

**THERMAL EFFECT OF ENERGY PRODUCING EQUIPMENT  
ON THE DETERIORATION OF FIRE -RESISTANTS  
AND ELIMINATION OF EROSION PRODUCTS  
INTO THE ENVIRONMENT**

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**The development of energy production caused by the evolution of modern industry is closely related with the intensification of technological processes. Since the exploration of the process of surface erosive deterioration that takes place in the flows of combustion products has acquired a larger scale, it is urgent to examine the phenomena that emerge in erosites, on the surfaces of  $Al_2O_3$ ,  $MgO$ , and  $ZrO_2$ . On the basis of the data found in scientific literature and results obtained during the high-temperature speedy experiments with the ceramic materials it would be purposeful to introduce adequate corrections into the estimatio system of environmental pollution.**

The development of energy production caused by the evolution of modern industry is closely related with the intensification of technological processes. When such materials are treated with high-temperature and tested in an aggressive environment, the erosive deterioration of the material's surface takes place during which the formed products of erosion are eliminated into the environment in the flow of combustion products. When eliminated into the air with the combustion products, the particles of the erosion products being very small, hard and sharp do pollute the environment.

The impact of heat flow on the formation of the microstructure in building and technical ceramics has been stressed in a number of the authors' papers [1, 2]. Since the exploration of the process of surface erosive deterioration that takes place in the flows of combustion products has acquired a larger scale, it is urgent to examine the phenomena that emerge in erosites, on the surfaces of  $Al_2O_3$ ,  $MgO$  and  $ZrO_2$ .

The fire-resistant materials that are heated by the high-temperature gas flow up to the sublimation temperature undergo the surface and volumetric physico-chemical alterations [3]. The character of erosive deterioration of the materials is determined by the surface effect caused by the flowing gas stream and the material's abilities to resist it. Unevenness of the surface formed by the moving environment, i.e. erosites, demonstrates the following characteristics: the place of the flow's break loose (which may differ due to the degree of mass transfer), the point of flow connection (which is periodically washed around from the front part to the edge) and the recirculation area (in the front part of which the deepening of the shape of a crater, cavity, crack or pit is formed). The mentioned characteristic uneven boundary places that were formed on the eroding surface remain during the entire period of erosive treatment [1].

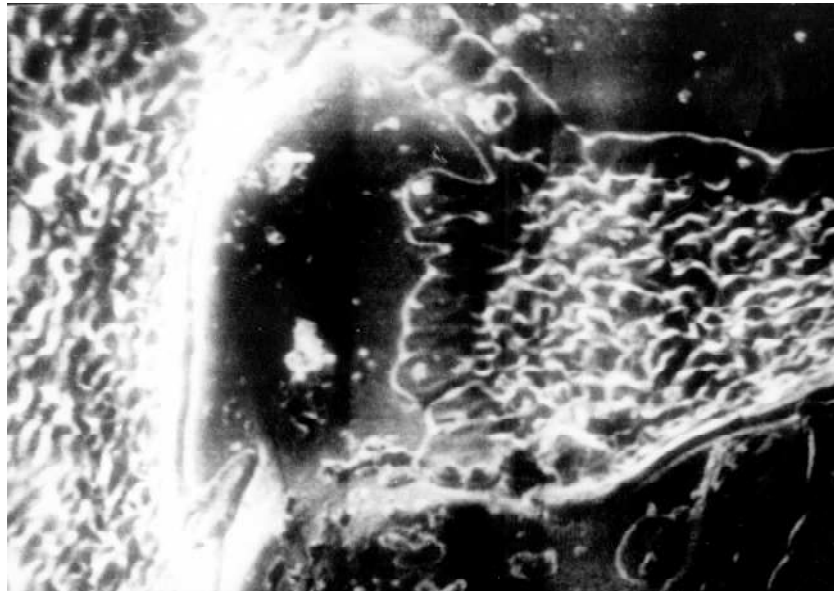
The offered model of erosion allows for the assumption that both even and uneven distribution of temperature and pressure in an erosite as well as the presence of the material's mass flows in the surface layer, under which erosites are distributed, do vary. Obviously, it causes considerable alterations. Here the sublimation speed from the surface  $m_{i,w}$  may serve as an example. It may be calculated with the use of the Herc-Knudsen equation:

$$m_{i,w} = \frac{\alpha(p_i^H - p_i)}{\sqrt{2\pi RT_w / M_i}}, \quad (1)$$

here  $a$  is the coefficient of accommodation;  $p_1^H$  is the pressure of saturated vapour on ceramics at the calculated temperature  $T_w$ , Pa;  $p_i$  points to gas pressure above the surface, Pa;  $M_i$  is the molecule mass of the  $i^{\text{th}}$  component;  $R$  expresses gas constant;  $T_w$  is the temperature of the wall, K.

On the basis of Equation (1) the following analysis of the process might be carried out. The numeration of the equation shows the difference of the quantities  $p_i^H$  and  $p_i$ . It shows that in an erosite the sublimation velocity may be estimated as the difference which two mass flows formed in this particular volume. When the balance of those two flows provided in the given erosion model is destroyed, the character of the process is changes. When  $p_i^H > p_i$ , the sublimate will be eliminated from the surface of an erosite, i.e. the mass losses will. Such a situation arises when the active flow from the surface layer into the recirculation area takes place and the sublimate is eliminated into the flow of combustion products.

Figure 1. shows the erosite area that is behind the obstacle and extends up to the edge of the connection point. It may perfectly illustrate how the difference of pressures calculated in Equation (1) is distributed. Most probably, such difference occurs in the area where the surface vortices of the combustion production are formed.

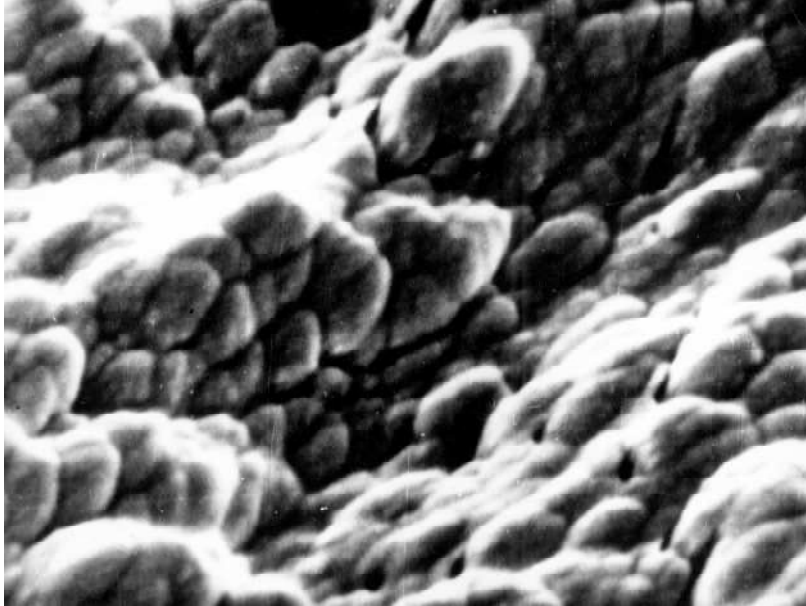


*Fig. 1. View of the erosite formed on the eroding MgO surface in the flow of combustion products at  $T_{\text{wall}}-1400^{\circ}\text{C}$ ;  $u-500\text{m/s}$ ; time of testing 180 min; enlargement  $\times 300$ . Flow direction: from left to right*

It is not known how much the balance between the sublimation and the erosion products is destroyed, yet, it is possible to guess that the difference of pressure from the edge of break loose (white line on the left in Fig. 1) and in the direction of the flow movement undergoes alteration. When  $p_i^H \leq p_i$ , the Herc-Knudsen formula does not give necessary information. However, the marks on the surface show that it takes place along the length of the erosite consecutively enough. If in the beginning of the recirculation zone the sublimate elimination takes place and some part of it is condensed in the place of the erosite's break loose point (due to its growth), further along the flow's direction an active elimination of the sublimate and erosion products into the flow takes place. Figure 1 shows the alteration of the processes of evaporation and condensation.

The calculations of the combustion products inside the erosite carried out on the basis of the theory of the liquid unviscosity flow [4] showed that the flow of viscous liquid on the surface cavity is calculated by a numerical solution of the Navier-Stocks equation. The process of the viscous liquid flow has been described according to the law of the mass impulse preservation.

The integrated area was covered with a net. The variable quantities (excluding velocity) in the net knot were calculated. During the calculation of the kinetic turbulent energy  $K$  and the velocity of the turbulent dissipation energy  $S$  the pushed net was used. It was pushed so that the knots of the new net in which the velocities were calculated when the knots were in the middle between the points where the pressure was controlled by velocities [6]. The flow in the erosites was calculated on the basis of the two-parameter turbulent model, elliptic equations and the "Aptek" programme package [7].



*Fig. 2. An eroding surface of the  $ZrO_2$  fire-resistant stabilized with  $CaO$  when explored at  $2000^{\circ}C$ , flow velocity  $500\text{ m/s}$ , duration  $10\text{ h}$ . Enlargement:  $\times 4.600$ . Flow direction: from left to right*

In the context of the volume of the erosite, the area of flow connection is specific because of a number of important processes that take place in it. Here heat delivery to the wall, structural alterations of the flow and the beginning of the material's column structure formation are observed. The connection area also determines the length of the recirculation place area.

Generally, the latter depends on the flow regime, form of profile, velocity in the place of break loose, the height of the obstacle, the character of turbulence, the geometrical form of the obstacle and the size of the channel. The dimensions of the recirculation area alter most significantly with the alteration of the Reynolds number [8].

In comparison with other parts of the erosite, here a notable alteration of the ceramic structure takes place earlier. It is the so-called additional baking that exclusively demonstrates a column structure [1, 2].

During the investigation of eroding surfaces the losses of the material's mass have been inescapably observed. It is the part of the material that one way or another has been decomposed from an eroding surface, entered the flow of combustion products and together with combustion products was eliminated into the environment. The products of erosion are small, hard particles that often possess a sufficiently developed surface, due to which their diffusion in the air is good [9].

In the group of high-temperature fire-resistants, when  $ZrO_2$  material whose system is constant is stabilized with  $CaO$ , it has been observed that at  $>2000^{\circ}C$  from the hard  $ZrO_2$ - $CaO$  solution an intensive evaporation of  $CaO$  takes place. Even the losses of mass from an eroding surface of such a strong erosion-resistant are clearly observed (Fig. 2).

The velocity of erosion of the  $ZrO_2$ - $CaO$  fire-resistant is easily observed: it makes  $0.005$ - $0.15\text{ g/m}^2\text{s}$  at the flow velocity  $u$ - $500\text{ m/s}$ . The velocities of other fire-resistants are similar or higher. The deteriorated surface turned into small, hard particles that were eliminated into the environment. The fallings found in the catcher of the products of erosion are shown in Figure 3.

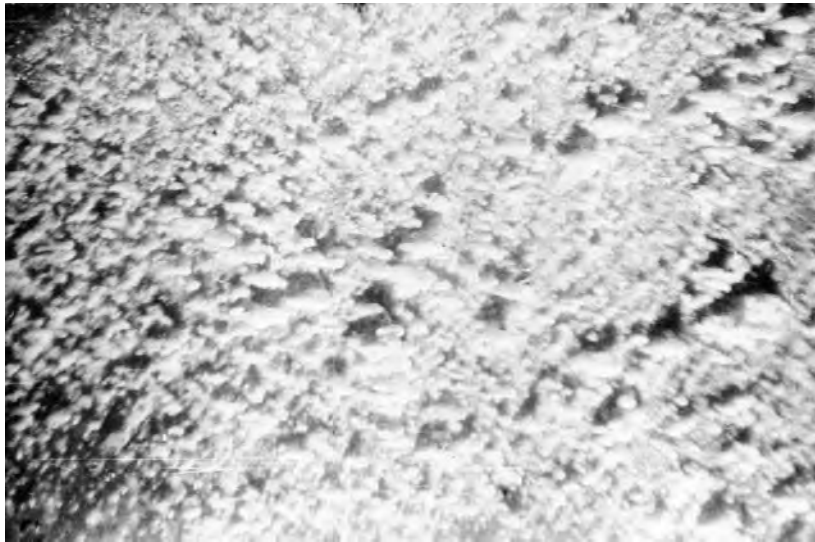


Fig. 3. The products of erosion found in the catcher during the experiment with the  $ZrO_2-CaO$  fire-resistant at  $T_{wall}=2000^0C$ ,  $u=500m/s$ , duration 10 h. Enlargement:  $x 100$

Energy production being of vital importance is closely related with high-temperature technologies, the production of large amounts of heat, high-temperatures and large amounts of combustion products that are eliminated through chimneys and thus affect the environment. On the basis of the data given in scientific literature and knowledge acquired during the high-temperature speedy experiments with the ceramic materials it comes out to be purposeful to introduce adequate corrections into the estimation system of environmental pollution. The concentration should be on the concordant development, a compromise between the environmental, economic and social goals of the society that would encourage the possibilities for achieving universal welfare for the present and coming generations without exceeding the permissible limits of environmental effect.

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