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Innovative Spray Tundish Mix for Energy Savings and CO_2 Footprint Reduction

As modern steel plants and manufacturing processes evolve, additional demands are placed on refractory installation and performance. Many traditional tundish working lining materials require long drying and preheating curves, which can inhibit equipment availability and production output. These heating requirements also result in high energy usage and CO_2 generation for the plant. To support the industry's productivity and environmental goals, the FAST TO CAST tundish spray product line was formulated. Developed as a cross-regional R&D collaboration, FAST TO CAST products can be sprayed onto the tundish permanent lining and taken directly to final heating, shortening or bypassing the traditional drying step. The resultant lining maintains its physical integrity and refractory performance, while offering reduced fuel requirements and a lower carbon footprint.

Introduction

Over the years, methods for effectively lining the tundish in continuous casting steelmaking operations have progressed to optimise efficiency, increase equipment availability, minimise cost, and reduce energy usage. The tundish is the last piece of processing equipment that encounters molten steel and while historically treated as a simple containment vessel, has evolved to become a key metallurgical vessel for maximising cast steel quality and yield [1].

Modern tundish wear linings generally fall into one of three categories: Dry-setting (or dry vibratable) mixes, cold-setting (or self-hardening) mixes, and slurry gunning (or sprayable) mixes. Each product category has inherent advantages and disadvantages over the others, both in terms of installation and performance (Table I). Advantages of slurry gunning mixes include their ability to be applied quickly, their lower density, lower specific consumption, higher insulation value, and their flexibility of use. Disadvantages include long dry-out times due to high amounts of water that are needed for proper installation. With this type of product, a working lining thickness can be applied in a variable manner, which can allow for thicker layers to be installed in high-wear areas such as the slag line.

It has also been found that sprayable compositions lead to considerably lower levels of carbon pickup in steel when compared to dry mixes [2,3]. Due to these advantages, this mix type quickly gained in popularity throughout the world after its introduction to the market in the 1980s and it remains one of the most dominant technologies to this day [3,4]. As a result of this popularity throughout the industry, special focus has been given to improving the efficiency of utilising this technology, while also reducing the energy consumption and resulting carbon footprint.

Design Requirements

To achieve the objectives of improving efficiency, equipment availability, and fuel consumption of slurry gunning refractory mixes, several considerations had to be addressed. For standard slurry gunning products that are prevalent in today's marketplace, there is an inherent demand for careful dry-out and preheating practices to maintain the physical integrity of the refractory and promote the best possible performance. Typical slurry gunning mixes incorporate water additions around 20–30 wt.% to achieve the proper application consistency and behaviour. For this water to be removed effectively, dry-out heating curves can reach

Table I.

Comparison of current tundish wear lining technologies. Abbreviations include not applicable (N/A).

	Dry setting	Cold setting	Slurry gunning
Equipment needed	Steel form/mandrel/ template, burner	Cold-setting machine, steel form/mandrel/template	Spray machine, burner
Liquid addition	N/A	Water or liquid binder	Water
Thickness flexibility	N/A	N/A	++
Heating requirement	Curing	N/A	Drying
Heating time	+	N/A	++
Energy requirement	+	-	++
Material density	High	High	Low
Insulating properties	+	+	++
Material consumption	High	High	Low
Casting sequence length	++	++	+

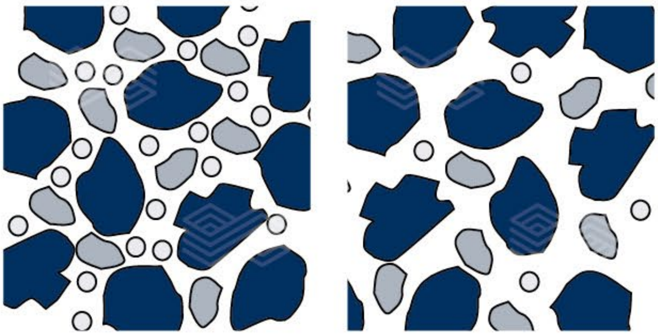
4–6 hours or more, depending on several variables such as specific material choice, lining thickness, and burner configurations. This controlled drying step is critical to reduce the likelihood of cracking, blistering, and spalling in the refractory working lining. By reducing or eliminating the drying requirement, the overall application process time can be reduced, while necessary energy inputs can be lowered as well. Other main aspects of the mix, such as equipment compatibility, application methodology, and overall refractory performance are expected to remain constant while the changes to drying requirements are made.

Methodology

Compared to the traditional products, the new FAST TO CAST series relies on both a modified binder package and grain size distribution to achieve the desired application advantages. By creating open channels of porosity within the refractory structure, water release can occur more freely (Figure 1). Modifications to the binder package enable uninhibited moisture escape, while maintaining mechanical integrity of the mix in both the as-applied and dried conditions. The combination of binder and grain size distribution also allows for proper compaction, sintering, insulation, and performance of the mix.

Figure 1.

Changes in particle size distribution can create (a) a denser, packed structure that is more likely to entrap free moisture or (b) an open structure through which moisture is more quickly and easily removed.



(a) (b)

Small-scale laboratory tests of the FAST TO CAST concept in both North and South America aimed to push the limits of this technology when exposed to aggressive heating. In addition to standard testing of the chemistry, water demand, and flowability, panels of slurry containing 20–30% water were subjected to direct flame exposure. In the North American study, the wet slurry was allowed to air set for 15 minutes, followed by application of a passing propane torch (flame temperature ~1980 °C) for 4 minutes. In the South American testing, a similar approach was taken where a panel was sprayed onto a vertical wall and subjected to direct, localised flame contact. In both cases, the material dried sufficiently within minutes and without signs of cracking, blistering, or spalling (Figure 2).

Field Trial Results—North America

Following the favourable laboratory studies, larger-scale field trials were commissioned. In North America, a series of four consecutive field trials were conducted at various customer sites, working to validate the FAST TO CAST materials over a wide range of conditions and to prove that repeatable results could be maintained.

The first trial in North America was conducted over a series of five individual tundish linings. Each lining was applied to a thickness of 50 mm and required an application time of 30 minutes per lining. All equipment parameters including water and air settings were kept consistent with the settings used for standard slurry gunning material. For this trial, thermocouples were installed on the surface of the permanent lining to determine the point at which complete dry-out of the wear lining was achieved.

Figure 2.

Measuring the FAST TO CAST (a) resistance to a propane torch in North America and (b) localised flame application to a vertical panel in South America. In both tests, cracking, blistering, and spalling were not experienced, and the refractory maintained proper strength characteristics.

(a) (b)

Figure 3 shows a comparison of drying curves used for the FAST TO CAST materials compared to the standard mix. For the FAST TO CAST, complete drying could be achieved in 2 hours with the burner going from room temperature directly to 550 °C, compared to a profile of more than 6 hours used for the standard mix. Thermocouple data shown in Figure 4 illustrates that all of the installed thermocouples reached a minimum of 100 °C within this time period, indicating that complete drying had been reached. When an aggressive heating curve such as the one used for FAST TO CAST is applied to a standard mix, significant cracking, spalling, and blistering can occur, as shown in Figure 5.

Further trials with the FAST TO CAST materials in North America tested variables such as spray lining thickness (ranging from 40–100 mm thick), permanent lining temperature (ambient and warm), and cast sequence length (6–18 heats). In these trials, the following were achieved:

- No slumping of the slurry on the tundish wall.
- No cracking, blistering, or spalling.
- Drying time reduced by up to 70%.
- Energy demand and CO_2 emissions from drying were reduced by up to 50%.
- Specific refractory consumption was reduced by an average of 20%.
- Lower shell temperatures were reached due to reduced thermal conductivity.
- Equipment turnaround time and availability was improved.
- No change in water demand, refractory performance, or deskulling behaviour.

Figure 5.

(a) standard slurry gunning mixes have the potential to crack, blister, and spall when subjected to aggressive heating conditions. (b) the FAST TO CAST formulation can absorb the stress of aggressive heating conditions without experiencing physical damage.

(a)

(b)

Figure 3.

Comparison of the drying curves for FAST TO CAST and a standard slurry gunning mix.

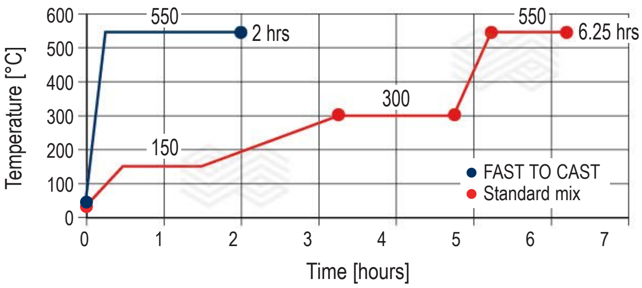
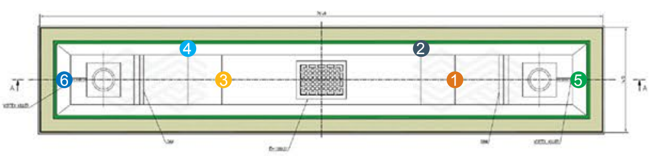
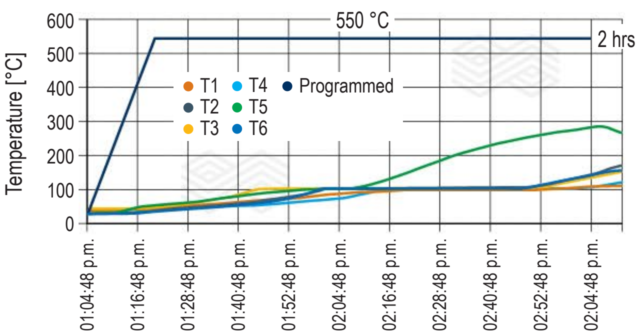


Figure 4.

Thermocouple (a) positions and (b) readings from one of the trial tundish linings. All of the thermocouples (T) reached temperatures above 100 °C within 2 hours, indicating that complete drying was achieved.



(a)



(b)

Trial Results—South America

In parallel to the trials in North America, trials in South America were also performed, but with a different objective. Instead of reducing the drying out time, the aim in this study was to take the tundish from the preparation area directly to the preheater, eliminating the dry-out process completely.

The first field trials have shown promising results. For example, a 50 mm lining thickness was applied and all equipment parameters including water settings were kept consistent with the settings used for standard slurry gunning material. The tundish bypassed the drying stage and was sent directly to the preheating station, then to the caster. Figure 6 shows pictures of the tundish after application, preheating, casting, and deskulling. No abnormal results were observed in these steps, such as cracks and spalling in the working lining or blackening of the permanent lining.

As shown in Figure 7, the temperature in all thermocouples was over 100 °C after 100 minutes of preheating, indicating that complete drying had been reached in the working lining within this time frame.

Figure 7.

Thermocouple (a) positions and (b) readings during the trial with direct preheating. All of the thermocouples (T) reached temperatures above 100 °C within 100 minutes.

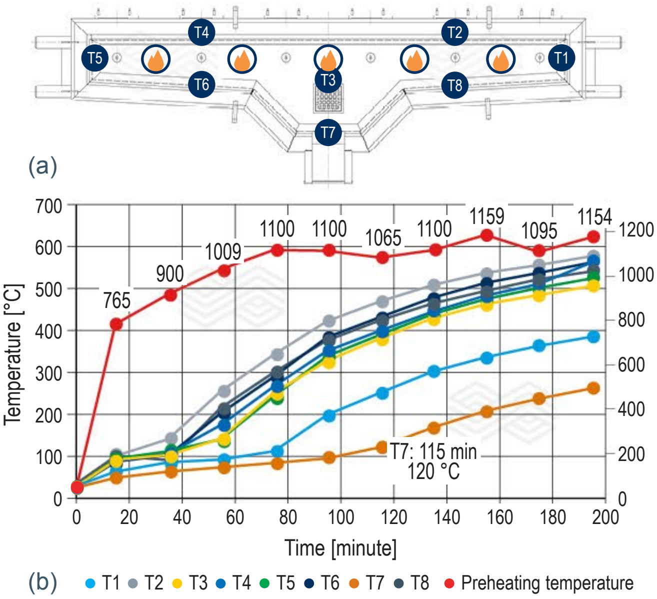


Figure 6.

Tundish after (a) application of the working lining, (b) preheating, (c) casting, and (d) deskulling.

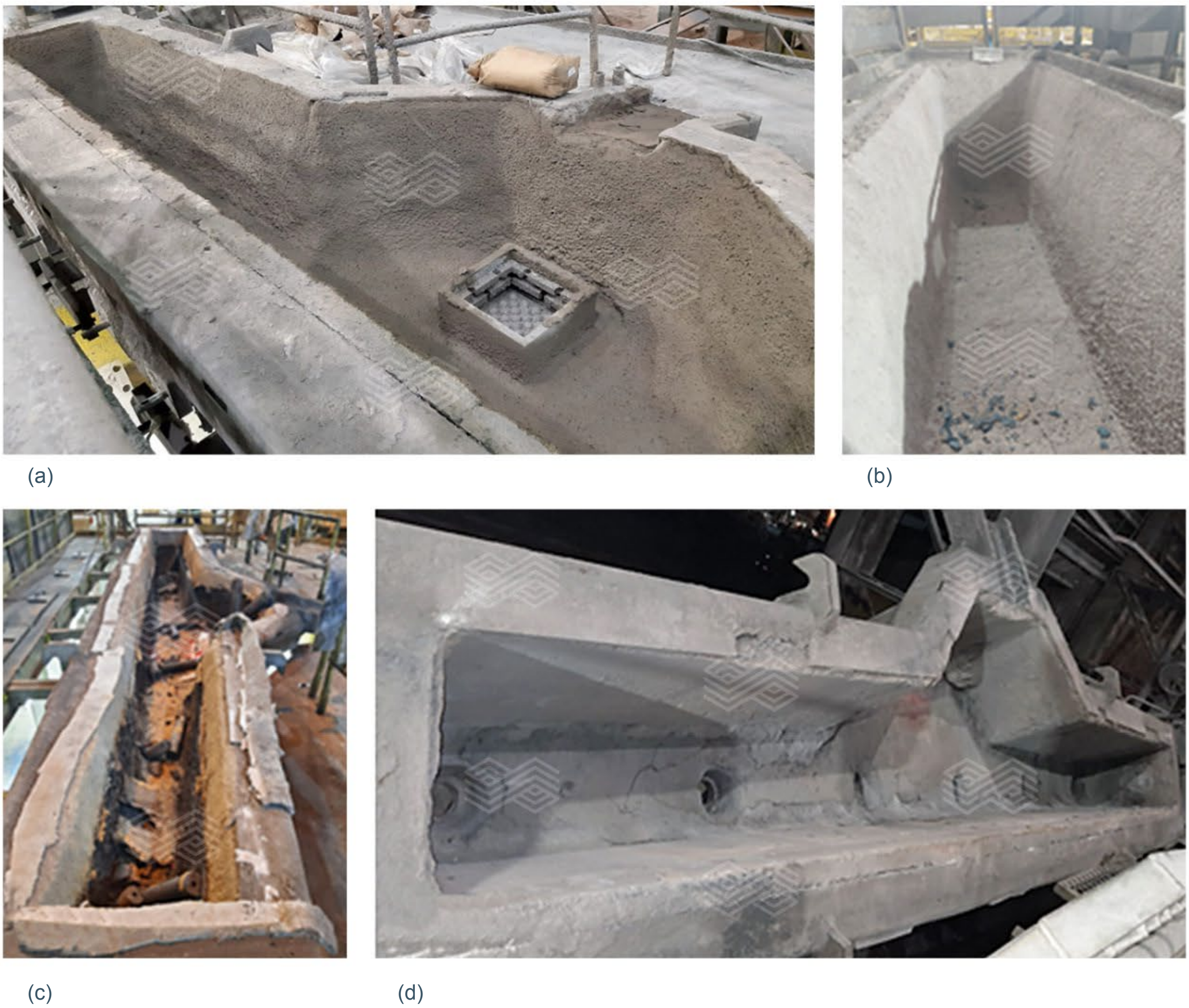


Table II.
Available FAST TO CAST grades and typical chemical compositions.

Brand Name	MgO [%]	Al_2O_3 [%]	SiO_2 [%]	CaO [%]	Fe_2O_3 [%]
ANKERTUN FTC11-BR	87.2	1.2	7.4	0.8	2.1
ANKERTUN FTC21-BR	74.8	1.4	19.5	0.7	2.3
ANKERTUN FTC10-MX	88.7	0.5	7.6	1.7	1.3
ANKERTUN FTC21-MX	79.8	0.5	13.9	1.7	2.1
ANKERTUN FTC24-MX	70.8	0.5	23.6	1.2	3.7

Current FAST TO CAST Product Portfolio

Following the successful field trials, the FAST TO CAST product portfolio detailed in Table II is now available.

Conclusion

As demand for efficiency in steelmaking operations continues to increase, the importance of equipment turnaround and availability is at an all-time high. For continuous casting, this means reliably having tundish vessels that perform well and are available quickly. Trials of FAST TO CAST grades in North and South America have produced results showing that the necessary drying time can be reduced by 70% or even eliminated completely, while energy requirements and CO_2 emissions from drying are also reduced accordingly. Additionally, the low density of these materials can decrease specific refractory consumption by an average of 20%, while also lowering heat transfer to the tundish shell. Furthermore, trial results showed that other important properties such as sprayability, refractoriness, and deskulling are unchanged as a result of the improved drying behaviour.

References

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