Analysis of Refractory Materials on Example of Experience of The Oxygen-Converter Department (JSC AMT, Temirtau, Kazakhstan)

Aseel Nadhem Fatehy¹, Mohammed Mhana Meteab¹, Ashraf Abdullah Ahmed*¹
¹Department of Mechanical, College Engineering, Tikrit University, Tikrit, Iraq
*ashraf.eng2002@gmail.com

Abstract. The article deals with the problems associated to the use of refractories in the metallurgical industry. In connecting with that, brief information about the refractories, their composition and classification was presented and as a practical example the operating experience of refractories in the oxygen-converter department of metallurgical plant was considered. Furthermore, steel teeming ladle as technological equipment which accounts for 30 ... 35% of refractories was studied and as a result, a lining project reinforcing layer 300-t teeming ladles made of refractories with a curve form has been designed. The project successfully passed the experimental stage.

Keywords: Refractory, temperature resistance, metallurgy, steel casting ladles, graphite, oxygen-converter department.

1. Introduction

The whole complex of physical qualities of the material is considered from the point of view of its behavior under the action of high temperatures. Refractoriness is a key property that determines the effectiveness of a particular product. It is expressed in a temperature threshold value, upon reaching which the deformation process begins. The minimum value for materials of this type is 1580 °C. For super-refractory materials, this value exceeds 3000 °C. The property of deformation under load is also taken into account. It indicates the mechanical integrity of the product, which is influenced by high temperatures. According to this characteristic, the refractory material for furnaces is tested, which experiences compressive stress. Mechanical persistence is calculated on the basis of the dependence of the processes of structure change on the temperature load. In addition to thermal persistence, chemical protection is also important. Since refractory materials in different operating conditions have to be in contact with aggressive chemical environments, the ability to resist this kind of destruction is also initially evaluated. Specialists, in particular, highlight materials that can remain stable when exposed to acidic substances, reducing gases and slags.

For ease of use of refractory materials, manufacturers initially give them a certain shape, but there is also a whole group of unshaped products. Standardization of molded refractories involves the production of traditional tiled and sheet products. Such varieties are used in the technical support of walls, ceilings, structures, etc. Also, materials with an individual form factor are common. Such products are made with the expectation of highly specialized application tasks, such as in the composition of thermal units, insulation components of equipment, in furnace structures and engines. In turn, refractory sheet materials have a universal purpose and are more often used to isolate...
industrial premises. As for unshaped products, they are used as fillers and these are bulk materials that fill the previously prepared technological niches.

The refractory materials in different operating conditions have to be in contact with aggressive environmental conditions, achieving a high reliability of refractories is very relevant task. For example, a steel teeming ladle which accounts for 30 ... 35% of refractories in several working conditions requires continuous improvement of the lining of the ladle for increasing its operation time. This paper aims to study, analyze the operating experience of refractories in the oxygen-converter department of metallurgical plant and to find a solution to increase operational time of refractories in the aggressive environments, partly for steel teeming ladle which accounts for 30 ... 35% of refractories.[1]

2. Materials and methods

Regardless of the size and form factor, the refractory must effectively perform the main task in the form of thermal protection. The quality of this function depends on the characteristics of the structure of the manufacture material. So, there are groups of aluminosilicate, oxygen-free and fibrous refractories[2]. The raw materials for the aluminosilicate are oxides of silicon and aluminum (see Figure 1).

In the production of oxygen-free thermal insulators, components are used, respectively, which do not contain oxygen compounds. Such elements include sulfides, silicides, nitrides, carbides, etc. Fibrous insulators are made on the basis of special synthetic substances. This category is widely represented by refractory sheet materials formed from polycrystalline or high-alumina particles. As a modifier, zirconium oxide is sometimes added to the composition of the fiber preforms.

2.1. Classification of carbon refractories.

This is a separate group of insulation materials that are combined using free carbon. The most common in this family are Graphite or carbon blocks, made of thermoanthracites and coke mixture (Figure 2).
To give the blocks the required form, bitumen and coal tar are used. To replace them, graphitized materials having thermal resistance 2000 °C can be used.

More complex in the term of technologically is pyrographite. It is a refractory material, the production of which is realized during the decomposition of carbon-containing gas mixtures. Also, in addition to the above-mentioned components of carbon thermal insulators, manufacturers often use materials such as chamotte, corundum, activating pastes and suspensions.

2.2. Chamotte refractories.

Chamotte refractories are specialized refractories intended for the kiln lining. Externally, such a product can be represented in different forms. The standard is considered to be the same refractory plate, but there may be other variations - this depends on the design of a particular furnace, as well as on the parameters of the blank. The basis of the composition is aluminosilicate components. In the process of roasting at elevated temperatures, primary chamotte is formed, which is then crushed and supplemented with a solution of clay and water. The properties of fireclay include not only withstanding extreme temperatures, but also the harmlessness of contact with the technical elements of boilers and livers. Since many refractories to maintain the insulation function are endowed with special chemical elements, they are not recommended to be used in the conditions of direct interaction with certain metals. In turn, the fireclay material based on fireclay is safe for the materials of the combustion chambers, and for the insulation of linings.

2.3. Periclase refractory

Such insulators are also called magnesia, since the basis of the composition is magnesium sulfate. They are obtained as a result of an unburned technological operation. If in the previous case, chamotte can be represented as refractory clay, then periclase is mostly a metallized product. It is often used as part of the alloy on which the kiln lining is based (Figure 3). Together with the magnesia component, steel, copper and nickel may be included in such a complex.
There is also a kind of periclase - carbon heat-resistant insulators, which are based on powder. A refractory plate made on the basis of periclase components, in particular, may contain about 25% graphite and a phenolic powder binder. This type is used in the protection of surfaces of electric arc furnaces and units working with gas mixtures. Also the combined use of periclase and fireclay insulators as part of a single structure is practiced.

2.4. Fireproof glass.
The uniqueness of this material lies in the fact that it is in various forms is included in almost all types of refractories. For example, liquid glass can be considered as a fusible insulator in the design of furnaces and boilers, along with metallized plates. Fibrous refractory glass may be part of alumina insulators. Structural versatility of the material determines the flexibility. Such glass is often used in cases when it is necessary to produce not just technical, but also decorative protection.

2.5. Bulk refractories.
In essence, these are powder products that are not specially molded. They do not have to be smelted or assembled in order to obtain specific dimensions. The most popular type of representation of a bulk insulator group is a refractory mixture, but there are other variations. Among them are suspensions, lump elements, powders and pastes. Depending on the consistency, it can be semi-dry or dry and plastic materials. As for use, bulk insulators are used as aggregates. Unshaped refractory mixture, for example, is included in the structure of the insulation protection of steel equipment. Thus, individual parts of open-hearth furnaces and steel-teeming ladles are protected from heat damage. Small fractional bulk refractories are used in the buildings of measuring devices.

Fireclay refractory. Industrial thermal protection based on clay materials belongs to the group of fireclay insulators. But in this case the emphasis is on a balanced combination of chemical elements, among which may be oxides, quartz, alumina ceramics, etc. By combining also the levels of calcium, sodium and magnesium, the technologist can obtain refractory material with different technical and operational characteristics. For example, water absorption can be 5-15%, and the refractoriness reaches 2000 °C. With a grain size of 2 mm, the user can count on protecting the masonry of 30 blocks with a 20-kilogram package of clay. What is important, refractories of this type dry out quickly, allowing furnaces and boilers to be put into operation as soon as possible after repair.
2.6. The use of refractories.

The nature of the application is determined by the set of properties and the shape of the specific product. Most refractories are oriented on the kiln lining structures and boiler structures. This allows increasing the service life of the unit as a whole or its individual part. Such materials can be used in the manufacture of a special clothing. Here we can note the tarpaulin refractory, which is also notable for wear resistance and persistence. Gloves, aprons and other clothing items for the industrial and construction industry can be made from the refractories. In narrower industries, for example, in the above-mentioned instrument making, both powder and molding products can be used. They serve not only to protect the elements of the device from elevated temperature, but also to regulate the thermal mode in accordance with the requirements for the conditions of use of the device.

3. Results and dissection

Considering the experience of operation of the refractory material in the conditions in the converter department of JSC "Arcelor Metal Temirtau" (JSC AMT, Temirtau, Kazakhstan). The capacity of the enterprise is 3...4 million tons of steel per year.

The main consumer refractories - oxygen converter department (OCD). Technological equipment which accounts for 30...35% of refractories - steel teeming ladle (see. Figure 4)[3]. The lining of the bucket will wear out faster than other heat engines and units due to the peculiarities of operation:

- The effect of “instantaneous” heating when the ladle is filled with molten metal and “slow” cooling after it has been drained;
- Mechanical impact of a jet of molten metal, having a large mass, when filling the bucket;
- Chemical effect of melt, slag.

Severe working conditions require continuous improvement of the lining of the ladle, increasing its operation time. The industry of Russia and the CIS countries cover the demands of this steel industry only by 20%, the rest of the refractories are imported. The largest enterprise of the Russian Federation is Bogdanovichsky OJSC “Refractories”, located in the Sverdlovsk province. Joint work of JSC AMT and OJSC Refractories on the extension of the life of the refractory lining of the ladle, has developed a special curved brick shape (Figure 5).
Mirror antennas are one of the most common narrow-band antennas of the VHF range. In antennas To solve the assigned tasks technicians together with specialists designed lining project reinforcing layer 300-t teeming ladles made of refractories with a curve form (Figure 5). The novelty lies in the "semi-circular" shape in bricks docking locations (previous forms - wedge line) allowing to make a dense ring ladle shroud circumference and to reduce the number of seams.

For trial operation 4 sets of armature linings with a curve form were made[4]:
- two sets of lining, consisting of refractory brand MKRKU-60 No. 455-14 number (Table 1.) , Used in metal zone and refractory brand MKBK-75 No. 455-14, used in the slag zone (Lining scheme No. 1). Persistence not less than 800 cycles;
- two sets of lining, consisting of refractory brand MKBK-75 No 455-14, used in metal zone and the slag zone (Lining scheme No. 2). Persistence not less than 1000 cycles.

Table 1. Refractory materials of the brands MKRKU-60 No. 455–14 and MKBK-75 No. 455–14, made according to TU 203-585-2014 and TU 1560-079-05802290-2010

| Physical and chemical Parameters                  | Value       |
|--------------------------------------------------|-------------|
| Refractory brand MKRKU-60                        |             |
| Mass percentage of Al2O3, %, not less             | 60.0        |
| Mass percentage of Fe2O3, %, not more than        | 3.0         |
| Softening start temperature, °С, not lower       | 1400        |
| Thermal stability, number of thermal cycles, not less | 6          |
| Open porosity, %, not more                        | 19          |
| Tensile strength at compression, N / mm2, not less | 40          |
| Refractory brand ICBK-75                         |             |
| Mass percentage of Al2O3, %, not less             | 75.0        |
| Mass percentage of Fe2O3, %, not more than        | 2.2         |
| Softening start temperature, °С, not lower       | 1420        |
| Thermal stability, number of thermal cycles, not less | 3          |
| Open porosity, %, not more                        | 23          |
| Tensile strength at compression, N / mm 2 , not less | 40          |

Service conditions for steel-ladle linings at the OCD:
- metal temperature at the issue from the converter - from 1630 to 1670 °C;
the residence time of the metal in the ladle - from 145 to 360 minutes, including with out-of-furnace treatment of the metal at the LFI (ladle-furnace installation) 40 - 85 minutes;

- The results of trial operation:
  - according to scheme No. 1: ladle No. 50 - 787 melts, ladle No. 48 - 968 melts;
  - according to scheme No. 2: ladle No. 60 - 790 melts, ladle No. 53 - 1157 melts.

At the final stage of experimental tests any observations on the operation of armature linings made according to schemes 1 and 2, by technological and technical personnel OCD.

It should be noted that when using linings obtained according to scheme 2 (ladle No. 53) of best results operation are expressed, lining in excellent condition (Figure 6) and in the purity of the armature layer at 1157 resistance melting. With an average stability of 800 melts, unit costs decreased 2.1 times. At the end of experimental tests after confirmation of positive results of JSC AMT decided to purchase commercial batch of refractories for testing on a larger number of the number of steel casting ladles.

![Figure 6. Armature layer of lining steel ladle No. 53, made according to scheme No. 2, from refractories brand MKBK-75, produced by Bogdanovichsky OJSC Refractories, after 800 heats](image)

4. Conclusion

The refractory materials in different operating conditions have to be in contact with aggressive environmental conditions, achieving a high reliability of refractories is very relevant task. For example, a steel teeming ladle which accounts for 30 ... 35% of refractories in several working conditions requires continuous improvement of the lining of the ladle for increasing its operation time. For this purpose, lining project reinforcing which layer 300-t teeming ladles made of refractories with a curve form was designed. The novelty lies in the "semi-circular" shape in bricks docking locations (previous forms - wedge line) allowing to make a dense ring ladle shroud circumference and to reduce the number of seams.

It should be noted that when using linings ladle No. 53 best results operation are expressed, lining in excellent condition and in the purity of the armature layer at 1157 resistance melting. With an average stability of 800 melts, unit costs decreased 2.1 times. This allows reducing the costs of metallurgical enterprises for the purchase of refractories.

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