

Actual Trends for the Tundish Refractory Lining

P. Tassot, Ch. Turrel

The demand for cleaner steels increases every year. In addition to lowering non-metallic oxide inclusions and controlling their morphology, composition and size distribution, clean steel requires lowering other residual impurity elements such as sulphur, phosphorus, hydrogen, nitrogen and even carbon. As such, the tundish is a metallurgical reactor in which a series of operations occur that require chemical, thermal, and physical control. The tundish has a very important role with regard to steel cleanliness, thermal homogeneity and in providing stable operation.

Traditional lining for the tundish is the wet spray which has given very good service in the last years, and is still the most used method for this application. However, a continuing effort was expended to further reduce the amount of hydrogen picked up today and allowing higher productivity in the steelmaking process. In the continuous casting area, many parameters were investigated: preheat times and temperatures, curing and drying times, and types of working lining. Out of these investigations, alternative solutions to wet spray are developed, e.g. dry vibration mixes with and without resin, heat and cold setting.

1 Introduction

In continuous casting of steel, a tundish acts as an intermediate vessel between the ladle and mould. Considered originally as nothing more than a reservoir to hold sufficient liquid steel to permit a ladle exchange to ingot without interruption of sequence casting, the requirements for the tundish became more severe. The demand for cleaner steel increases every year. In addition to lowering non-metallic oxide inclusions and controlling their morphology, composition and size distribution, clean steel requires lowering other residual impurity elements such as sulphur, phosphorus, hydrogen, nitrogen and even carbon. As such, it is a metallurgical reactor in which a series of operations occur that require chemical, thermal, and physical control. The tundish has a very important role with regard to steel cleanliness, thermal homogeneity and providing stable operation.

The operation of a tundish needs to be geared to:

- Promote inclusion flotation by maximizing residence time
- Ensure inclusion assimilation by a captive and non-corrosive slag
- Prevent thermal and chemical losses from the melt
- Minimize short-circuiting and dead zones, and
- Offer the steelmaker an optimal design for quality and yield.

The insulation of the tundish is essential. High superheat above liquid temperatures will increase central segregation, affect grain size, and even produce breakouts owing to local solidified shell thinning of cast products, interrupting the continuous casting sequence. On the other hand, low superheat in the tundish will promote clogging of tundish nozzles, macro-inclusion entrapment, and will af-



Fig. 1 DVM installing device at ACERINOX

fect flux powder melting which increases the probability of melt sticker formation.

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Fig. 2 Electrical heater for hot setting DVM

Dry tundish working linings permit:

- A fast installation that can be performed by less manpower than other technologies [1]
- Latent heat of the backing lining to be applied for bond formation, in a nearly dust-free, ultra-fast installation without harmful organic fumes
- Steel cleanliness by a strong reduction of the hydrogen pick-up [2]
- Improvements in availability and costs:
 - Very long casting sequences (e.g.10 to 20)

- Very easy deskulling – installation
 - Equipment is nearly service-free, low cost
 - The amount of circulating tundishes can be reduced
 - Drying or pre-heating prior to steel casting may not be needed or very reduced.
- An additional advantage is the life of backing lining is prolonged due to smaller thermal shocks.

2 Industrial results DVM resin-bonded

The majority DVM is presently resin-bonded. Several thousand tons of magnesia based materials are produced annually in this way and installed with a simple steel mandrel or more sophisticated vibrating mould. The powder is stored in a hopper and can be delivered manually or through user-friendly devices that can save installation time like at ACERINOX (Fig. 1). The total installation time for a 30- to 40-t tundish is less than 1 h with two people. The drying time is less than 60 min at a temperature close to 350 °C.

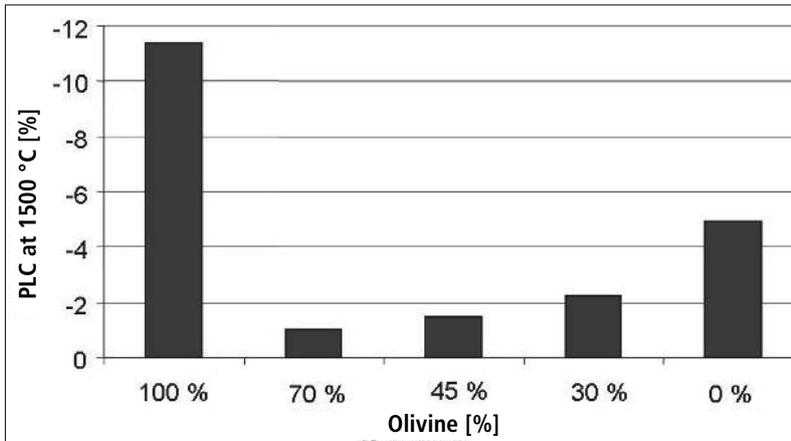


Fig. 3 Evolution of the post linear change vs. Olivine content in MgO based DVM

Tab. 1 Main properties of DVM

	Calde™ MAG DRY R 90	Calde™ MAG DRY R 80
MgO [%]	90,0	79,0
SiO ₂ [%]	3,0	12,6
CaO [%]	3,2	2,5
Fe ₂ O ₃ [%]	1,6	3,1
Material requirement [g/cm ³]	1,95	1,91
Maximum size [mm]	2	2
Cold crushing strength 200 °C [MPa]	1,8	1,8
Cold crushing strength 1000 °C [MPa]	0,5	0,5

This allows, the temperature inside of a 3 to 5 cm lining to reach the 180 °C, needed for the transformation of the resin. Different ways are possible:

- Hot air blower (gas):
 - Natural gas or LPG, must be controlled carefully, prone to hot and cold spots on mould
 - Low cost, easy to set up
- Electric (Fig. 2):
 - Low curing temperature due to direct heat up of mould / material interface, uniform heating avoids hot and cold spots
 - Use depends on local gas versus electricity price per unit.

Typical material properties are summarised in Tab. 1. In addition the financial advantage of Olivine (forsterite) addition, PLC values have been shown to be improved with the addition of this material resulting in lower crack formation during heat up (Fig. 3). Fig. 4 shows the easy deskulling of a tundish at TKS Terni with a DVM material. Some additional interesting co-induced advantages have also to be noted.

- While the dry system does not weaken with water, the safety lining service life has been increased significantly. Otherwise the increased wear resistance of the DVM allows a better protection of the safety lining. During the deskulling phase the safety lining is very stressed due to mechanical attack. With the residual thickness obtained with the DVM the deskulling becomes easy and following can be done without external engine.
- With an increased wear resistance, DVM allows a much better stabilisation of the steel temperature over time that also enables a temperature decrease up to 10 °C by tapping.
- The soft drying of the DVM for setting the resin enables a very sensible reduction in energy consumption close to 60 %, and a decreasing of the noise by 10 dB at continuous casting platform.

But one of the major advantages of the DVM is the reduced hydrogen pick-up at the start of the sequence casting.

3 New developments resin-free

In order to minimise the drawbacks of resin-bonded systems, both environmental aspects as regards health and safety or technical aspects (other organic products such as



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Fig. 4 Easy deskulling after cooling down

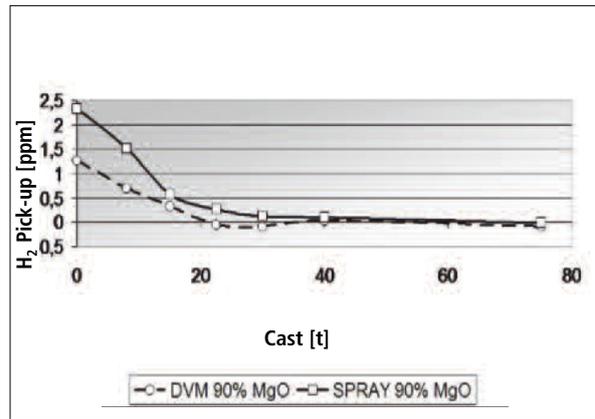


Fig. 5 Hydrogen pick-up in tundish with DVM and spray

waxes, oils and sugar compounds) have been used with some success, but these also release gases into the atmosphere which can be harmful to a greater or lesser extent. Although in most cases they are non-toxic, the odour can be powerful and unpleasant when significant quantities of product are heated.

A more promising development is the use of mineral bonds compatible with the magnesite matrix and using dry placement methods. These products have sufficient strength for handling and require little or no pre-heating for removal or stabilisation. In this publication they are referred to as MB-DVM, for Mineral Bonded Dry Vibrating Mix.

3.1 Technical specification

Magnesite matrix with a sizing chosen to:

- Avoid segregation
- Give good dry flow

- Enable rapid compaction with low energy
- Generate minimal dust.

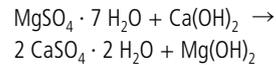
A bonding system designed to:

- Have stability in storage suitable for varying climatic conditions
- Use a hardening process to maximise use of the residual heat of the permanent lining, and thus permit limited or no use of additional heat for setting
- Avoid offensive or irritating odour
- Contain no low temperature residual fluxes.

3.2 Hot setting solution

The principle is based on the use of metallic salts which can react with basic powders such as calcium hydroxide to form gypsum type minerals over a wide range of temperature below 200 °C.

An example of typical reaction is given below with magnesium sulphate at a temperature between 80 and 200 °C depending on the activator level and type [4]:



The reactions are controlled not only by temperature but by other minerals called activators and inhibitors that can combine and be adjusted to postpone or activate the reaction.

The adjustable bonding behaviour of MB-DVM is illustrated in Fig. 6, which shows how the presence of activators and inhibitors allows to impart mechanical strength both in case of hot installation (using only residual heat of residual lining – case 2) or in cold condition (using any kind of heating equipment: case 1).

Generally a dwell time of 1 to 2 h at a minimum temperature of 120 °C will develop optimum strength.

After subsequent heating, remaining volatile elements (mainly water) are removed from MBS without producing a noxious, irritating or dangerous vapour. CALDE™MAG BDHD 8015 is the solution allowing the minimizing of the hydrogen pick-up at the start of the sequence.

3.3 Cold setting solution

The use of a mineral bond that hardens at cold temperature represents an original alternative to the resin-free newly developed DVM. This type of material does not require any heating to develop the sufficient strength for handling before preheating. The main advantage is an additional energy cost saving as gas or electric consumption for heating is not required.

The mineral binder in this case consists of an inorganic chemical reagent, which is hardened by mixing with a specific catalyst.

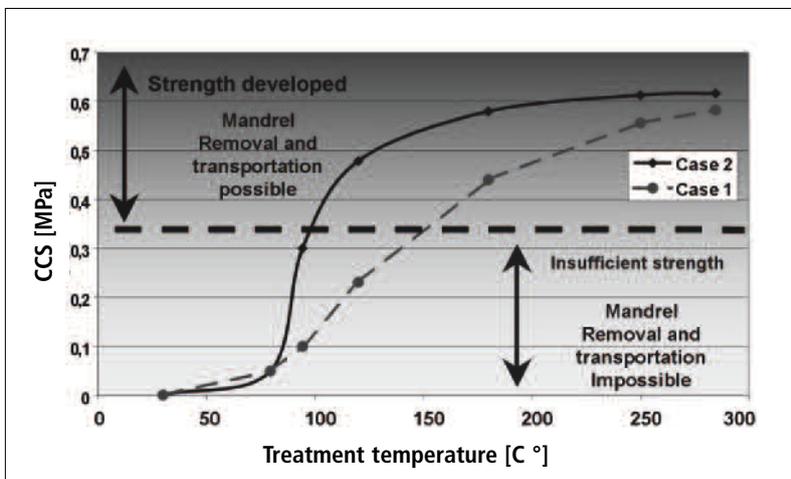


Fig. 6 Evolution of the strength in MB-DVM

Tab. 2 Main properties of DVM

Material properties	Temperature	Units	Spray	DVM hot setting resin-bonded	DVM hot setting resin-free	DVM cold setting resin-free
MgO		%	87	90	88	
SiO ₂		%	5,2	3	8,5	7
CaO		%	3,1	1,2	2,5	1,8
Fe ₂ O ₃		%	1,6	1,6	0,4	1,8
Water requirement		%	21	–	–	–
Material requirement		g/cm ³	1,7	1,95	1,9	1,77
Bulk density	150 °C	g/cm ³	1,51	1,92	1,8	1,60
Weight loss	150 °C	%	19	0,2	1	0,8
Weight loss	1000 °C	%	3,1	3	3,4	2,2
CCS	1000 °C	MPa	0,8	0,5	0,2	8
CCS	1500 °C	MPa	5	3	2	14
PLC	1000 °C	%	-0,5	0	0	-0,15
PLC	1500 °C	%	-2,2	-2,4	-2,2	-2,3

In practical terms, the binder is mixed at the same time with the accelerator and the matrix. The ratio accelerator/mineral bond, as well as the size distribution of the aggregate (mainly the fineness) are precisely adjusted to control the working time and the hardening time of the final mix.

To allow this accurate regulation of the bond and the accelerator, they must be added as chemicals in liquid solutions. A special automatic mixing facility is used that allows the distribution of the final mix into the tundish, without manual handling. The facilities main features are:

- A hopper equipped with an alveolar valve for regular distribution of the aggregate at the nozzle of a screw mixer where the binder and the accelerator are injected as well
- A conveyor belt with controlled speed
- A rotary axe between the conveyor belt discharge and the screw mixer, allowing movements in all directions to cover the geometry of the tundish
- A pumping system for the liquid, electronically controlled and adjusted at a central control panel.

The mixed material is then slightly and manually rammed (one person needed) as pouring goes along. Another standard solution consists of vibrating shortly. In this case only 1 operator is needed.

The flow rate usually varies from 30 to 60 kg/min. In these conditions, as an exam-

ple, the total installation time for a 30- to 40-t tundish is less than 45 min with 1 to 2 persons (Fig. 7).

As mentioned above, no heat is required during the hardening period and the formwork can be usually removed in less than 5 min after the end of the installation by hot tundish and 20 min in case of cold tundish (Fig. 8). The "green" mechanical strength is in this case a little higher than with the resin-bonded materials. This allows an easier de-moulding and transportation with the crane up to the caster. No dedicated specification for final preheating before cast are needed.

4 Main properties

The main properties are summarised in Tab. 2.

Pre-heating of the tundish contributes to the destruction of some hydrocarbon binder deeper in the lining, which will slowly release hydrogen that is picked up in the steel. Hydrogen control in steel is an important facet in the production of rail grade steels or pipes [5]. Notable sources for hydrogen are in alloy and lime additions, slag and furnace linings (resin or hydrocarbon binders).

The ladle treatment before casting in the tundish is not neutral and initiates 0,6 up to 1 ppm hydrogen pick-up. Fig. 9 shows the influence of the refractory lining on the hydrogen pick-up in the tundish for a DVM resin bonded. The first 40 t are very sensitive [6].



Fig. 7 Installation of the cold setting mix at GSW Santander

5 Conclusion

Alternative solutions to the wet spray gunning are available for the tundish insulating working lining.

The solutions primarily in use now are a range of resin-bonded materials with 50 to 90 % MgO. New developments in resin-free materials appear very promising. Alternative solutions for either hot or cold setting are also available.

One is now able to determine with the customer the optimal solution for his particular tundish.



Fig. 8 Installation of the cold setting mix at GSW Santander

As the wearing refractories can release hydrogen, control of the drying and heating process is recommended in order to guarantee total elimination of the H₂O/H₂ sources. Choosing a DVM is one possibility for reducing strongly the risk of hydrogen pick-up.

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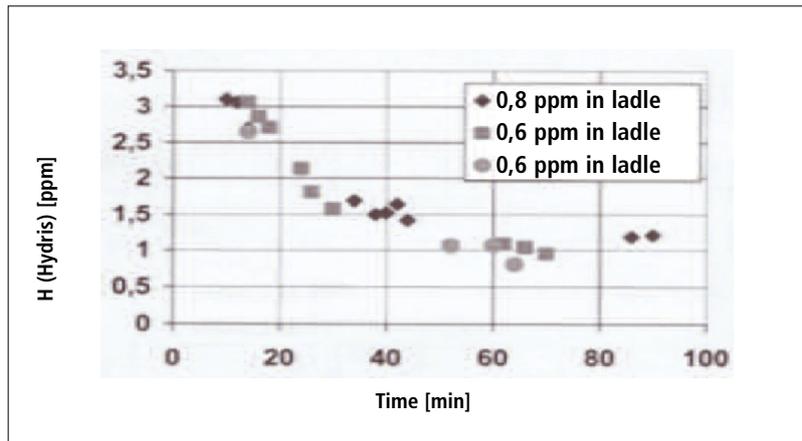


Fig. 9 Hydrogen pick-up in a new tundish (first ladle) after R. Hurst

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