Journal of Mining and Metallurgy, 39 (3‡4) B (2003) 475-488

INFLUENCE OF THE CORDIERITE LINING ON THE LOST FOAM CASTING PROCESS

Lj. Trumbulović[1], Z. Gulišija [2], Z. Aćimović-Pavlović[3], Lj. Andrić[2]

1 High Technical School - Užice
2 Institute for Technology of Nuclear and Other Mineral Raw Materials- Belgrade
3 Faculty of Technology and Metallurgy-Belgrade

(Received ; accepted)

Abstract

This paper discuss the influence of the refractory cordierite lining on the structure and mechanical properties of Al-Si and Al-Cu casings obtained from the Lost foam casting process. So far there has not been any report of the research on cordierite lining in the literature and moreover the cordierite ceramics have never been used in foundries.

In the light of these facts, this paper investigates the possibility of using cordierite for manufacturing evaporable model refractory linigs. Our results indicate that the application of cordierite ceramics is comparable to talc-based refractory linings in both Al-Cu and Al-Si castings, while cordierites are favourable in Al-Cu case due to their higher melting temperature.

Keywords: cordierite lining, Lost foam casting process, quality casting, talc

1.Introduction

For casting by means of the Lost foam casting process, the moulds with unbounded sand are used. The models and gating systems are produced manually or industrially from expanded polystyrene and thay are not taken out from the moulds before the castings (fig.1.).

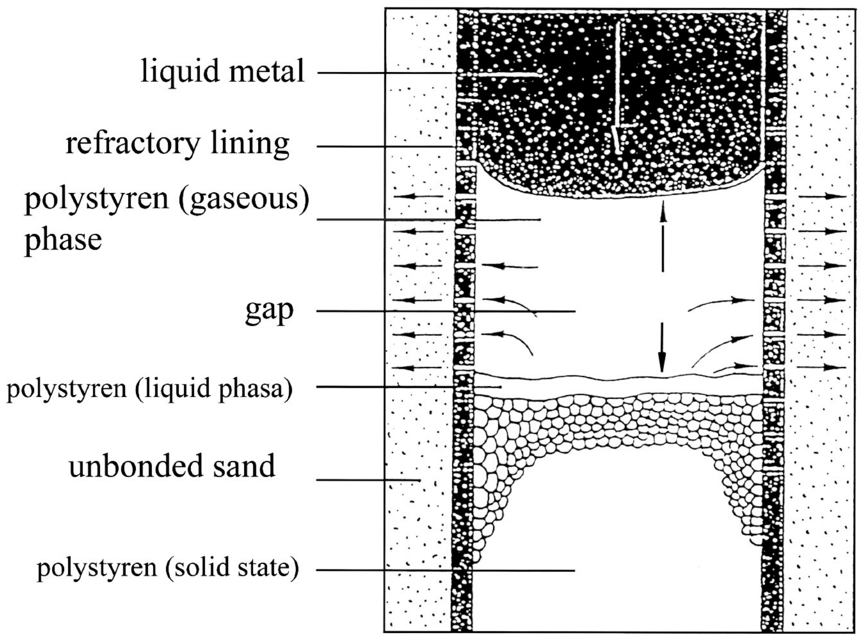

Figure 1. The Lost foam process

In the phase of pouring of liquid metal, the solid expanded polystyrene model with the chemical formula $(C_8H_8)_n$ and mollecular mass of 300000 passes through the decomposing process were the liquid and gas products are formed. At the same time, the process of castings formation and solidification is in progress. The decomposing process is endothermal so that the solidification of the casting in the „full mould%is performed under the undercooling conditions [1-7].

The liquid metal casting velocity during the pouring into the „full mould‰ compared to the casting velocity during the pouring into the sand mould is lower and is limited by the decomposing and evaporation speed of the model. The pouring temperature is the primary factor of the influence on the decomposing speed of the model. The higher temperatures increase the decomposing speed of the model as well as the speed of gas and liquid formation, and the pressure increase in metal. The pouring temperature has to be determined in correlation with the type of polymer out of which the model is made, primarily by comparing the model density [8-9].

In addition to the pouring temperature and model density, significant factor influencing casting quality are the type and thickness of the model refractory lining (fig. 2, 3), sand permeability for mould making as well as casting and pouring · system construction. To obtained positive effects in the process, these paramters have to be determined in advance for each exact casting and demands lengthy research [7, 10-16].

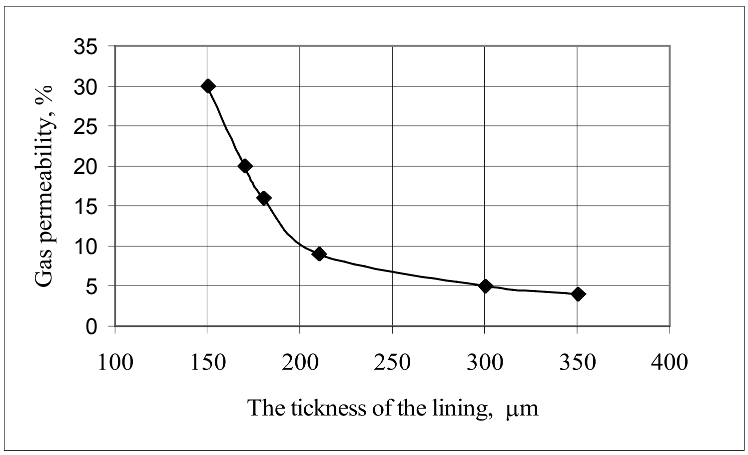

Figure 2. Dependence of the gas permeability on the thickness of the lining [7]

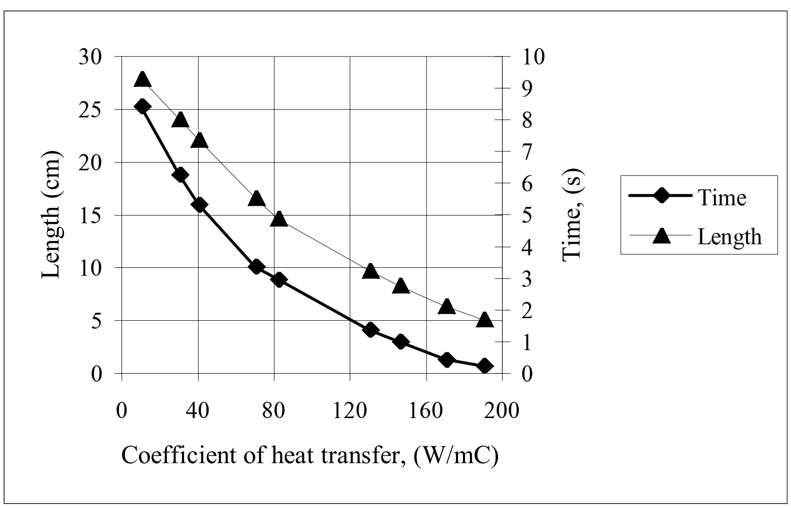

Figure 3. The effect of the insulating lining on the metal flow and the time of the pouring, [7]

1.1. General Aspect of the refractory lining

Model refractory lining have to satisfy a number of specific demands for the Lost foam process:

- coresponding refractoriness of the linings,
- permeability should be compatible to that of sand which is used for mould making: highly permeable lining is used for rougher sand and medium and low permeable lining for finer sand,
- there should be a possibility of controlling and adjusting lining layer thickness,
- quick drying,
- dried layer should be visible on the model,
- lining should easily stick to the model,
- appropriate strength, resistance to abrasion, resistance to cracks during storage, resistance to bending and deformation during mould · making,
- if rougher sand is used for mould-making and a high casting temperature, then the refractory lining layer should be thicker [16-18].

Refractory linings, depending on the purpose, represent complex mixtures of over fifteen components. The four basic components are refractory powder, liquid carrier or solvent, binders and agents for maintaining suspension. On the market, the linings are delivered under commercial names and their composition and manufacturing technology are well-kept business secret. There are various types of linings, especially made satisfy numerous requirements of different casting procedures, type of material cast and casting configuration. However, these is a permanent need for further research in order to achive a choice of optimal type and lining thickness for materials and configuration of the castings obtained by the Lost foam process.

1.2. Cordierite and talc

Cordierite is classified as a special ceramic insulating material. It is a finely porous material, composed of oxides MgO, Al_2O_3 and SiO_2. Cordierite as a mineral $2MgO \cdot 2Al_2O_3 \cdot 5SiO_2$ is very rarely found in nature so it is generally obtained synthetically for industrial needs. Synthesis of cordierite can be obtained directly from oxides MgO, Al_2O_3, SiO_2 or from natural raw materials which carriers of these oxides. For these purposes, raw materials such as kaolin, talc and technical clay material are used. Cordierite melts at temperatures 1460-1550^{0}C. Cordierite masses have a short baking interval and this is on of the basic problems in the production of cordierite ceramics. If baking is performed below the optimal temperature, a sufficient quantity of cordierite will not be formed, and if it is performed above the optimal baking temperature, part of the formed cordierite will be decomposed to mulite and metasilicate of magnesium. In both cases, this will have negative effects on the technical characteristics of cordierite [19-21].Đ

In the aim of expanding the interval of the synthesis condition and improving a number of properties within these experiments, an additive for the cordierite mixture was used- feldspar in the amount 5% [8].

In the way, the interval of the synthesis condition was expanded to 40-60^{0}C. The widespread application of cordierite ceramics is a result of, firstly due to its properties- low inductive capacity, low thermal expansion coefficient, high resistance to thermal shock and good mechanical properties. Cordierite ceramic belongs to the group of materials which has a very low thermal expansion coefficient, thermal stability and is used as an insulating element and detail in electrothcermics [20-21].

Talc is a magnesium hydrosilicate of which the general formula can be show as $H_2Mg_2(SiO_3)_4$ or $Mg_6(OH)_4(Si_8O_{20})$ with Al_2O_3, FeO, NiO, CaO as impurities. Hardness according to the Mohs scale is 1, and density is 2,6-2,8 g/cm^3. Talc is used in many industrial branches due to its properties of low hardness, sticking ability (surface lining), high melting point, chemical inertness, low electrical conductivity, distinct capability to absorb greases, dyes, resins and low hydroscopicity [10].

2. Experimental

Several cordierite masses have been researched for the production of linings of polystyrene models (table 1.). Optimal results were obtained by the sample 1 (designation of the lining: C).

Table 1. Receptures for cordierite mixtures (mass. %)

Sample	Clay	Talc	Alumina	Dunite	Feldspar
1	24	47	24	-	5
2	81	-	-	19	-
3	79	21	-	-	-

Lining C was production with the following composition:
- cordierite · based refractory powder with a particle size of 40 μm and 90 mass %,
- suspension maintenance agent, carboxymethilcellulose up to 0,5%,
- binding agent, bentonite, max. 1 mass %,
- $Na_3P_3O_{10}$ 1-2 mass %,
- liquid carrier, water up to suspension density of 2 g/cm^3.

A small amount of binding agent was used in the lining since clay replaced the role of the binding agent from the cordierite mass content.

For comparative examinations, a talc-based lining was used (designation: T) with the fallowing composition:
- refractory powder · talc showing up to 88 mass %, with a particle size 40 μm,
- binder : bentonite 3 mass %,
- Bindal H: 8 mass %,
- dextrine: 0,5 mass % lucel 0,5 mass %,
- liquid carrier: water , up to the necessary density of 2 g/cm^3.

The linings were applied by dipping and overflowing. Lining „clusters‰ were dried at ambient temperature for 24 hours. After drying, casting was performed by the Lost foam process and testing of the casting quality. Test casting with alloys Al-Si was performed at a casting temperature of 720 ^{0}C, as well as with Cu-Al alloy at a casting temperature of 1200 ^{0}C.

3. Results and discussion

The chemical composition of lining C and T is presented in table 2.

Table 2. Chemical composition of lining C and T, mass %

Designation	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO
C	46,2	28,0	2,4	6,18	15
T	60,86	4,11	1,28	1,07	3,1

The test results C and T suspension preparations on the polarizing microscope are shown in fig.4 and fig. 5.

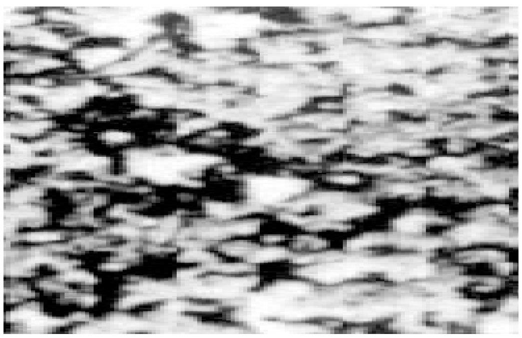

Figure 4. Microphotograph of C suspension

Figure 5. Microphotograph of T suspension

In the suspension of the ceramic lining C, the presence of tiny irregular cordieritescales, linked with binder, and uniformely distributed in solvent, is shown. Observing the the prepared lining suspension talc basis, tiny, irregular scales of talc and chlorite, whose dimensions were rarely exceeding 20 μm, were noticed. The scales were rather homogenousy distributed in the lining mass and linked by hexametaphosphate.

Homogeneity of the refractory filler distribution in the lining suspension depends on suspension preparation in the course of lining application. It is necessary to provide continuous slow mixing, keeping defined density ($2 g/cm^3$) and temperature ($20\text{-}22^0C$). The obtained linings, C and T, did not crack, not scale or wipe off. After casting and shaking casting out of the mould, the lining was easily removed from the casting surface.

Analysis of microphotographs obtained by electronic microscopy, shows that sample C contains the mixture of big and small particles and fine pores.

Surface morphology changes are not visible, however, with higher magnification, porous appearance is visible on the sample surface (fig.6). Talc particles are of uniform size and similar morphology (fig. 7.). From the aspect of ceramic powders used as refractory fillers, grain size difference is favourable. Particles of different grain size contribute to better uniform, continuos lining on the pattern, due to better correspodence between the particles.

Figure 6. SEM photograph of sample C

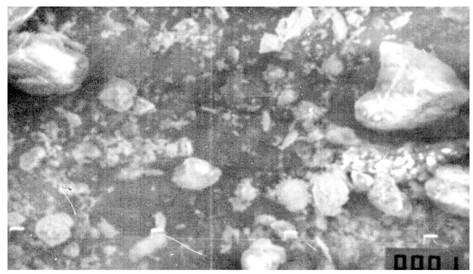

Figure 7. SEM photograph of sample T

An x-ray diffractogram of a cordierite mixture (composition 1, table 1.) used for making refractory lining shows presence of glassy phase with dominant role of cordierite (fig.8). A small quantity of spinel and feldspar was detected in the structure.

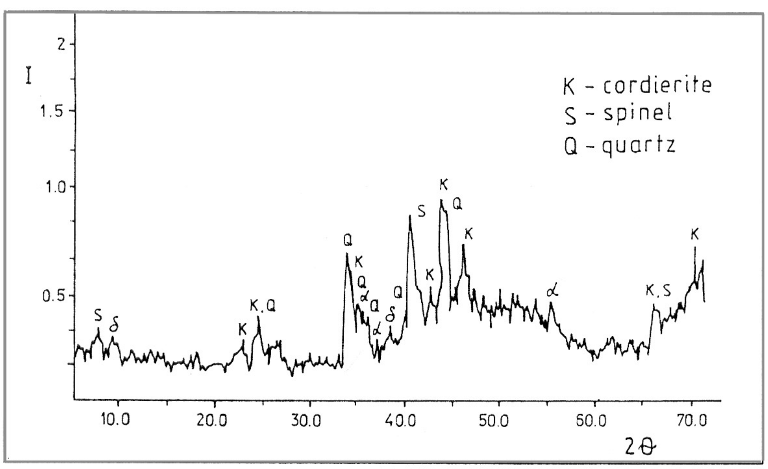

Figure 8. Roendgenogram of lining C suspension

In order to determine the temperature at which components react with each other, an investigation of cordierite using a heating microscope was performed. The results of the study showed that no changes occur up to 900^{0}C, slight shrinking begins at 1020^{0}C and expansion begins at 1300^{0}C, rounding at 1320^{0}C, melting and running at temperatures between at 1360-1370^{0}C. Thus, a firing range for obtaining cordierite for making linings has been established.

An x-ray diffractogram of lining suspension T (fig.9) showed dominant presence of talc.

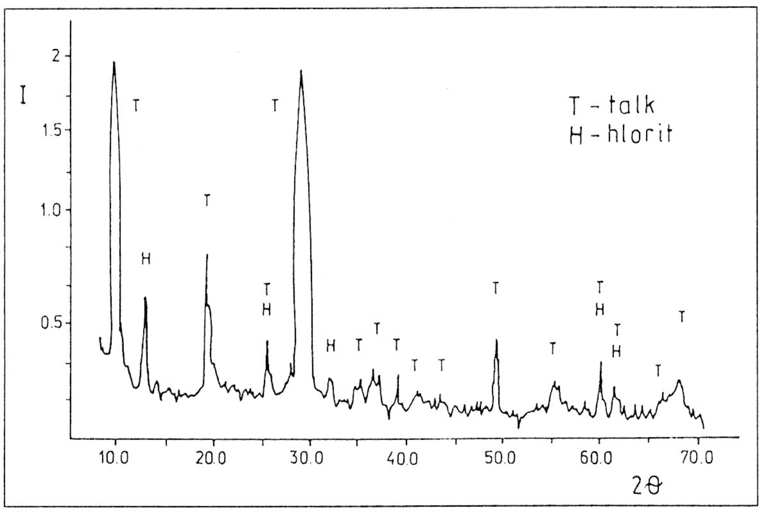

Figure 9. Roendgenogram of lining T suspension

After de-moulding, it was concluded that the casting were exact copies of the model and that no penetration and sintering of the lining with sand and casting occurred. The lining was easily removed from the casting surface, therefore no additional fettling of the model was necessary. This contributes to a decrease in production costs as the fettling of castings is an expensive foundry operation. The surfaces of castings cast using linings **C** and **T** were smooth and clean. Layer thickness varied from 0,2-0,7 mm. On examining the structural and mechanical properties of the obtained castings, it was concluded that there were no significant differences between the samples cast with linings C and T.

Mechanical properties of castings (tensile strength, hardness) were within the limits prescribed by the standard for this type of alloy. Almost identical structures of the obtained castings point out that C and T linings had no different influences to the crysallization process. Measurements of the geometrical parameters of the lining structure showed that the applied C and T linings influenced the decrease of structure dispersity. The expected effect of undrecooling due to endothermal process of model decomposition was not observed. In actual fact, it can be concluded that linings C and T showed insulation effects which was a reason for the decreased dispersity of lining structure.

4. Conclusion

Investigation of refractory linings based on cordierite and talc suspension show positive results when making linings of Al-Si and Al-Cu alloys by means of the Lost foam casting process. Cordierite can be sintered easily, raw materials for its synthesis are available and inexpensive. The characteristic of cordierite to show low coefficient of thermal expansion makes it interesting for study and application in ceramic linings because of reduced risk from lining cracking at temperature changes during the process of liquid metal pouring. As cordierite also has high refractory properties, its application should be extended to casting alloys with melting temperatures below 1200^0C. Development of cordierite based ceramic lining can contribute to development of the Lost foam casting process, as well as to its application in castings from a larger number of metals and alloys. Further research in this field should be directed to studying modification process in order to moderate the insulating effect of ceramic lining, which causes grain growth in the structure.

Acknowledgments

Results presented in this paper are a part of the investigation on the Project MHT.2.06.0051.B/1: „Development and production of novel materials for application in metallurgy, civil engineering and mechanical machine industry‰ This project has been financed by the Ministry of science, technology and development of Serbia. Research is organized and performed by Faculty of Technology and Metallurgy-Belgrade and Institute for Technology of Nuclear and Other Mineral Raw Materials-Belgrade.

References

1. Raymond W. Monroe: Expandable Pattern Casting, AFS, Inc. (1994),USA, pp.30-60
2. Z.Aćimović, S.Tripković,M.Duričić, Lj. Trumbulović, A. Ćitić: Internat. Congress MET-97, Sofia, Proceedings 3(1997)12,42-47
3. Cho Nam Don, Korea: 56 Gisserei Weltkongress, Dusseldorf, 7.1-7.10, May 1989
4. Rong Shean Yang, His-Chien Hsiao: *Transact. of Japan Foundry Eng. Soc*. 14(1995)10-17
5. H. Tsai, T. S. Chen: Modeling of EPC · Metal flow and heat transfer during the filling stage, Hartford, USA (1998).
6. Z.Aćimović: EPC Method, Monograph, Faculty of Technol. and Metallurg. , Belgrade (2000)
7. Z. Aćimović, M. Tomović, Z. Gulišija, S. Tomović: Bulletin of the Chem. and Technolog. of Macedonia, 14 (1995),12, 101-105.
8. Z.Aćimović, Lj.Pavlović, M.Đuričić,S.Tripković: Interceram, 6, (2001), 345-350.
9. Z.Aćimović, Lj.Pavlović, M. Stamatović, Z. Janjušević :Science of Sintering, 32(3),179-186(2000).
10. Lj. Trumbulović, Z. Aćimović, S. Marković, Lj. Pavlović: XXX October Conf. , Proceedings II, 423-426, Bor (1998)(in Serbian).
11. D.K.Agromal, *J. Am. Ceram. Soc.* 69(1986)847
12. S. Milošević, Lj. Pavlović: Domestics Nonmetallic Mineral Raw Materials for Commercial Use, ITNMS, Belgrade (!998), 10-58 (in Serbian)
13. M. Jovanović, M. Ristić, *Chem Ind*. 8(1957),1373.
14. R.W.Dupon, R.h.Thompson, *J. Am. Ceram. Soc.* 73 (1990)335
15. N. Nikolić, S. Radić, A. Maričić, M. Ristić, Cordierite Ceramics, Serb. Academy of Sciences and Arts, Čačak-Belgrade, 2001.
16. Ž. Josipović, S. Marković, Z. Aćimović, S. Petrović: Foundry 194,

XLI(1994)17-22.

17. Lj. Trumbulović, Z. Aćimović, Lj. Pavlović, Z. Čeganjać, *Technica* 3(2003) (in press)
18. S. Manasiević, Lj. Trumbulović, Z. Aćimović, *Technica* (in press, 2003)
19. Lj. Pavlović, Z. Aćimović, Lj. Trumbulović, *Technica* 4(2002),1-10.
20. Z. Aćimović, Lj. Pavlović, Lj. Trumbulović, Lj. Andrić, *Materials Letters*, 57(18)(2003)2651-2664.
21. Lj. Trumbulović, Z. Aćimović, S. Panić, M. Đuričić, S. Andić: XXXIV October Conf.. Proceedings,(2002)477-480.