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EMISSION OF SULFUR OXIDE INTO THE ATMOSPHERE IN THE PROCESS OF BURNING THE ORGANIC FUEL IN POWER-GENERATING BOILERS

There had been built the nomographic charts for the determination of specific mass emissions of sulfur oxide. There had been analysed the influence of separate factors on the value of mass emissions.

Key words: *sulfur oxide, combustion value, effluent gases, heat stress of furnace unit, excess air factor.*

Introduction

Protection of atmosphere is one of the most important issues for all industrial regions since the ecological restrictions hinder the development and extention of the industrial and energy power producing enterprises. The most dangerous atmosphere pollution relates to the burning of organic fuel in the boiler houses. The main problem which arises as a result of hazardous air emissions is their direct or indirect influence, exerted on biological sphere and human health.

Fluid or hard organic fuels, used in energy power production, contain sulfur. Chemical composition of any fuel may be determined from references [1]. In the process of fuel burning there appears the sulfur oxide SO_x=SO_2+SO_3 which is the most harmful air pollutant. Sulfur dioxide relates to the first group of contaminents, the amount of which in fuel burning products very little depend on its burning technology and may pretty exactly be determined on the known composition and fuel characteristics and furnace design. Usually the volume share of SO_2 makes up 97-99 %, and a share of SO_3 1-3% of the total SO_x output. Therefore the total amount of SO_x emissions is suggested to be determined as calculated on sulfur oxide SO_2.

Fuel gas practically does contain the sulfur compounds, therefore the products of combustion do not contain the sulfur oxide. Since this fuel goes up in prise, the coal becomes the alternative fuel, the content of sulphur in which may go up to 2,8 – 3,1%. Changing gas for coal requires to consider the factor of ecological expediency. Mass concentration as well as a specific mass emission of SO_2 from burning of one kilo of fuel (m, g/s) may be such a factor.

Insufficient use of means of instrumental control for concentration of repugnant substance in effluent gas, in particular SO_2, as well as the need in its evaluation on the stages of designing, reconstruction or modernising of fuel using units stipulated for the use of different calculating methods [2 – 7], application of which is characterized by different accuracy and unhandiness.

In view of the above-mentioned there was a task to develop a simple engineering method for the determination of the expected emissions of sulphur oxide into the atmosphere during burning the fluid and hard types of organic fuel in the furnace unit of power-generating boilers.

Main results

Using [1], for the set type of fuel we determine the energy value of as-received basis Q_l^o, mJ /kg; percentage of sulfur S^o; theoretical volume of air V^0, m^3/kg and theoretical volume of effluent gases V_G^0, m^3/ kg. Depending on combustion method of fuel and design of furnace arrangement there will be determined the sectional area of furnace unit F, m^2, air-to-fuel ratio in the furnace unit α_F and in affluent gasses α_{EG}.

The volume of combustion products in the furnace unit shall be determined on [1], m^3/kg:

$$V_G = V_G^0 + 1{,}016 \cdot (\alpha_F - 1). \tag{1}$$

Further on there will be determined the correlations

$$S^* = S^o / V_G, \tag{2}$$

$$V^* = V^0 / V_G, \tag{3}$$

$$\beta = 7 \cdot S^* \cdot 10^{-3}, \tag{4}$$

$$\alpha^* = \alpha_F / \alpha_{EG}. \tag{5}$$

Heat stress of sectional area of furnace unit, MJ/m^2

$$q_F = \frac{B \cdot Q_n^p}{F}, \tag{6}$$

where B – momentary discharge of the-fired fuel.

After that the percent-volume of oxygen in combustion products r shall be determined from fig.1, and percent-size of SO_3 – from fig. 2 for the normal capacity or for the boiler steam capacity. Then there will be determined the value of the factor [3]:

$$A = (\beta - 0{,}01 \cdot SO_3) \cdot 10^3. \tag{7}$$

The specific mass emission of sulfur oxide into the atmosphere m, g/s (burning 1kg/s of the-fired fuel) shall be determined by nomographic chart, presented in fig. 3. In case of partial load of boiler , value m shall be multiplied by value [3]: $D^* = (D_i / D_n)^2$, or $Q^* = (Q_i / Q_n)^2$, whereD_i and Q_i – current discharge of steam or boiler capacity, and D_n and Q_n– nominal boiler steam capacity and boiler capacity correspondingly.

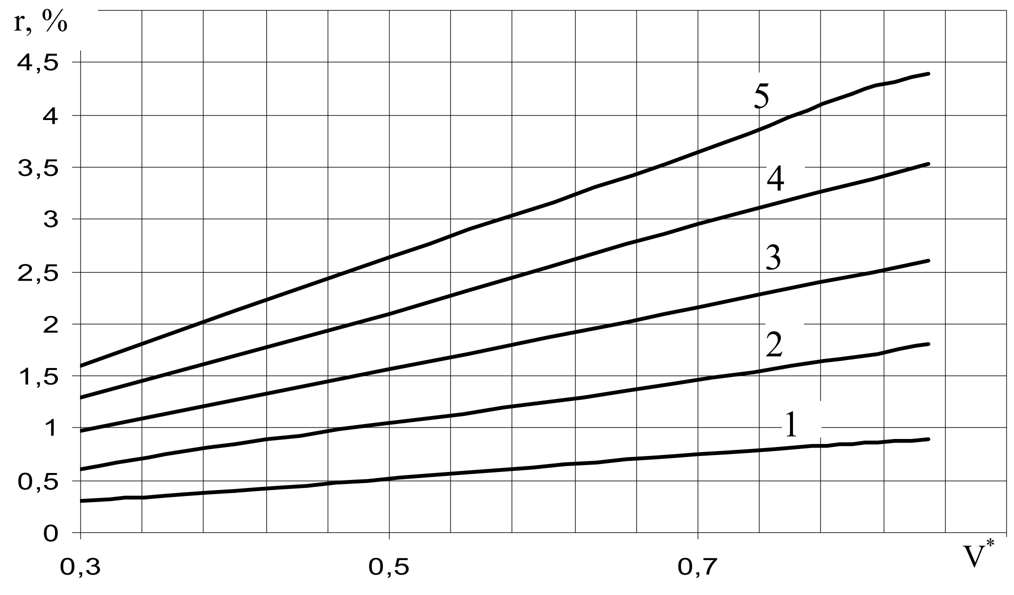

Fig. 1. Content of excessive air in combustion products: 1 – α_T=1,05; 2 – 1,1; 3 – 1,15; 4 – 1,2; 5 – 1,25

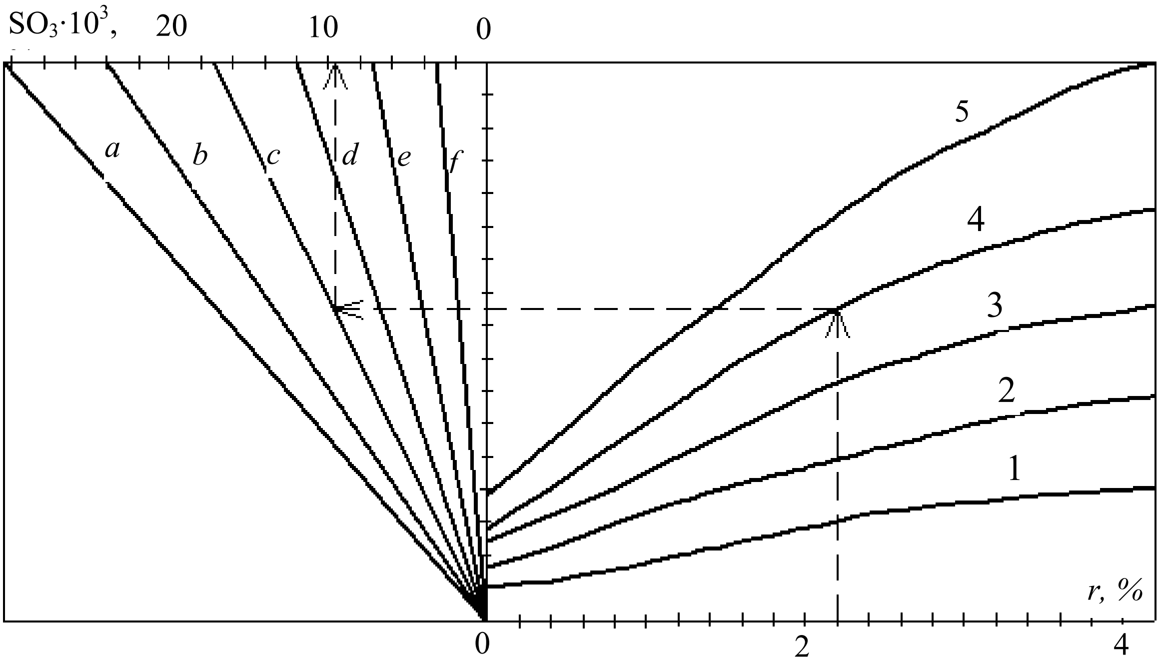

Fig. 2. Nomogram for determination of SO_3 percentage in combustion products : 1 – β=0,5·10⁻³; 2 – 1; 3 – 2; 4 – 0,5; 5 – 4; a – q_F=9 MW/m^2; b – 7; *c* – 5; *d* – 3; *e* –2; *f* – 1

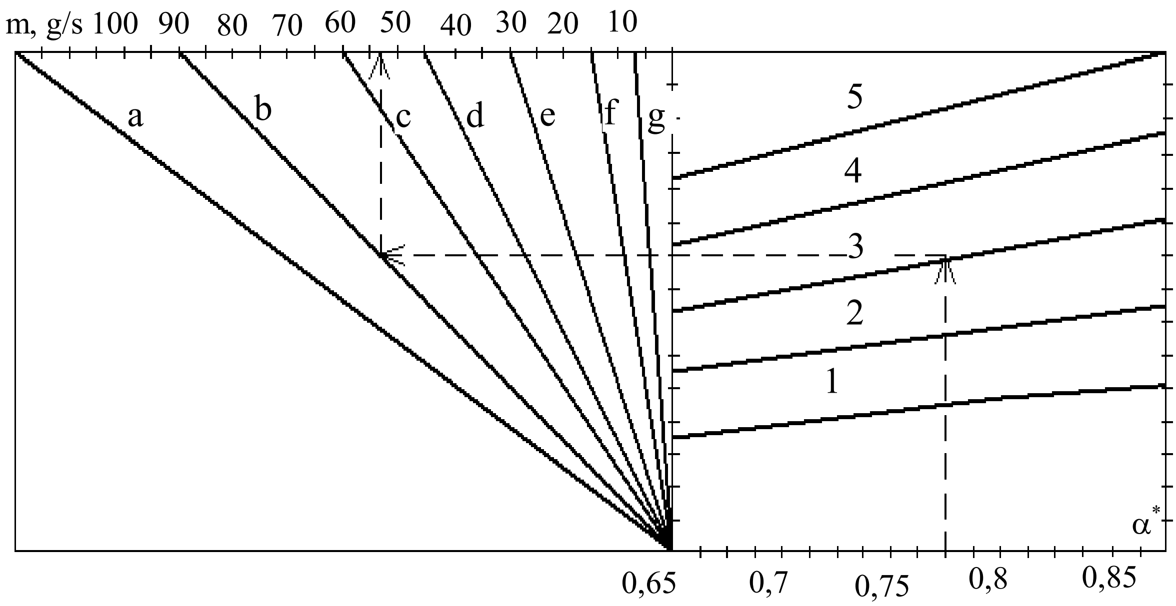

Fig. 3. Nomographic chart for the determination of specific mass emission of sulfur oxide in to the atmosphere: 1 – V_G=4 m^3/kg; 2 – 6; 3 – 8; 4 – 10; 5 – 12; a – A=4; b – 3; c – 2; d – 1,5; e – 1; f – 0.5; g – 0,2

For example, in the boiler, which operates with nominal capacity, we burn heating oil with characteristics: $Q_l^o = 38{,}97$ MJ/kg; S^o=2,6%; V^0=10,2 m^3/kg; V_G^0=11 m^3/kg. the operating factors are the following: α_F=1,05, α_{eg}=1,23, q_F=8 MW/m^2. It is necessary to determine the mass emission of sulphur oxide into the atmosphere. On the base of the initial data on the formulas (1) – (5) we determine: V_G=11,51 m^3/kg; S^*=0,226 kg·%/m^3; V^*=0,886; β=1,582·10^{-3}; α^*=0,853.

From fig. 1 we determine: r=0,95; and from fig. 2 – SO_3 ·103 ≈ 5. Than the value *A* in formula (7) will make up1,532, and value *m* on the nomographic chart in fig. 3 will equal 44 g/s. Detailed calculations of m using the methodic [3] give the result m=43,25 g/s. The above data show that the relative error in determining m on the suggested nomographic charts makes up 1,7 %, which is satisfactory for the engineering practice.

The main factors, influencing the mass emission of sulfur oxide, apart from S^p, are the factors of excess air in furnace α_F and heat stress of furnace cross section q_f. Dependences $m = f(\alpha_T)$ and $m = f_1(q_F)$ for high-sulfur residual oil, characteristics of which are mentioned above, and that of coal from Mizhrichnenske field of Lviv-Volynsk basin with the characteristics: Q_l^o=21,56 MJ/kg; S^o=3,1%; V^0=5,66 m^3/kg; V_G^0=6,09 m^3/kg [1] – are shown in Fig. 4 and Fig. 5 correspondingly.

Fig. 4 shows that for the similar burning modes of fuel, the emissions of SO_2 when burning coal are by 9 – 10% higher, than when burning heating oil. This is explained by the higher content of sulfur in the working mass of fuel. The biggest influence α_F on the value m is observed in the range of values 1,05 – 1,15. The increase in α_F by 0,1 results in the increase in mass emission of SO_2 by 2,8% for heating oil and by 3,2 % for the coal.

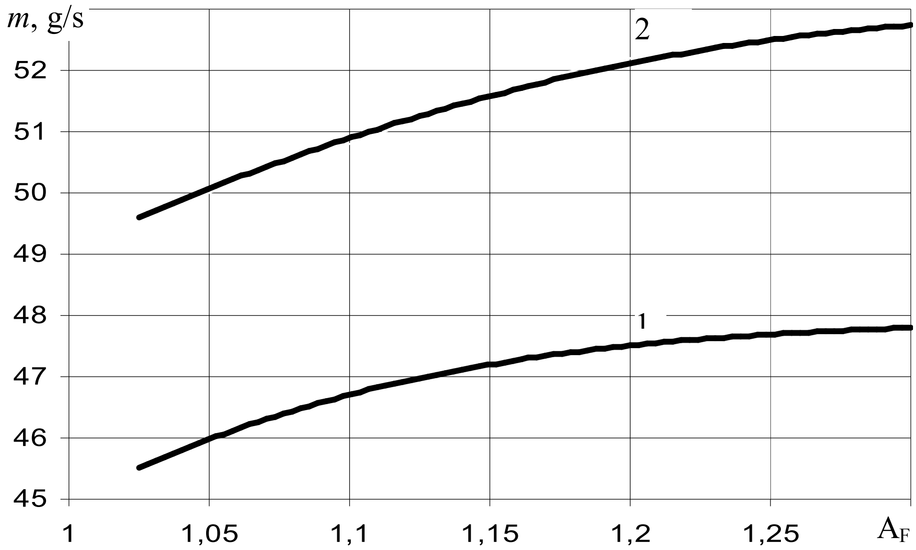

Fig. 4. Current values of mass emissions of sulfur oxide under condition that q_F=2 MJ/m^2, and air inflow ratio equals Δα=0,2; 1 – heating oil; 2 – coal

Fig. 5. Influence of q_F on the mass emission SO_2 under condition α_F =1,2 and $\Delta\alpha$ =0,2.1 – heating oil; 2– coal

Dependences, presented in Fig. 5, testify that the more forced burning of in furnaces favor the decrease in emissions of sulfur oxide. Increasing q_F by 1 MJ/m^2 we observe the decrease in SO_2 emissions in average by 1 % both, in heating oil and in pulverized-coal-fired furnace.

Conclusion

1. The constructed nomographic charts allow to determine the expected emissions of sulfur oxide when burnining heatng oil and coal in the furnace of power-plant boiler with sufficient accuracy for the engineering practice.
2. The secure decrease in emissions of SO_2 is achieved in case of decrease in factors of air excess in furnace and more forced burning of fuel.

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