

SHINAGAWA TECHNICAL REPORT

急乾燥対応型高耐用吹付け材 「SIG (Shinagawa Improved Gunning)」 について

Dry Gunning Material “SIG (Shinagawa Improved Gunning)” with High Durability and Quick Drying Properties

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製品紹介／PRODUCT

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要 旨

施工時間の短縮，施工方法の簡便さから，近年は吹付け材の使用量が増加傾向にある。一方で，吹付け材は補修用の材料として使用されることが多く，イニシャル施工で使用可能な高耐用吹付け材が望まれている。そこで，簡易的な乾式吹付け工法を採用し，溶液バインダーをノズル部で混合する吹付け材を開発し，従来の乾式吹付け材と比較して約 2 倍の強度向上と優れた乾燥性を両立することに成功した。

Abstract

Because of short construction time and simplicity in relining work, application of gunning refractory material has been increasing in recent years. Gunning material is generally used as repairing material for base refractories. Due to the above reasons, however, requirements for gunning material applicable for initial relining has increased in association with its better performance. In this regard, a new dry gunning material, SIG, in which binder solution is mixed with pneumatically transported SIG gunning material in the vicinity of the gunning nozzle was developed. In comparison with conventional gunning material, SIG gunning material exhibits almost doubled mechanical strength and superior quick drying properties.

1. 緒言

不定形耐火物は，流し込み施工，吹付け施工，圧送施工，スタンプ施工など用途に合わせて様々な施工方法があるが，不定形耐火物生産量は流し込み材と吹付け材が大半を占めている。吹付け施工は型枠の設置や脱枠が不要であり，施工方法が簡便で工期の短縮が可能であるといったメリットがある。一方で，イニシャル施工は緻密な組織を有する定形耐火物あるいは流し込み材が使用され，吹付け材は補修材として使用するのが一般的であるが，焼却炉などの型枠の設置が難しい設備においては吹付け材をイニシャル施工で使用されることもあり，吹付け材の高耐用化が望まれている。今回，高強度で耐摩耗性に優れ，かつ急速乾

1. Introduction

In accordance with application purposes or construction conditions, various relining methods, can based to reline with monolithic refractories such as casting, gunning, spraying with pump pressure feeding or stamping. In terms of quantity of production, monolithic refractory relining carried out by casting and gunning occupies quite large portion. Because there is no requirement for construction and demolishing work of a mold form, monolithic refractory gunning work can be carried out simply and easily with minimized construction

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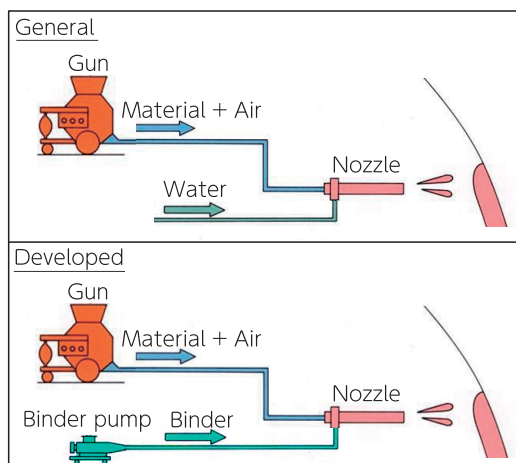


Fig. 1 Schematic diagram of conventional and SIG gunning method.



Fig. 2 General view of SIG gunning machine.

燥に対応することでカーボンニュートラルに貢献できる次世代吹付け材「SIG (Shinagawa Improved Gunning)」を開発したので報告する。

2. 施工装置について

一般的な乾式吹付け工法とSIG吹付け工法をFig.1に示す。一般的な乾式吹付け工法は、粉体をエア搬送し、ノズル部で水と混合させて施工する。一方、SIG吹付け工法は水の代わりに溶液バインダーを使用するのみであり、別途バインダーポンプは必要となるが、一般的な乾式吹付け装置での施工が可能である。SIG吹付け装置をFig.2に示す。

3. 材料の品質特性について

3. 1 強度特性

加熱後曲げ強さをFig.3に示す。従来の乾式吹付け材は結合剤としてアルミナセメントを使用しており、セメントの水和物生成により低温で強度を発現するが、温度上昇に

time. Gunning refractories are usually used as repairing material for base refractories which were initially relined with shaped refractories or casting refractories with a densified structure. In some cases, such as incinerators, where mold form construction is difficult, however, gunning refractories are used as initially relined refractories. In this regard, gunning refractories with high durability and improved performance are required.

In this article, SIG (Shinagawa Improved Gunning) a newly developed gunning refractory material is introduced. It is characterized by high mechanical strength and abrasion resistance as well as quick drying properties which, due to minimized necessity for forced drying by combustion, contributes to carbon neutrality.

2. Gunning Machine

A comparison of general type dry gunning machine, and of newly developed SIG gunning machine is presented in schematically illustrated in Fig.1. In general type gunning operation, pneumatically transported dry gunning material is mixed with water the vicinity of the gunning nozzle. Is the SIG gunning machine, instead of water, binder solution is mixed with pneumatically transported gunning material. Except for the pumping system for water binder solution, conventionally used gunning machine components are applicable for SIG gunning operation. A general view of the SIG gunning machine is shown in Fig. 2.

3. Characteristics of SIG Gunning Material

3. 1 Mechanical strength

The modulus of rupture of SIG gunning material gunned body after heating at various temperatures compared to conventional gunning material is shown in Fig. 3. Since alumina cement is used as binder in conventional gunning material, mechanical strength is created by cement hydrate formation from the low temperature range. When the heating temperature is elevated, the formed cement hydrate reverts to a non hydrate mineral component. Because

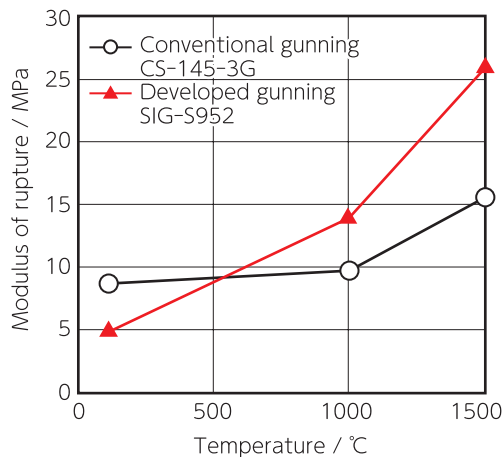


Fig. 3 Modulus of rupture of conventional and SIG gunning materials after heating at various temperatures.

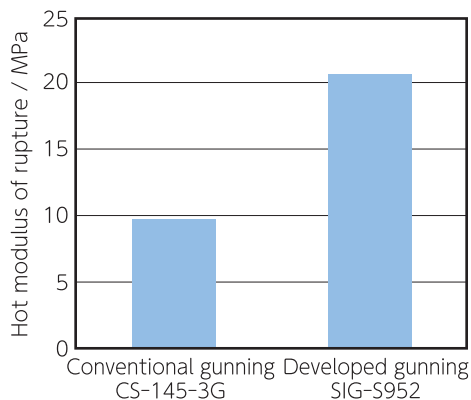


Fig. 4 Hot modulus of rupture of conventional and SIG gunning materials at 1200°C.

伴う水和物の脱水により無水和のアルミナセメント鉱物に戻ること1000°C加熱後の強度はほぼ変化していない。一方、開発品のSIGは溶液バインダーがゲル化し、温度上昇に伴って強固なケミカルボンドを形成するため1000°C以上の温度では従来の乾式吹付け材の約2倍の強度を有した¹⁻⁴⁾。また、1200°Cでの熱間曲げ強さをFig.4に示すが、開発品のSIGは熱間においても2倍以上の曲げ強さを示した。これは、SIGはアルミナセメントを含有しておらず、CaO-Al₂O₃-SiO₂系の低融点化合物を生成しないためと考える⁵⁾。

3. 2 耐アルカリ性

Fig.5に耐アルカリ性試験結果を示す。試験は、1300°C、3時間加熱とした。実線が試験前形状、点線が浸潤および溶損した範囲を示す。開発品のSIGは従来の乾式吹付け材と比較して、優れた耐アルカリ性を示した。これは、開発品

of such constituent change of alumina cement hydrate, the mechanical strength of conventional gunning material gunned body which is heated at over 1000 °C is not changed much. The mechanical strength of SIG gunning material gunned body is created by formation of a strong chemical bond induced by gelation of binder, which is reinforced more by temperature elevation. Because of such mechanical strength manifestation mechanism, SIG gunning material gunned body which is heated at over 1000 °C exhibits almost doubled mechanical strength of conventional gunning material¹⁻⁴⁾. As per Fig. 4, in which hot modulus of rupture of the gunned bodied measured at 1200 °C of conventional and SIG gunning material, are compared SIG gunning material exhibits over doubled hot modulus of rupture. Because cement is no contained, CaO-Al₂O₃-SiO₂ compounds with low melting point are not formed in the SIG gunning material gunned body⁵⁾. That is, high mechanical strength of SIG gunning material at elevated temperature is explainable by the non-existence of frangible components in its gunned body.

3. 2 Alkali resistance

Cross sections of conventional and SIG gunning material samples after alkali resistance test in which both samples were heated at 1300 °C for 3 hours with alkali agent situated on their top surface are shown in Fig. 5. The solid and dotted lines in Fig. 5 indicate the original top surface of the samples and corroded surface line by penetration of alkali agent, respectively. Compared to conventional gunning material, SIG gunning material exhibits superior alkali resistance. It is inferred that superior alkali resistance of SIG gunning material is attained by its raw material blend composition with no cement components and formation of glass layer, which is generated by the reaction between the matrix, which is enriched with silica derived from binder solution and alkali agent.

3. 3 Drying property

It is generally acknowledged that permeability of the monolithic refractory body is markedly improved by utilizing a binder solution⁶⁾. In order to

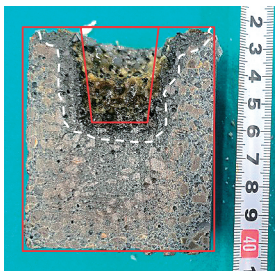
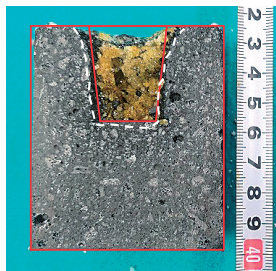
	Conventional gunning material (CS-145-3G)	Improved gunning material (SIG-S952)
Cut section after alkali resistance test		
Corrosion and penetration index	100	58

Fig. 5 Cross sections of conventional and SIG gunning material samples after alkali resistance test.

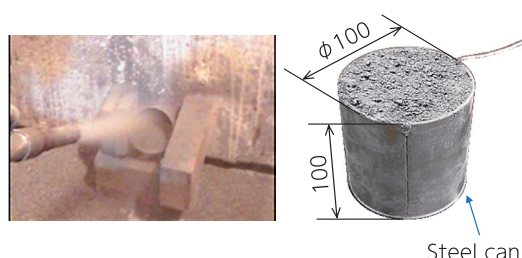


Fig. 6 Exterior appearance of thermal explosion test sample and its preparation method.

のSIGがセメントを含んでいない配合設計であることと、溶液バインダー由来のシリカに富むマトリックスがアルカリと反応してガラス質を形成したことによるものと推察する。

3. 3 乾燥性

一般的に、溶液バインダーを使用すると通気率が大幅に向上することが知られている⁶⁾。そのため、電気炉投入法の試験条件を厳しくして乾燥性を評価した。サンプル作製方法およびサンプル外観写真をFig.6に示す。まず、缶内に吹付けてサンプルを作製し、水蒸気がサンプル上面からしか抜けないようにし、吹付け後に室温で3時間養生したサンプルを、1000℃に加熱した電気炉内に投入した。サンプルの内部温度変化をFig.7に示す。上記の厳しい条件でも爆裂は発生せず、乾燥終了期温度は約140℃と優れた乾燥性を有する結果を得た。また、実炉において施工厚み250mmに対して乾燥せずに使用した実績もあり、実炉でも優れた乾燥性を実証済である。

4. 製品ラインナップ紹介

Table 1, Table 2にSIG製品の品質表を示す。アルミナ質とSiC質をラインナップし、焼却炉、溶融炉、産廃炉、

ascertain that effect on the drying property of SIG gunning material, a thermal explosion test, in which test samples were thrown in an electric furnace in which the internal atmosphere was kept at high temperature, was conducted with much severer experimental conditions. The exterior appearance of the thermal explosion test sample is shown in Fig. 6 along with its preparation method by gunning the SIG material in steel can. After gunning in steel can, the SIG gunning material test sample was cured in the steel can at room temperature for 3 hours so that the moisture component is evaporated only from the top surface. Such prepared thermal explosion test samples were thrown in an electric furnace in which the internal atmosphere was kept at 1000 °C. Under such severe test conditions, the SIG sample survived without explosive breakage. As per Fig. 7 in which the change in internal temperature measured with thermocouple embedded in SIG sample is shown, approximately 140 °C internal temperature was recorded at the final stage of drying in the thermal explosion test, which indicates of good drying property of SIG gunning material. The excellent drying property of SIG gunning material was also verified in practical application in which SIG gunning material gunned to 250 mm thickness was used for operation without drying.

4. Line-up of SIG Gunning Material

The Major specification of alumina-base and SiC-base SIG gunning materials are summarized in Table 1

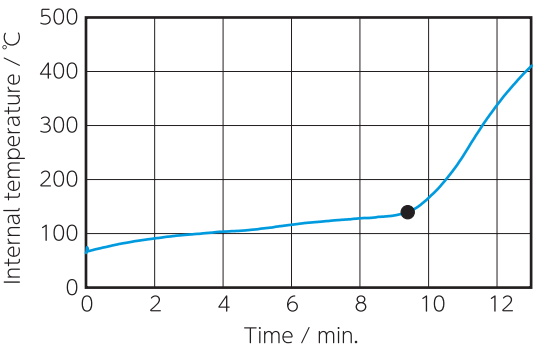


Fig. 7 Change of internal temperature in SIG test sample during thermal explosion test.

and Table 2, respectively. By selecting the suitable alumina-base or SiC-base SIG gunning material, initial relining or repairing can be performed with SIG gunning material in various kinds of furnaces, namely, incinerator, melting furnace, industrial waste treatment furnace, cement kiln or heating furnace.

5. Conclusion

Newly developed gunning material “SIG (Shinagawa Improved Gunning)” which can be used at various industrial furnaces was introduced in this article.

Table 1 Major specifications of alumina-base SIG gunning materials

		Al ₂ O ₃ · SiO ₂		Hi-Al ₂ O ₃
		SIG-A502	SIG-A602	SIG-A802
Construction requirements / kg·m ⁻³		2,100	2,300	2,400
Chemical composition / mass%	SiC	-	-	-
	Al ₂ O ₃ SiO ₂	50 47	61 35	77 17
Linear change / %	110°C/24h	-0.01	-0.03	-0.03
	1000°C/3h	-0.12	-0.21	-0.32
	1500°C/3h	+0.31	+1.67	+1.60
Modulus of rupture / MPa	110°C/24h	5	5	5
	1000°C/3h	10	14	17
	1500°C/3h	13	15	18
Thermal conductivity / W·m ⁻¹ ·K ⁻¹	at 250°C	1.2	1.3	1.4
	at 500°C	1.2	1.4	1.6
	at 750°C	1.3	1.4	1.6
	at 1000°C	1.4	1.5	1.8

Table 2 Major specifications of SiC-base SIG gunning materials

		Al ₂ O ₃ · SiC					Hi-SiC
		SIG-S302	SIG-S502	SIG-S702	SIG-S802	SIG-S902	SIG-S952
Construction requirements / kg·m ⁻³		2,300	2,300	2,350	2,400	2,450	2,450
Chemical composition / mass%	SiC	32	51	71	80	90	95
	Al ₂ O ₃	38	27	16	11	4	-
	SiO ₂	27	19	11	6	3	3
Linear change / %	110°C/24h	-0.02	-0.03	-0.03	-0.04	-0.04	-0.04
	1000°C/3h	-0.05	-0.04	-0.04	-0.05	-0.04	-0.04
	1500°C/3h	-0.10	-0.14	-0.15	-0.18	-0.20	-0.22
Modulus of rupture / MPa	110°C/24h	5	5	5	5	5	5
	1000°C/3h	10	11	12	13	14	14
	1500°C/3h	15	16	17	20	24	26
Thermal conductivity / W·m ⁻¹ ·K ⁻¹	at 250°C	2.4	3.1	3.6	5.7	7.0	9.4
	at 500°C	2.5	3.2	3.7	5.8	7.1	9.2
	at 750°C	2.7	3.4	3.7	6.4	7.6	8.8
	at 1000°C	2.9	3.8	3.8	6.1	7.4	8.4

セメントキルン，加熱炉など幅広い使用条件に対応可能である。

5. 結言

各工業炉向け吹付け材「SIG (Shinagawa Improved Gunning)」を紹介した。SIGは，従来の乾式吹付け材と比較して高い強度を有し，急乾燥に対応可能な次世代の乾式吹付け材である。今後も更に製品ラインナップを拡充し，乾燥時間短縮等によるCO₂削減や高耐用化による耐火物使用量の削減といった環境問題に取り組む予定である。

SIG can be rated as next generation dry gunning material which, in comparison with conventional gunning material, is characterized by high mechanical strength and quick drying properties. It is expected that, by upgrading and expanding the line-up of SIG gunning materials, the introduced gunning material will contribute to environmental conservation by reducing the CO₂ emission volume realized by shortened drying time and/or in unit consumption of refractories realized by improved durability.

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