

ENVIRONMENT-FRIENDLY MAGNESIA-BASED LIGHTWEIGHT SPRAYING MATERIAL FOR TUNDISH LINING

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ABSTRACT

Magnesia-based tundish spray material is one of the key refractory materials in the continuous casting process and is applied as a sacrificial working lining to protect the permanent lining. There is an ever-increasing demand from the tundish working lining for reduced inclusion pick up and impurities, as well as health, safety, and environmental friendliness. Reducing the consumption of spray materials and their costs are the key objectives of both the producer and the end users. This paper reports on a lightweight tundish spray material, MONO L.I.T.E, that has been developed and the results of its successful industrial trials. The trial results have confirmed that the spray material consumption has reduced to 16% compared to the normal tundish spray material in use while improving drying, insulation, deskulung, and thus the life of the permanent lining. A reduction of carbon footprint of 230 kg per tundish lining has been reported.

INTRODUCTION

The traditional idea of using tundish as an intermediate vessel between the ladle and caster to maintain an uninterrupted casting has changed in steel plants. The nature and type of tundish lining materials and their processing techniques, decide the thermal homogeneity, heat loss, operational stability, and the life of the permanent lining. Recently, the tundish operations in continuous casting have focused on making a) clean steel and b) helping the environment by reducing the carbon footprint of the lining materials. Making clean steel refers to reducing the content, composition, size, and morphology of inclusions. Clean steel also focuses on the level of other residual impurities such as H, N, S, P and C^{1,2,3}.

Carbon footprint reduction in the steel-making process is an essential aspect today. The complete value chain of the steel-making process involves elevated temperatures varying from 1000 to 1750°C at various stages. All the vessels involving the steelmaking process are lined with the refractory materials.

Refractory materials involve carbon footprint emissions in various stages of their manufacturing and use. The emission starts with the mining of the raw materials, processing and calcining or dead burning of raw materials. The manufacturing and sintering operations are the major sources of carbon emission in the case of shaped products. Installation, drying and preheating stages of the unshaped or monolithic products like tundish spray, play a vital role in determining the carbon footprint or emission level^{4,5,6}.

The current state of the art of the tundish lining technology majorly classifies the lining materials into spray, dry mix, and cold set mass⁷. However, the tundish spray is still the preferred lining material (78% usage level) for its ease of installation, such as formless installation, low density

(good thermal insulation) compared to dry mixes and cold set, ease of deskulung etc. However, the tundish lining material is a slurry made of dead burnt magnesite, olivine, binders, and fibers, in general. The carbon footprint of tundish spray lining materials during the manufacturing process originates from the dead burnt magnesite used in the product, which is around 1927 kg of CO₂equ. per ton of MgO⁸. The slurry formation demands a water level anywhere between 18% to 25%, depending upon the nature and composition of the spray material. The lining material needs to be dried and preheated to remove the moisture used in the forming process. This stage involves intensive fuel use and carbon emissions.

The refractory industry adopts various ways to manufacture and use tundish spray material to combat the issue of carbon emission: use of recycled materials, development of fast-drying materials, etc. Another approach to reducing the carbon footprint is to reduce the consumption of tundish lining materials per tundish (reducing density) in use, thus reducing the water addition and drying energy required. Another tangible benefit of this measure is to reduce the thermal conductivity of the lining, and the energy loss from liquid steel, and improve the life of the permanent lining.

This work has attempted to develop a lightweight tundish spray material, MONO L.I.T.E (hereafter referred to as TS1), which reduces the 16% spray material consumption per tundish coating in application, while maintaining a similar performance as that of current materials in use. Industrial trials have been successfully carried out in a South American steel Plant to validate the concept.

EXPERIMENTAL

Tundish spray material TS1 of 70% MgO content has been developed on a lab scale and the details of spray materials are presented in Tab. 1. The current material in use, Monolite 70GF (hereafter referred to as TS2), and competitor material are also presented for comparison.

The current product in use is TS2 and TS1 was selected for a trial in a South American steel plant. The complete characterization of TS1 is presented in comparison with TS2, in Tab. 2.

For the characterization of TS1, one ton of TS1 was made with DBM 90, Olivine, cellulose fibre, and other relevant additives in the production plant to have a better distribution of fibre and additives. The loose fill density of material (LFD) was measured as per the internal procedure of the Monocon lab. A 5kg production sample of TS1 was wet mixed with the required water for 5 minutes to spray consistency. The slurry bulk density (BD) was measured as per Monocon's internal standard. Samples of 100mm x 25mm x 25mm, for modulus of rupture (MOR), BD, and permanent linear change (PLC)

were made by casting into a steel mold. For thermal conductivity measurement (hotwire method, GBT5990), samples of 230mmx114mm x 64 mm brick was cast into a steel mould. All the samples were cured for 24 hrs., demoulded, and dried at 110°C for 24 hrs. The MOR measurements were made as per the internal procedure at Monocon lab, while the BD and PLC were made as per relevant British standards (BS EN ISO 1927). Dried samples were fired in a furnace at various temperatures as required. A similar procedure was followed for preparing samples for an already existing product TS2. The physical, mechanical and thermal characteristics of materials are presented in Tab. 2.

Tab.1: Tundish Spray Material

Material	TS1	TS2	Competitor
Chemistry, %			
MgO	70	70	69
SiO ₂	21	22	22.5
CaO	1.2	1.4	1.3
Fe ₂ O ₃	4.3	4.5	4.6

Tab. 2: Physical, Mechanical and thermal characteristics

Characteristic	TS1	TS2	Competitor
LFD, g/cc	1.29	1.32	1.42
Mixing water, %	18	20	21
Slurry B.D, g/cc	1.79	2.17	-
B.D, after			
110°C /24hrs	1.29	1.7	1.85
1100°C/1 hr	1.32	1.61	-
1550°C/3hrs	1.38	1.64	-
MOR, after			
110°C /24hrs	0.2	0.15	0.3
1100°C/1 hr	0.1	0.05	-
1550°C/3hrs	0.28	0.35	-
Permanent Linear change, %			
1550°C/3hrs	-2.9	-2.6	-
Thermal Conductivity, W/mK			
At 1200°C	0.33	0.47	-

INDUSTRIAL TRIALS

Nine tons of TS1 were used to carry out an industrial trial in a steel plant in South America. In total, eleven tundishes (billet casting) were sprayed using a tundish spray machine available locally. The trial details are presented in Tab.3.

A tundish after spraying is shown in Fig.1. The tundishes were dried with a gas burner up to a set temperature of 500°C (Fig.2). Drying time was measured in the sprayed tundish lining. The time required to reach a temperature of 100°C at the interface between the sprayed lining and the permanent safety lining is defined as the drying time in these measurements. To measure the drying time required for the temperature to reach 100°C, thermocouples were inserted at

various locations of one of the sprayed tundishes (Fig.3). To determine the drying time, thermocouples were inserted in the areas furthest away from the surface, these are, behind the turbulence stopper at floor level (T3), and in the corner of the floor-wide-narrow wall (T1), and wall near to nozzle 2 (T2). The thermocouple T4 is on the surface of the sprayed material, in strand 2.

Tab. 3: Trial details of Tundish spray

Parameter	TS1	TS2
Consumption, Kg/Tundish	818	970
Difference, Kg	-152 (16%)	
Spraying time, min.	14-16	16-22
Drying time, min.	175 to 255	240 to 360
Gas consumption difference, m ³	7%	

A drying program was used to estimate the time required to reach 100°C, with a starting temperature of 300°C (Fig.3). The time required to reach 100°C was monitored and then further heated till the total time of drying was 7 hrs.



Fig.1: Tundish after spraying



Fig.2: Tundish with thermocouples

After drying, the tundishes were preheated to 1100°C before being taken into the casting operation. The tundishes were used successfully for casting low and medium-carbon steel, as shown in Tab.4.

RESULTS AND DISCUSSIONS

The lightweight tundish material TS1 has shown a distinct behaviour in all characterizations as observed in Tab. 2 while

the chemical analyses of materials remain on a similar level (Tab. 1). The loose fill density (LFD) does not show a significant difference while the slurry BD of the material, TS1 is 17% lower in lab measurement even with 2% lower water requirement than TS2. The BD of materials continues to show similar differences across all firing temperatures. The effect of lower BD of TS1 is visible in thermal conductivity measurements, where a significant reduction of 30% for material TS1 compared to TS2.

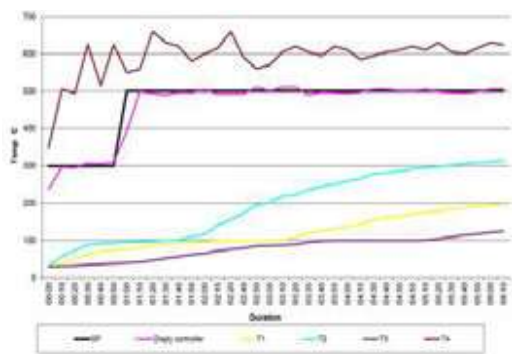


Fig.3: Temperature profile in tundish

Industrial trials of TS1 were smooth, with less demand in water level as noticed in lab conditions. The most important observation is a reduction of 16% in material consumption of TS1 compared to TS2 (Tab. 3). This has a significant value in terms of carbon footprint reduction of material. The reduction in spray time is an obvious outcome of reduction in material requirement of TS1 compared to TS2.

The driving behavior of TS1 is faster than TS2. This is the result of two factors: the lower water demand of spray material TS1 and the reduced quantity in place for the same thickness of lining. The savings in material, spray time, and drying time are the tangible benefits noticed during the industrial trials.

The tundishes have been subjected to the same preheating schedules before casting, and the behavior of the material during casting was good. The 11 tundishes underwent a casting sequence of 5 to 12 ladles (360 to 820 mins.), depending on the conditions that prevailed in the caster (Tab.4). The deskulling was smooth in all cases.

Tab. 4: Tundish casting history

Tundish	Ladle casted	Operation time, min	Reason for stop
1	5	360	Maintenance
2	6	430	Maintenance
3	7	490	BOF Delay
4	3	193	BOF Delay
5	10	780	-
6	4	250	BOF Delay
7	3	210	BOF Delay

8	11	770	End of sequence
9	12	820	End of Sequence
10	8	630	Nozzle issue
11	11	750	Maintenance

CARBON FOOTPRINT

The significant reduction in material consumption, spraying water addition, and the drying energy has resulted in a CO₂ equ. reduction of about 230 kg per tundish. This value can increase significantly with the increase of tundish size and MgO content in the product. These calculations are based on the standard values of CO₂ footprints for mining and processing of raw materials, manufacturing of the product, and the natural gas used in the drying process.

CONCLUSIONS

A lightweight tundish spray TS1 developed on a lab scale has been successfully used in industrial trials, resulting in a 16 % reduction in material consumption, and a significant reduction in water demand, drying time and energy. The material behaviour during casting and deskulling is satisfactory. The significant carbon footprint reduction of 230 kg per tundish has been calculated based on the facts observed during industrial trials.

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