PROTECTING THE ENVIRONMENT

METHODS OF REDUCING FLUORIDE EMISSIONS
IN THE USE OF EXOTHERMIC SLAG-FORMING MIXTURES

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The combustion of exothermic slag-forming mixtures (ESMs) used to make synthetic slag during the casting of special steels and alloys is accompanied by the emission of toxic gases. Such emissions pollute the air at the work station and result in the release of pollutants into the surrounding region through the ventilation system of the steelmaking shop. Fluorides of metals are added to the ESM to lower the melting point and viscosity of the slag and to catalyze combustion. Although the end result is an improvement in the quality of the surface, the fluoride compounds are also the most hazardous of the toxic emissions generated in the slag treatment. Thus, reducing the amount of volatile fluorides that enter the air during the combustion of fluoride-bearing mixtures is the most important problem in ensuring the safety of workers and the environment.

We conducted studies to determine the efficiency of different methods of reducing the concentration of fluorides in the combustion products. Fluorides of silicon and aluminum are volatile at the combustion temperature of the exothermic mixtures. When those compounds react with moisture in the air, they form highly toxic hydrogen fluoride. We performed calculations to evaluate the effectiveness of reducing fluoride emissions by efficiently choosing the fuel, oxidant, and slag-forming components of the ESM.

The quantity of volatile fluorides formed can be reduced using calcium-silicon in place of powdered aluminum, which is the most commonly used fuel component. Figure 1 graphically shows the results of calculations of the composition of the combustion products of mixtures containing up to 30% fuel and oxidant (sodium nitrate), slag-forming additions, sodium fluoride, and calcium fluoride. The total quantities of fluorides emitted depend little on their composition, which is related to the occurrence of exchange reactions in the slag. In mixtures containing aluminum, the volume of hazardous emissions increases with an increase in the concentration of fluorides in the initial composition. In mixtures with calcium-silicon, these emissions reach a maximum due to a decrease in the heat of combustion in the presence of a high concentration of fluorides. When aluminum is replaced by calcium-silicon, the volume of fluorides released is more than halved because no volatile fluorides of aluminum are formed.

Another method of reducing fluoride emissions is to replace the sodium nitrate used as the oxidant by carbonates of sodium or calcium. We performed calculations for mixtures ranging in fluoride concentration from 3 to 30% and having different oxidants (sodium nitrate and sodium carbonate). It is apparent from Fig. 2 that for the mixtures with sodium nitrate the volume of fluoride emissions increases with an increase in the content of fluorides in the initial composition. The volume of emissions is markedly higher for sodium fluosilicate than for sodium fluoride, since the former readily decomposes and forms silicon tetrafluoride. Fluoride emissions are nearly absent when sodium carbonate is used, which can be attributed to the substantial reduction in combustion temperature (Fig. 3) and the bonding of fluorides by products of the decomposition of sodium carbonate to form nonvolatile compounds.

Finally, the volume of emissions can be influenced by changing the composition of the slag-forming components and increasing their basicity. In calculations, basicity was changed by adding different quantities of oxides of calcium and silicon while the composition of the active part – containing calcium-silicon and sodium nitrate – was kept constant. The results of the calculations (Fig. 4) show that an increase in basicity is accompanied by a sharp reduction in the amount of fluoride emissions.
Fig. 1. Effect of the concentration of fluorides in the mixture and the type of fuel on emissions of volatile fluorides.

Fig. 2. Effect of the concentration of fluorides in the mixture and the type of oxidant on emissions of volatile fluorides.

Fig. 3. Effect of the concentration of fluorides in the mixture and the type of oxidant on combustion temperature.