MICROPORE CARBON FURNACE LINING

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ABSTRACT

Modern constructions of electric ferroalloy furnaces are still based on applying in the lower "liquid" areas the standard carbon materials. What can be illustrated by the experience from several years, in the part of tap hole, hearth walls and bottom, is that so-called carbon or semigraphite microporous materials are successfully being applied. These materials, compared to the standard carbon, give better resistance to the attack by liquid metal and other wear factors.

Generally this group includes materials characterised by considerable share of pores of diameters below 1μm (significantly exceeding 90% of total porosity). The microporosity increases the resistance to the infiltration of the liquid metal. The effect of microporosity can be obtained by introducing silicon (or its compound) additive to materials based on electrically (or gas) calcined anthracites, electrographite and binder.

Moreover, by introducing other ceramic additives, the microporous materials are more resistant to dissolution by the liquid metal. Observing the trends of "improving the materials" in the last years, it is clearly seen that the share of non-carbon additives is bigger and bigger, so we can reasonably speak of rather carbon-ceramic materials. In this paper, the survey of the most important quality criteria, which must be met by the carbon furnace linings, as well as the new testing methods will be presented.

1. INTRODUCTION

The main features of the carbon material group that determined their usefulness in lining the submerged arc furnace are the following:

- Very high refractoriness, resistance to temperature changes and good compression strength in the whole temperature range, that significantly exceeds the temperature level in the arc furnace,
- Considerable thermal conductivity variation can occur depending on the carbon graphitization degree (amorphous, semi-graphite and graphite carbon materials), that facilitates forming the congealed metal or slag on the surface,
- High resistance on chemical effects of the slag,
- Moderate thermal expansion.

2. EXPERIMENTAL

2.1 Potential deterioration mechanisms for carbon materials

For further clarification a list of strengths and potential weaknesses of carbon and semigraphite blocks is presente

The list shown in Table 1, is arranged according to increasing risk of damage. Temperature and pressure as they occur in submerged arc furnaces are not detrimental to carbon and graphite (mechanical strength increases with temperature). [1,2,3)]

Table 1: Potential deterioration mechanisms for carbon/semigraphs blocks

	Relevance to today's carbon lining
High temperature	-
Thermal stress	-
Reaction with alkalies	++
Mechanical erosion	?
Infiltration by liquids	+
Oxidation by water from leakages	++
Interaction with liquid metal	?
Mistakes in construction / design	+++
Inadequate operation	+++

2.2 Wear Mechanisms

Three wear mechanisms are prominent to submerged arc furnaces : thermal stress, alkali attack and erosion (or dissolution)[4)].

In passing, an additional danger for the carbon lining are thermal stresses, that appear as the result of significant temperature differences between liquid process products filling the hearth and plate coolers or cooled submerged arc furnace shell. This difference in extreme cases can reach 1500 K, that causes the increase of carbon materials volume. This problem has been solved through compensation by means of expansion gaps, filled with the plastic carbon paste of high conductivity.[5)] Thermal stress is again no longer important for modern carbon and standard graphite blocks as calculations have shown.[6)] These calculations were made for standard carbon with thermal conductivity of $\lambda \leq 5$ W/mK. As thermal conductivity has a decisive influence on thermal shock resistance, modern lining blocks with values of $5 < \lambda < 50$W/mK are resistant against thermal shock. The stress occurring in a lining composite is subject of precise calculation today and can be compensated by expansion joints if necessary (dry assembly).

The reaction of carbon with alkali is of complex nature, but alkali attack only occurs between 8000C and 11000C. In fact it is essential for materials based on Anthracite. The result depends on temperature of heat treatment of the Anthracite that can be also exemplified by the diagram below.

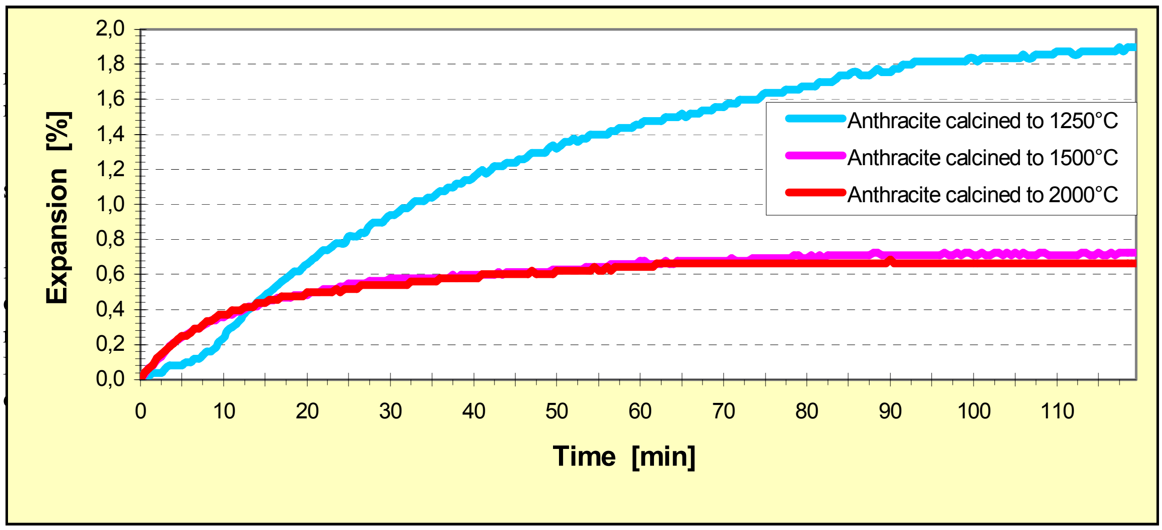

Figure 1: Sodium expansion of carbon samples made with anthracite calcined at different temperatures

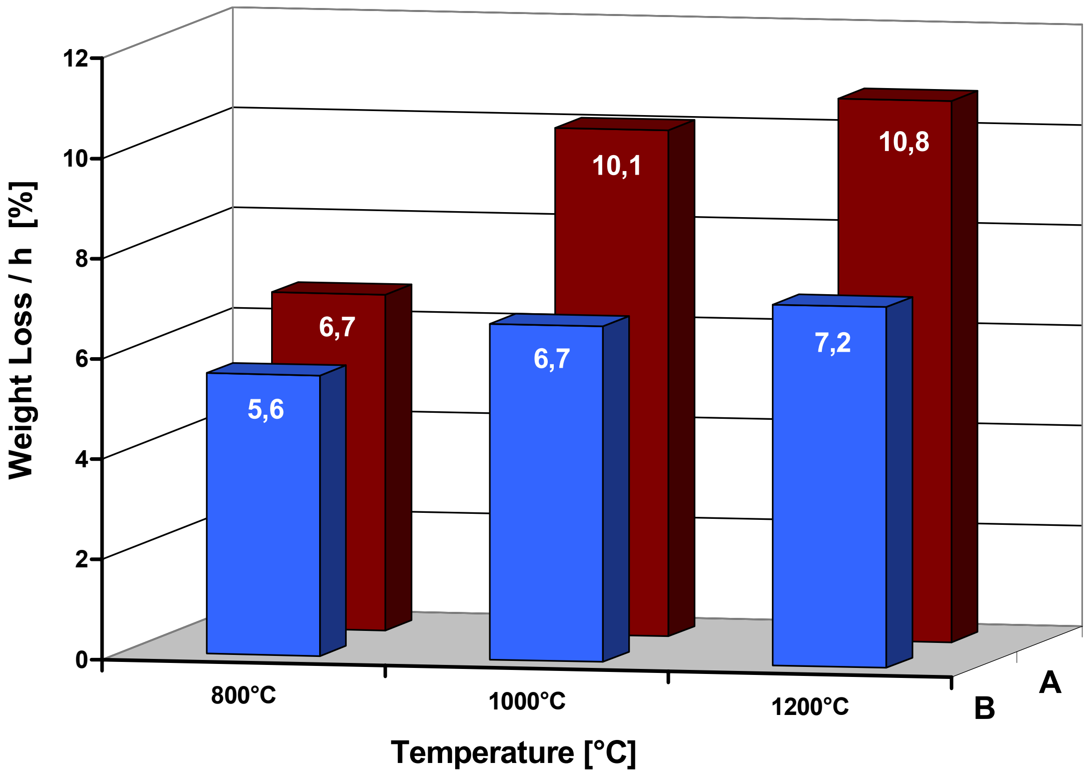

Figure 2A: Oxidation of standard carbon (A) versus micropore carbon (B)

Figure 2B: Oxidation of standard carbon (A) versus micropore carbon (B) - samples after testing at Cigure

The better solution to solve this problem is to use micropore carbon material. Micropore carbon material is resistant against alkali attack - addition of artificial graphite to the recipe and SiC formation in the material matrix during baking improves alkali resistance.

The oxidation of carbonaceous lining by water is a problem not solvable in general, but research work shows (Figure 2A and 2B) that micropore carbon has better oxidation resistance than standard carbon.

Furthermore the influence of hot metal (and slag) on the surface of carbon and micropore carbon has been investigated. For this purpose a special test has been developed (see principles below). Samples of various carbon materials have been tested this way against FeMn and FeMnSi to get first orienting information. It is not the purpose of this paper to discuss test conditions in detail, this must be subject of a separate publication. For the application of refractories it is important, that tests conditions are close to reality, constant and reproducible

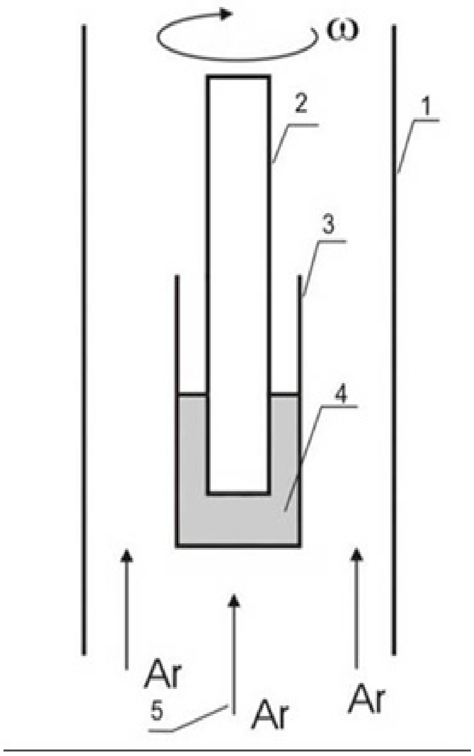

Figure 3: Schema of test -resistance to ferroalloys

Investigation of the resistance of furnaces linings to liquid metal exposure:.

- disintegration of material in liquid metal. (The change of shape of the samples of material and mass loss as well as the change of sample dimensions during experiment).
- infiltration of metal towards sample.

Test conditions:

Cylindrical samples (2) [dimension: diameter-30 mm; length-230mm] of material submerged in liquid metal (4) under a rotary movement:

Temperature [at furnace lab. (1)]: t=1470 C

Inert atmosphere (5): protection by Argon,

Crucible (3): alumina (99,5 % $Al2O3$)

metal phase (4): FeMnC or Fe MnSi

rotation speed: **ω** =100 rpm (stick of material was rapidly submerged into liquid metal on distance 5 cm under rotary movement 100 rpm with precession from vertical axis ± 0.5 cm. After of experiment a stick of material was rapidly pulled out from liquid and cooled in 'inert' gas).

Time of experiment: 1 hour

For further clarification some pictures from carbon samples after metal test are shown.

Experimental remarks:

A low corrosion of submerged material is observed.

FeMnSi: practically no corrosion. A layer of metal on surface of stick which was easy to remove.

FeMnC: Low corrosion - two kind of corrosion: all surface and grains removing, penetration of alloy into holes. Very strong connection of metal with carbon material. White drops of metal on surface.

Figure 4A: Standard carbon - samples after test

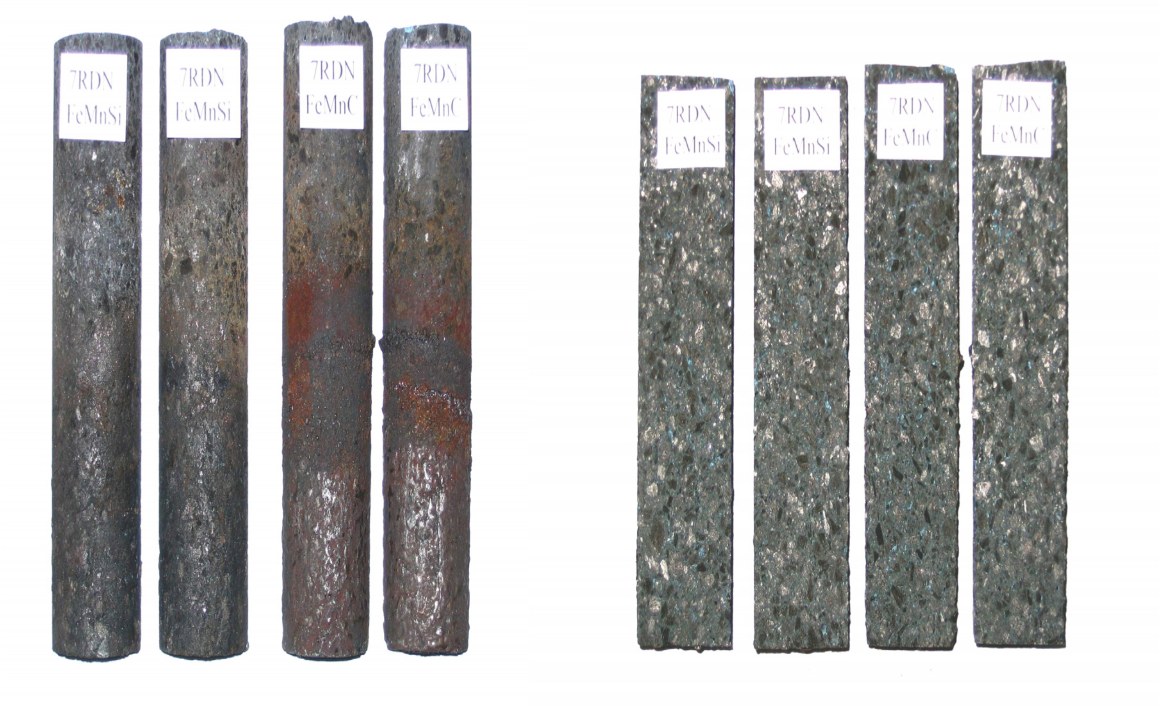

Figure 4B: Microporous carbon - samples after test

3. DISCUSION

- These properties can be fundamentally improved by the use of additives of non-carbon type during production process of these materials:
- Method of adding a fine ground silicon to the raw materials composition causes the decrease of pore diameter in the finished product up to d< 1 μm, so to the size below the values, that allow the liquid metal to penetrate, as well as the increase of resistance to alkalis and oxidation exposure
- Addition of compounds of alumina to raw material composition definitely increases the resistance to dissolution by the liquid metal.

4. CONCLUSION

1. The tests proved the favorable influence of the non-carbon additives, due to which the so called microporous materials are definitely more resistant to : liquid pig iron infiltration, dissolution by liquid metal or destructive exposure of alkalis.
2. Test of resistance to alkalis exposure and test of resistance to liquid metal exposure also allowed to establish that the materials based on electrically calcined anthracite (average temperature of anthracite calcining : 2000 C) are better than materials based on gas calcined anthracite (average temperature of calcining : 1200 C)
3. Currently it is difficult to give a clear-cut answer about which feature of the anthracite determines such behavior during the process. One thing is clear however: that the anthracite selected for production of furnace materials in SGL is specific, i.e. has a totally different petrographic composition than other known anthracites :

- high share of inertial material ca.35% , mainly in form of fuzynite relatively low vitrinite factor (= 60)
- heat treatment resistance (stability of grains) after calcining in 2200 C is estimated as very good
- additionally characterized by low iron content - very favorable feature

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