mainly by increasing the total carbon while not changing the water content.

After many investigations, we focused our research on several different particle sizes of carbon black. As a result, we developed castables with high corrosion resistance and spalling resistance while retaining workability. In this report, we describe the characteristics and the results in actual use of the newly developed castables.

2. Characteristic Features of Newly Developed Castable

As shown in Fig. 1, we often find by microscopic observation that the matrix is damaged

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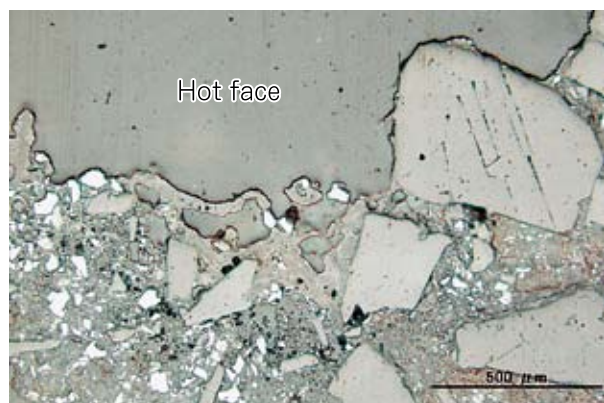


Fig. 1 Microstructure of conventional castable for metal line after use.

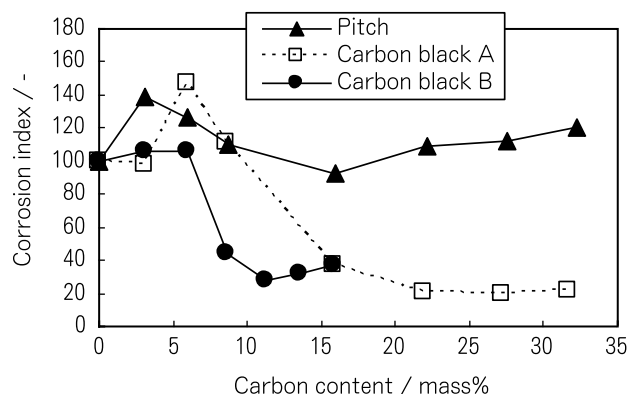


Fig. 2 Result of corrosion test of sample composed of only matrix.

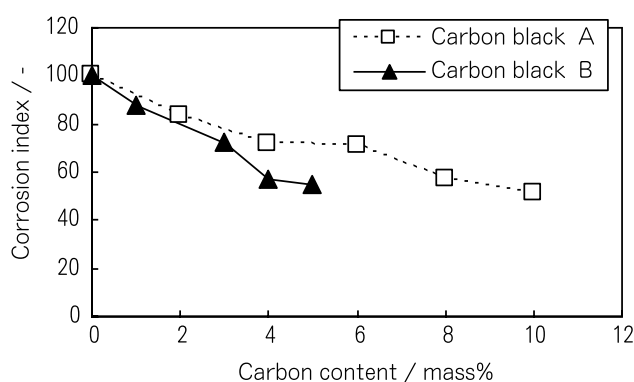


Fig. 3 Result for corrosion test of sample with aggregate and matrix.

た配合においてカーボン原料の種類・添加量を変えて耐食性を評価した結果をFig. 2に示す。検討したカーボン原料は、ピッチとカーボンプラックA、B（平均粒径A>B）とした。ピッチは添加量を増加させても耐食性がほとんど変わらず、カーボンプラック添加量は増加させると、ある添加量で急激に耐食性が向上することがわかった。また粒子径の小さいカーボンプラックBの方が少ない添加量で耐食性が向上した。

上記の結果を受けて、骨材を含めた配合においてカーボンプラックの種類・添加量を変えて耐食性を評価した。Fig. 3に示すように、効果はやや小さいものの、 $-75\mu\text{m}$ のみの配合と同様に耐食性が向上する効果が認められた。

Table 1に従来材より約3割の耐食性向上が認

much more than the aggregate on hot face of trough castables after use at the metal line. Based on this damage situation, we studied the method to improve corrosion resistance of matrix. Fig. 2 shows the results of the corrosion test of samples composed of only matrix which is based on typical trough castable formulation, but contains only fine raw materials of less than $75\mu\text{m}$. The type and quantity of carbon materials were changed in these samples. A pitch, a carbon black A and a carbon black B are used as carbon materials. Carbon black A is larger than carbon black B in particle size. The pitch did not improve corrosion resistance at all. On the other hand, carbon blacks improved corrosion resistance significantly and this effect seems to appear only one carbon black was added with large amount. Carbon black B, which has smaller particle size than carbon black A, improved corrosion resistance with a smaller amount than carbon black A.

Fig. 3 shows the results of the corrosion test of samples with aggregates and matrix. The type and quantity of carbon black were changed in these samples. The corrosion resistance became higher with more amounts of carbon blacks. These results denoted the same tendency of the corrosion test of the samples with a matrix.

Table 1 shows the results for the properties of the samples of which the corrosion resistance had been improved to about 30 percent better

Table 1 Properties of tested samples

	Ordinary materials	Sample 1	Sample 2	Sample 3
Carbon black A content / mass% [-75 μ m carbon black A content / mass%]	2 [6]	8 [24]	-	4 [12]
Carbon black B content / mass% [-75 μ m carbon black B content / mass%]	-	-	4 [12]	1 [3]
Corrosion index / -	100	68	69	72
MOR after heating 1500°C / MPa	5.0	2.7	0.9	3.2
Apparent porosity / %	16.4	17.8	24.2	17.2
Limit temp. of explosive spalling / °C	600	500	700	600

められたものについて、各種の試験を行った結果を示す。カーボンブラックAのみを使用したSample 1は耐爆裂性が低下した。またカーボンブラックBのみを使用したSample 2は高気孔率、低強度となった。耐爆裂性が低下すれば乾燥条件によっては爆裂の危険性が高まるし、高気孔率、低強度の材料では酸化や摩耗損傷の増大が生じやすくなると考えられる。

これに対し2種類のカーボンブラックを添加したSample 3は高耐食性を維持しつつ、カーボンブラックAの多量添加で生じた耐爆裂性の低下、およびカーボンBの多量添加で生じた高気孔率、低強度の問題が解消している。この結果は、カーボンの添加量だけでなく、複数のカーボンの組み合わせ方を工夫することによっても、より優れた材料が得られることを意味している。

3. 実炉適用結果

粒径の異なる2種類のカーボンブラックを使用したことを特徴とする開発品の使用結果をTable 2に示す。開発品を適用した結果損耗速度が減少した。さらに従来材で発生していた亀裂は、開発品には認められず (Fig. 4)、良好な結果が得られた。

4. 結言

より高性能な珧材の開発を目的に検討を重ねた結果、以下の知見を得た。

than ordinary materials. Sample 1 which contained a lot of carbon black A decreased the explosion resistance. Sample 2 which contained a lot of carbon black B exhibited high porosity and low-strength. The risk of explosion in actual use rises when the explosion resistance decreases. If the materials have a high porosity and the low-strength, they will be damaged easily by abrasion of metal and oxidation.

However, sample 3 which contained two kinds of carbon black had high corrosion resistance, and solved the problems of decreasing the explosion resistance, high porosity and low-strength. These results suggest that the improvement of characteristics of these materials does not depend only on the amount of carbon black, but also on the strategy combining two or more carbon blacks.

3. Actual Use Results

Table 2 shows actual use results of the newly developed castable which contains two kinds of carbon black. The wear rate was significantly reduced by applying the newly developed castable. Cracks, which sometimes occurred in the ordinary castables after use, were reduced by using the newly developed castables. (Fig.4).

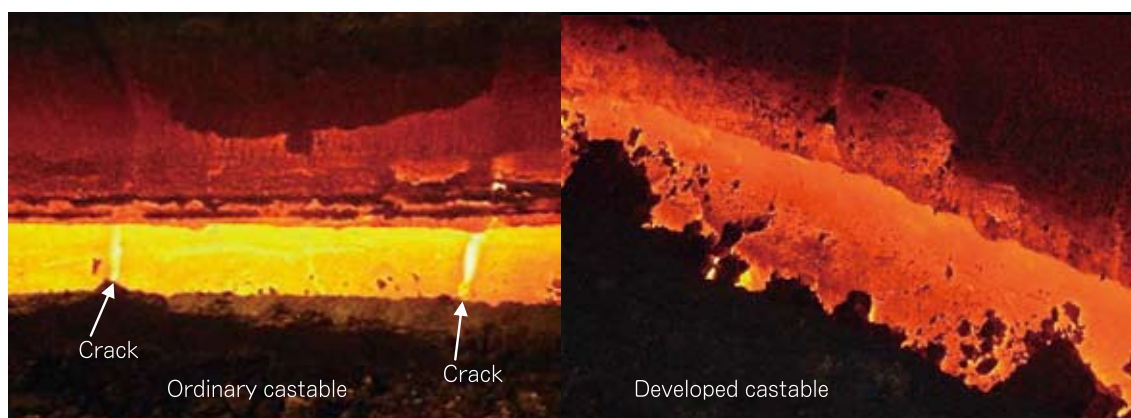


Fig. 4 Photographs of trough after use.

Table 2 Actual use results

	Metal zone	
	Ordinary [Low carbon]	Development
Maximum wear rate (mm/kt)	3.9	2.9
Note		Less cracking

- (1) マトリックスのみの侵食試験において、カーボンブラックの添加量が多いほど耐食性が向上する。
- (2) 骨材を含めた配合でも、その効果は小さいものの、同様に耐食性が向上する。
- (3) 単一のカーボンブラックを多量添加した場合、耐食性以外の特性に問題が生じたが、カーボンブラックを組み合わせることによって解消できた。
- (4) 本開発品を実炉に適用した結果、損耗速度が減少したほか、亀裂・剥離が抑制される効果も認められた。

4. Conclusion

We carried out research in order to develop high performance castables and got the follow results.

- (1) The corrosion resistance of samples with a matrix became higher when carbon black was added in large quantities.
- (2) The corrosion resistance of samples with aggregates and matrix improved when carbon black was added in larger quantities. These results denoted the same tendency of the corrosion test of the samples with a matrix.
- (3) When a single carbon black was used in large amounts, the characteristics other than corrosion resistance became worse. But these problems could be solved by adding two kinds of carbon black to sample.
- (4) As a result of actual use of the newly developed castable. The wear rate was significantly reduced, such as cracks and peeling compared to the ordinary castables.

References

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