www.czasopisma.pan.pl PAN www.journals.pan.pl

ARCHIVES
of
FOUNDRY ENGINEERING

ISSN (2299-2944)
Volume 21
Issue 2/2021

94 – 98

10.24425/afe.2021.136104

14/2

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

A New Technology of TRIAD Cement-Free Castables – Practical Aspects

B. Cygan [a, b], J. Dorula [c], J. Jezierski [a, *]
[a] Silesian University of Technology, Department of Foundry Engineering,
7 Towarowa, 44-100 Gliwice, Poland
[b] Teksid Iron Poland Sp. z o.o., 49 Ciężarowa, 43-430 Skoczów, Poland
[c] Vesuvius Poland Sp. z o.o. , Foundry Division - Biuro Handlowe, Portowa Business Center,
8 Portowa, 44-100 Gliwice, Poland
* Corresponding author. E-mail address: jan.jezierski@polsl.pl

Received 09.04.2021; accepted in revised form 07.06.2021

Abstract

The article presents the new technology of the refractory materials used for the ladles and pouring devices. The aim for solving the majority of the problems that originated from the refractory lining was to develop the group of cement-free TRIAD products by Vesuvius company. The cement-free setting system in the TRIAD products eliminates calcium oxide (CaO) that occurs in low and extra low cement concretes resulting in its higher strength at higher temperatures. The features of the new cement-free castables were described. One of the most unique features of this technology is the porous material structure. Small venting microchannels are formed during the concrete setting process. These micro-channels allow for removing water vapor from the lining without affecting its refractory properties. On the other hand, the diameter of pores is so low that it disallows the penetration of slag and metal into the lining, extends its operating life at the same time facilitates cleaning and removing build-ups. The procedure of the preparation of these materials, as well as the method of building of the lining, were presented. An example of the practical use of these materials in the ductile cast iron foundry was presented, showing the advantages of the new refractory materials over the traditional ones.

Keywords: Cement-free concrete, Refractory lining, Pouring ladle, Pouring device, Cast iron

1. Introduction

The history of refractory high-alumina cement concretes began almost 80 years ago. The beginnings of this technology are linked with high-cement materials applied traditionally. Another big step forward in developing the technology of refractory linings for furnaces and ladles was the use of low-cement refractory concretes. The development was possible thanks to the versatility of high alumina cement that primarily promoted the monolithic properties of those materials [1,2].

The use of CAC (Calcium Aluminate Cement) monolithic materials forces us to use special technologies and observe appropriate steps including mixing, pouring, and setting the materials as well as the process of dry-out and curing (heating). Each of the steps is associated with the process of high alumina cement hydration. As the monolithic refractory material needs to be heated up to the working temperature, the water previously required for hydration and forming hydrates is removed. The strength at high temperatures is achieved via synthesis and ceramic bonds. Special care should be taken during initial drying so as not to change the parameters of concrete installed and to avoid cracks and explosions [2]. To reduce these problems in the refractory industry, for the recent twenty years researchers have been conducted to obtain concretes with as low cement content as possible. The physical properties of refractory compounds have been largely improved by reducing cement content and decreasing the addition of water. However, the development makes such a lining more difficult to apply and dry.

The aim for solving the majority of the problems was to develop the group of cement-free TRIAD products by Vesuvius company. The cement-free setting system in the TRIAD products eliminates calcium oxide (CaO) that occurs in low and extra low cement concretes resulting in its higher strength at higher temperatures. Under industrial conditions, it is hard to control the chemical phenomena that occur in the chemistry of cement. Slight changes in parameters during preparation, mixing and the drying process of high alumina cement monolithic refractory linings resulted in an unstable lining behavior. By contrast, the technology of cement-free TRIAD castables aims to eliminate the problems in the repeatability and the life of refractory lining [3].

2. TRIAD technology features

One of the most unique features of TRIAD technology is the porous material structure. Small venting microchannels are formed during the concrete setting process. These microchannels allow for removing water vapor from the lining without affecting its refractory properties. On the other hand, the diameter of pores is so low that it disallows the penetration of slag and metal into the lining, extends its operating life at the same time facilitates cleaning and removing build-ups.

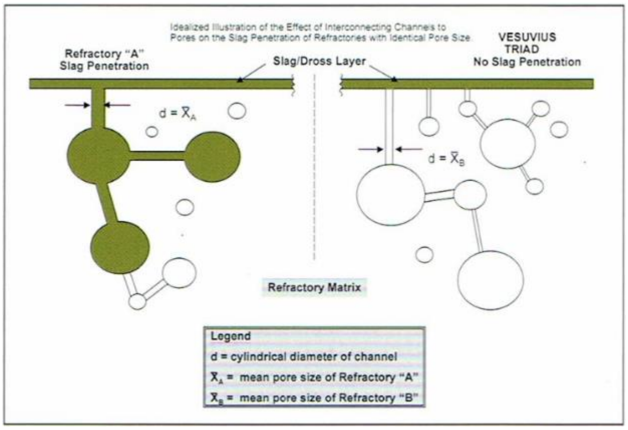

Fig. 1. Comparison of the porous structure of a TRIAD group castable to a conventional low-cement refractory material [3]

Comparison of the porous structure of TRIAD group castables to a conventional low-cement refractory material is presented in Fig.1. The low diameter of pores makes it impossible for the slag and metal to move into the lining, and it extends its life, facilitates cleaning and removing build-ups.

One of the basic methods for assessing the flexural strength and modulus of elasticity is the 3-point bending test (Modulus of Rupture = MOR). The flexural strength specifies the largest stresses within the material at the moment of rupture. Therefore, the 3-point bending test is one of the standard tests for refractory materials, and the values obtained during the test are recorded in the datasheets of each refractory material [1,3]. Figure 2 presents a comparison of TRIAD 85 castable and its equivalent in the form of Low-Cement Castable (LCC) containing 85% Al2O3, The higher strength of LCC at 110°C results from cement setting force in the hydrated phase. As temperature rises to 800°C the cement dehydrates, and the system strength comes from tightly packed grains typical for low-cement systems. This strength reaches its peak at approx. 1,400°C, were some ceramic bonds begin to act. At 1,600°C the strength decreases due to the presence of liquid phase created while reaching the fire-resistance limit. The flexural strength of TRIAD 85 castable reaches its peak at 1,100°C and remains higher than LCC at temperatures ranging from 1,100°C to 1,600°C. The results translate into a better behavior of the whole lining at a working temperature.

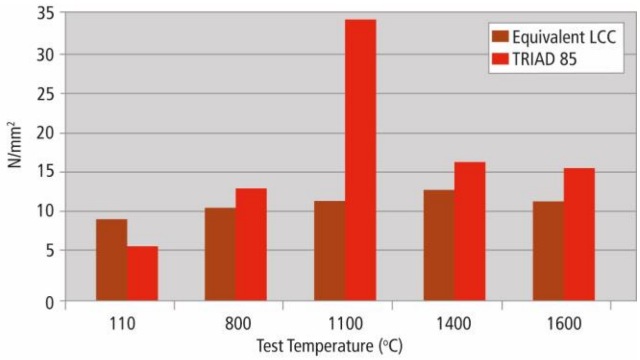

Fig. 2. Comparison of test results for a 3-point bending test: TRIAD 85 vs. LCC [1]

Another standard test conducted for refractory materials includes a compressive strength test. Figure 3 compares TRIAD 60 castable and its counterpart LCC containing 60% Al_2O_3. The presented comparison shows that the strength of TRIAD castable is much better at the range of working temperatures than its equivalent in the form of LCC.

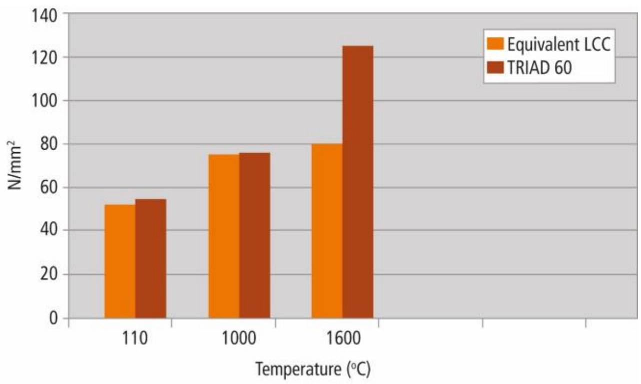

Fig. 3. Compressive strength: TRIAD 60 vs. LCC (60% Al_2O_3) [1]

The refractory materials that contain cement need a sufficiently long time to complete the reactions involving water and cement before the dry-out process begins. It usually takes from 18 to 24 hours. If we start curing (heating) the lining before the processes are completed, it will significantly impair the mechanical properties of the refractory lining. The cement-free technology makes it possible to significantly reduce the dry-out and curing cycle of the refractory lining. The dry-out cycle begins instantly after removing the former, which reduces the whole installation time. Figure 4 presents a comparison for typical dry-out and curing curves for low-cement concretes and the TRIAD technology.

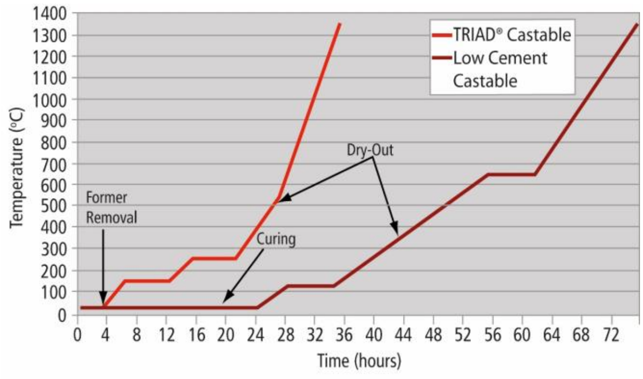

Fig. 4. Typical dry-out and curing diagram [1]

The above-mentioned technological and practical aspects induced to the installation of a monolithic lining made of TRIAD cement-free castable in a pouring furnace operating on the molding line for ductile cast iron production in the Teksid Iron Poland plant, Skoczów, Poland. The conducted chemical analysis of slag (see Table 1) coming from the pouring furnace showed a very aggressive environment for refractory materials SI = 0.60 (SI – Slag Index calculated using the following formula: ([MgO]+[CaO]+[Fe_2O_3]+[MnO])/([Al_2O_3]+[SiO_2]).

Table 1.
Results of slag chemical analysis

Chemical analysis	Treatment ladle	Pouring box
SiO_2	37.73	43.11
Al_2O_3	12.74	19.18
TiO_2	0.26	0.47
Fe_2O_3	16.49	14.36
CaO	11.29	7.49
MgO	18.73	13.35
K_2O	0.09	0.08
Na_2O	0.19	0.18
Cr_2O_3	0.05	0.06
P_2O_5	0.01	0.03
BaO	0.10	0.10
Zn	0.62	0.55
MnO	2.91	2.44
Slag index*	0.98	0.60
	acidic	acidic
Slag index is calculated using the following formula ([MgO]+[CaO]+[Fe_2O_3]+[MnO])/([Al_2O_3]+[SiO_2])		

a)

b)

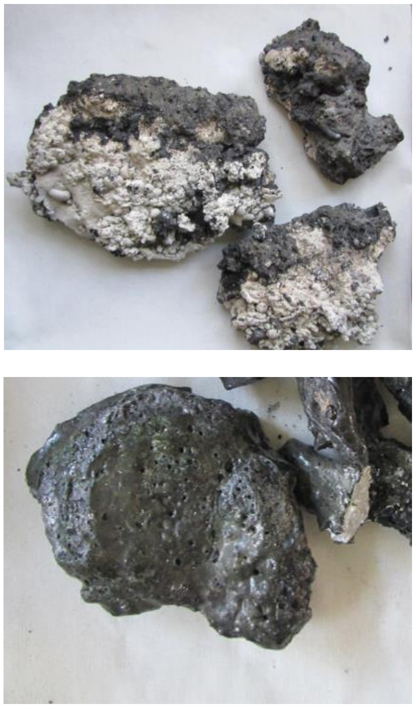

Fig.5. Samples of slag collected in the R&D Department of Vesuvius Poland Sp. z o. o., Skawina a) come from a process ladle b) come from a pouring furnace

3. The tests under the foundry conditions

The frequent changes of cast iron grades make it necessary to empty the pouring furnace regularly, leads to variable pouring temperatures, require various processes (Sandwich, In-mold), which eventually forces us to search for higher quality concretes/castables allowing us to limit line downtimes caused by pouring furnace replacements. This constitutes a serious challenge both for manufacturers of such materials and foundries being heavily interested in extending the life of linings. It is worth noting that taking care of the molten metal surface (liquid metal surface) makes also it a very important stage of the operation. It includes thoroughly removing slag both at the deslagging stand and in the pouring furnace.
Pouring furnace used at TEKSID Iron Poland Sp. z o.o. (Fig. 6.) is a gravity type of pouring furnace.

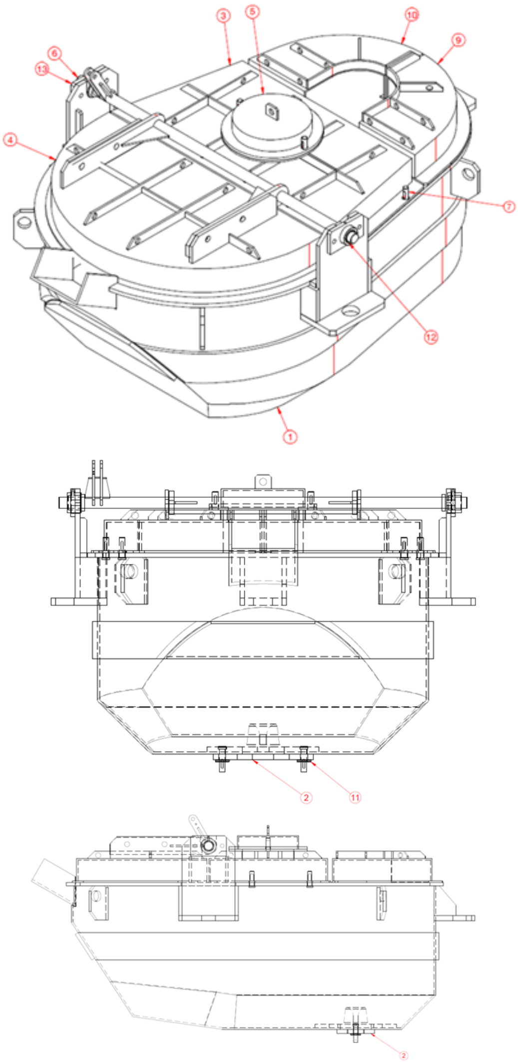

Fig. 6. Pouring furnace overview; 1 – main vessel, 2 – nozzle plate, 3 – cover - solid part, 4 – cover - movable part, 5 – burner cover, 6 – cover opening arm, 7 – vessel stopper, 9 – right half-cover, 10 – left half-cover. 11 – insert, 12 – washer, 13 – bushing bracket

The pouring furnace chosen for tests works under relatively variable and extremely harsh conditions. It is used to fill molds for both ductile cast iron (Sandwich process) and gray cast iron (output cast iron for In-mold process). The pouring furnace works in a three-shift system, six days a week. After this period, it is subject to a periodic overhaul. A distinctive feature of such devices is the variable metal level during their operation (during the mold pouring process). The variable level results from the periodic adding/replenishing of molten metal, i.e. refreshing metal with a new cast iron portion delivered to the pouring furnace (usually every 5 – 12 min.). In some ways, this operation affects "the natural zone of aggressive slag impact" on the lining, which is shown in Figure 7.

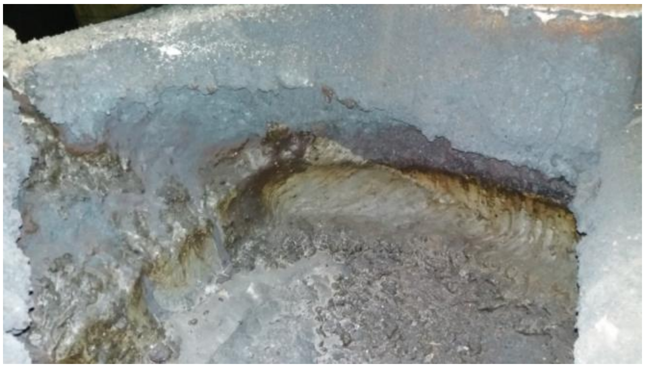

Fig. 7. An example of "the natural zone of aggressive slag impact" (traditional refractory lining)

At stage one, after thorough removal of the used lining, the pouring furnace was fitted with refractory lining by using materials supplied by the FOSECO company (Vesuvius Group). As already mentioned, the quality of lining (in addition to material advantages), depends greatly on observing strictly the manufacturer's instructions. A few relevant stages (it is not possible to present the full overhaul documentation) of the lining replacement process are presented in Figure 8.

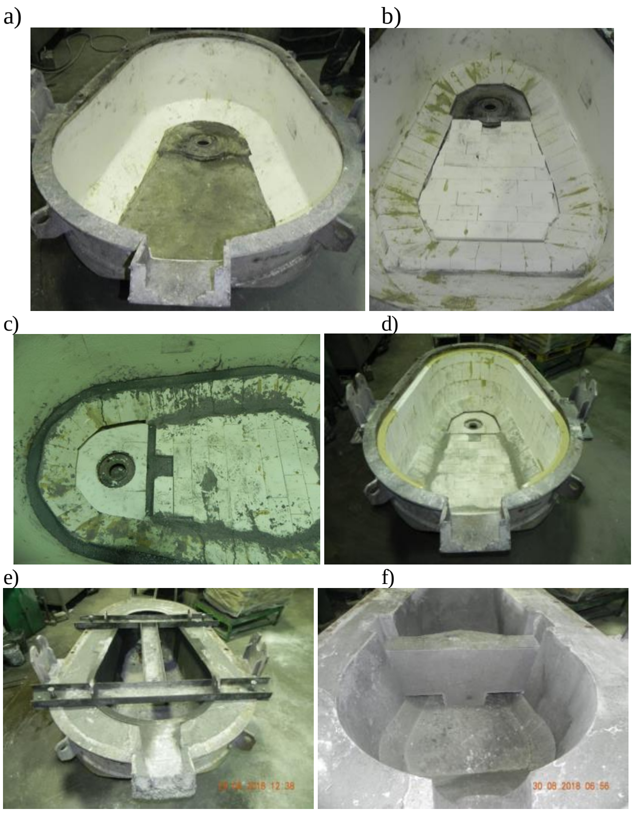

Fig. 8. The stages of pouring furnace lining installation: a) applying insulation, b) lining installation on the ladle bottom, c) filling the gaps using Triad compound, d) lining installation on the whole ladle surface, e) pouring the ladle walls with Triad liquid compound, f) ready to use ladle after removing formers [4]

Subsequently, the process of dry-out and curing was conducted as instructed by a specialist from FOSECO Another step was the commissioning stage. After the one-week operation, the pouring furnace was subject to analysis for lining wear (especially in susceptible areas). Photo documentation was conducted to cover each stage to show the wear of the lining and its repairs. Subsequent stages were carried out the same way with providing full photo documentation showing the lining condition.

After four weeks of operation, the refractory material was removed from the pouring furnace. The tests performed under production conditions at Teksid Iron Poland Foundry confirmed the rightness of using such castables for (gravity type) pouring furnaces. A certain extension of lining life has been obtained, which provides some profits considering the extension of overhaul periods. By contrast, the observations conducted during the tests indicated the need to search for new solutions to extend the lining resistance to harmful slag impact, especially in susceptible areas.

Another big challenge for foundries using this type of pouring furnaces and for the refractory manufacturers is and, probably will be, to develop a refractory material composition being more resistant to the harmful slag impact.

4. Conclusions

Summing up, the tests of applying the new generation castables performed under production conditions at TEKSID Iron Poland Sp. z o.o. Foundry confirmed their suitability for the purpose, which showed that the material could be an interesting solution for such pouring furnaces.

Acknowledgments

Financed by the Ministry of Science and Higher Education under the agreement No. 12/DW/2017/01/1 dated on 07.11.2017 r. on the amount of 4 433 520,00 Polish zloty.

References

[1] Drevin, J. (2014). Triad – a new range of user-friendly, high-strength refractory concretes. *Przegląd Odlewnictwa*. 9-10, 390-393. (in Polish).

[2] Rybak, M. (2011). Influence of alumina cement hydration conditions on concrete properties. *Piece Przemysłowe & Kotły*. 1, 21-25. (in Polish).

[3] Drevin J. (2011). Triad – Triad high-performance castable linings. *Foundry Practice*. 253(6) 16-20.

[4] Cygan B., Dorula J., Jezierski J. (2018). TRIAD - modern technology of non-cement concrete in cast iron foundry. In Congress Proceedings of the 73rd World Foundry Congress "Creative Foundry", 23rd–27th September 2018 (pp. 561-562). Krakow, Poland: Polish Foundrymen's Association.