CAUSES OF FRACTURE IN THE CHAMOTTE LINING OF A STACK

S. Goberis,¹ K. Yarushyavichyus,¹ and A. Shpokauskas¹

Translated from Ogneupory i Tekhnicheskaya Keramika, No. 4, pp. 48 – 52, April, 2000.

The temperature and corrosive action of the effluent gases on the chamotte lining of the stack of an oil-refining enterprise is considered. It is established that fracture of the lining is caused mainly by the interaction between the SO₂ present in the effluent gases and mullite. During service of the stack, aluminum sulfates form, and in cooling new formations arise (tschermigite) that disrupt the chamotte lining.

INTRODUCTION

A smoke stack 120 m long with an upper internal diameter of 3.6 m has been erected at the oil-refining enterprise in Mazheikiai (Lithuania) for removing the combustion products from the sulfur-producing equipment. The design was developed in 1985 by the Novokuznetsk department of VNIPITeploproekt and the stack began operation in 1988. After a ten-year operation, examination of the stack showed that the lining was considerably damaged; cracks 50 – 100 mm wide and several meters long appeared in many places, and in some places the lining fell off and the brickwork crumbled. The heat-insulating layer from glass-wool mats was completely broken.

In order to determine the causes and the mechanism of fracture of the lining we analyzed the temperature and corrosive action of the effluent gases and studied the changes in the composition of the chamotte and the refractory concrete.

CHARACTERISTIC OF THE OBJECT

The trunk of the stack is made of monolithic reinforced concrete to a height of + 107.5 m; above this level the stack is fabricated from acid-resistant bricks of class B (GOST 474-80) bonded by a refractory mortar. The lining is made of chamotte bricks of grade ShB-II (GOST 8691-73) bonded by a refractory mortar. The space between the trunk and the lining is filled with broached glass-wool mats of grade 2M-125 (GOST 21880–76).

The expected parameters of the combustion products are as follows: flow rate of the exhaust gases 5.0 – 6.1 m³/sec,1 temperature 500°C, dew point + 200°C, and aggressive component SO₂ (from 0.12 to 1.0 vol.%); the moisture content of the gases fluctuates from 11.8 to 23.46 vol.%. The amount of SO₂ in the effluent gases in operation was determined systematically (Fig. 1a). The results of the analyses showed that the content of SO₂ in the gases did not exceed the designed maximum value; the content of the other components was not specified. In order to evaluate the amount of ammonia in the gases we took gas samples for three days and determined the content of NH₃ (Fig. 1b).

Fig. 1. Content C of SO₂ (a) and NH₃ (b) in the effluent gases.

1 Institute of Thermal Insulation, Lithuania.
2 Under normal conditions.
Fig. 2. Diagram of the state of specimens of chamotte bricks (a) and refractory mortar (b): 1, 3) middle; 2, 4) external layers subjected to chemical corrosion.

The temperature of the gases entering the stack under normal working regime was 540–560°C. During the operation we detected a temperature of 600°C.

RESULTS OF THE STUDY

When examining the stack we took samples of the chamotte lining and the refractory mortar used in it. The chamotte bricks and the mortar on the internal side of the stack were corroded to a depth of 40–70 mm. On the side of the thermal insulation the corrosion penetrated 10–20 mm for a total thickness of the lining equal to 123 mm. The diagram of the state of the chamotte specimens and the mortar is shown in Fig. 2.

A qualitative x-ray phase analysis of the newly formed minerals in the chamotte specimen and the mortar was made in a DRON-2 diffractometer with a cobalt anticathode and an iron filter. The diffractograms of the chamotte specimen (Fig. 3) show that its internal part contains mainly mullite, cristobalite, and quartz; the low amount of new formations contains tschermigite (alumoammonium alum) and a hydrate of acid alumsulfate. In the external layers of the specimen subjected to chemical corrosion new formations predominate (tschermigite, hydrate of acid alumsulfate and some chamotte minerals, i.e., mullite and quartz).

The diffractograms of the refractory mortar (Fig. 4) show that the predominant new formations are calcium sulfates. In the internal least changed part of the mortar the first place belongs to chamotte minerals and anhydrite, and in the corroded external layer the predominant substances are gypsum formed in the interaction between various dehydrated calcium hydroxides contained in the portland cement and SO₂. In both cases there are crystals of tschermigite and a hydrate of acid alumsulfate.

The molecular masses and the densities of the minerals of the refractory lining and the new formations are presented in Table 1. The data of Table 1 allow us to estimate the variation in the masses and molecular volumes in the formation of

TABLE 1. Molecular Mass and Density of Minerals in the Composition of Refractories in the Lining and in New Formations [1]

<table>
<thead>
<tr>
<th>Substance</th>
<th>Formula</th>
<th>Molecular mass</th>
<th>Density, g/cm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mullite</td>
<td>3Al₂O₃ · 2SiO₂</td>
<td>426.05</td>
<td>3.15</td>
</tr>
<tr>
<td>Calcium silicate</td>
<td>CaSiO₃</td>
<td>116.16</td>
<td>2.90</td>
</tr>
<tr>
<td>Tschermigite (hydrate of ammonium-aluminum sulfate)</td>
<td>(NH₄)₂SO₄ · Al₂SO₄ · 24H₂O</td>
<td>906.66</td>
<td>1.64</td>
</tr>
<tr>
<td>Aluminum sulfate</td>
<td>Al₂(SO₄)₃</td>
<td>342.15</td>
<td>2.71</td>
</tr>
<tr>
<td>Hydrate of acid aluminum sulfate</td>
<td>Al₂(SO₄)₃ · H₂SO₄ · 2H₂O</td>
<td>476.26</td>
<td>2.40*</td>
</tr>
<tr>
<td>Gypsum</td>
<td>CaSO₄ · 2H₂O</td>
<td>172.17</td>
<td>2.31 – 2.33</td>
</tr>
<tr>
<td>Anhydrite</td>
<td>CaSO₄</td>
<td>136.14</td>
<td>2.90 – 2.99</td>
</tr>
</tbody>
</table>

* Chosen for calculation.