FIRE AND INDUSTRIAL SAFETY (CIVIL ENGINEERING)

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DEVELOPMENT OF METHODS IMPROVING INDUSTRIAL SAFETY OF TECHNOLOGICAL PROCESSES IN ASPHALT-CONCRETE PLANT MIXERS

Problem statement. The problem of improvement of industrial safety of technological processes in mixers of asphalt-concrete plants is considered on the basis of analysis of organic impurities content in incomplete combustion products**,** and estimation of efficiency of purification of asphalt-concrete plant emissions in the presence of “wet” flue gas purification system is given.
Results and conclusions. It has been found that the efficiency of hydrocarbon fuel burning affects the amount of hydrophobic dust thrown into the atmosphere, and burning of heavy fuel oil is attended by significant incompleteness of fuel combustion, and this is connected with the processes of fuel dispersion and evaporation. The optimal measures for efficient combustion and cleaning of hydrophobic dust are described.

Keywords: industrial safety, incomplete combustion products, asphalt-concrete plant mixers, fuel burning efficiency, dispersion, fuel nozzle, heat losses, mazut.

Introduction

Industrial safety of technological processes in asphalt-concrete plants (ACP) is related to reduction of emissions into the atmosphere. The process of hot asphalt concrete mix preparation involves risk of non-compliance with required combustion mode. Incomplete fuel combustion results in significant increase in hydrophobic dust amount.

Hydrophobic dust amount depends on organic impurities content in emissions of ACP mixers.

Efficient mazut combustion in mixers of ACP is highly conjectural, especially in cold period.

In [1] it was established that there is high nonuniformity of temperature fields in ACP furnaces, as well as considerable incompleteness of fuel combustion. Experimentally determined efficiency of ACP furnaces in cold period is 60—65 %.

Mazuts used in ACP are characterized by high viscosity and significant sulphur content, which affects the yield of SO_2.

When mazut temperature goes down to the chilling temperature, mazuts loss their fluidity and acquire special viscous properties preventing them from discharge, transportation by pipes and spraying in fuel nozzles. In order to avoid undesirable deposits in pipes and their full plugging, it is essential to maintain constant temperature of mazut providing its fluidity.

According to the safety standards, maximum allowable temperature of mazut heating in open tanks should not exceed 95 ^{0}C. In closed tanks under pressure, in pipelines and coil pipes the temperature of mazut heating can be increased.

In ACP, the temperature of mazut heating in tanks is 75—80 ^{0}C.

The analysis of operation of furnace system of the mixer D-597A has shown that in operating conditions mazut remainder in the main pipe before the spray nozzle cooled to the ambient temperature has the viscosity more than 700 (relative viscosity). Cold mazut was expelled to the furnace and spread over the liner, leaking into the gaps between bricks. “Block” from cold mazut disrupted the normal operation of the plant.

Further researches have shown that liner destruction was typical at inferior operation of the furnace system and related to the formation of acids from sulphur oxides at the presence of water which always is present in mazut. As a result, the furnace was changed for the new one 2—3 times in a season.

Such furnace modes also hinder the work of the operator when using spray nozzles which have narrow range of efficient operation (with high completeness of combustion) by the coefficient of air excess in contrast to the swirl nozzles, which give rise to additional difficulties in the maintenance of stable combustion.

Available asphalt-mixing plants include burners with mechanical atomizing burner. Regulation of fuel consumption is effected by way of changing the pressure of mazut before the nozzle. Reduction in pressure results in deterioration of fuel dispersion, which leads to its excessive consumption.

Time of conversion of liquid components into the combustion products is determined by the time of heating and evaporation of the fuel drops, as well as by the time of mixing and combustion of remainder of the fuel.

The size of fuel drops affects the furnace length required to the complete combustion. Its reduced length (relation of the furnace length to the diameter) depends on maximum size of the fuel drops.

Important peculiarity of the sprayed liquid fuel heating is the difference in combustion rate of large (1000 mc) single drops, as was reported by Godsave, and smaller (53 mc) drops of sprayed fuel, as was described by Bolt and Boyle. It can be explained by the fact that ratio of flame radius to drop radius is 3:1 for larger drops, and approximately 19:1 for smaller drops.

These results correlate well with experimental findings of Wise, Lorell, and Wood. According to these data, distance from the drop surface to the flame front is constant and independent of drop radius. Increase in fuel amount burnt in a time t, can be determined on the basis of dependence (1):

$$dw = r \cdot Q^{n} \cdot dt, \tag{1}$$

where *dw* is the amount of unburnt fuel in a time *t*, %; *r* is the relative rate of reaction, parts of the fuel burnt for 1 sec; *Q* is the amount of unburnt fuel, %; *n* is the order of reaction. The amount of unburnt fuel *Q* depends on (2):

$$\varphi = \left(\frac{D}{D_0}\right)^2, \tag{2}$$

where D and D_0 are instantaneous and initial values of drop diameter, respectively.

Heat losses in operating processes in furnaces are least dependent on chemical processes (less than 1 %), on fuel component mixing (up to 2 %), on spraying and evaporation (up 8 %).

The model of economic feasibility of a furnace with consideration for fuel evaporation effects was proposed by Korse, Bikham, and Walker.

This model allows one to calculate heat losses depending on construction parameters, type of fuel, and operating conditions. Assessment of heat losses with consideration for evaporation reveals influence of the number of mixing elements and reduced length of combustion chamber on heat losses.

However, evaporation model described above not only permits one to determine heat losses but also gives rise to the necessity of analyzing mutual influence of different types of losses during combustion. Output parameters of evaporation model of heat generation (correlation of fuel components in vapor phase and part of evaporated fuel) are basic input data for the model economic feasibility which characterize mutual relations of the losses inside the chamber.

Thus, evaporation of mazut drops is crucial in assessment of the optimal length of furnace which provides minimum heat losses.

D. B. Spolding [3] considers that the length of furnace required to complete combustion proportional (3):

$$d^2 \cdot v_0 \cdot \rho_e / \mu, \tag{3}$$

where d is the diameter of the drop, v_0 is the speed of injection; ρ_e is the density of fuel drops; μ is the dynamic viscosity of the gas.

Assumption on possibility of obtaining the required efficiency of combustion in standard furnace at heating up to 100—110 ^{0}C ^{0}C at the nozzle inlet at the expense of reduction in mazut viscosity can be taken as confirmed with consideration for the fact that according to the evaporation model of D. B. Spolding, optimal length of the furnace required for complete combustion of mazut depends on the drop diameter squared.

In the absence of such heating determination of dispersion of mazut drops reveals considerable part of large-sized drops. As for such drops, the length of zone of evaporation and burning more than furnace length, which along with irregularity of the air excess coefficient is the reason for low efficiency of heat generation in ACP furnaces.

Fuel consumption standards set for ACP of each type, as a rule, are far exceeded. Examination has shown that operation of ACP changes noticeably in 2—3 years after the beginning of operation. Fuel losses in drum dryers of ACP, determined with the use of technique developed in BeldorNii (Belgorod Road Institute) are quite considerable and dependent on initial humidity of mineral materials. Increase in fuel losses in ACP with mixer Д-508 and Д-597 is of greater intensity than in ACP with mixers Д-645-3 and Teltomat.

For the purpose of improving fuel combustion we propose to change the design of combustion assembly for air supply in combustion chamber along the tangent (cyclone furnace); to feed air, thus cooling furnace muffle; to feed additional air in drum dryer, thus making “two-chamber” fuel combustion.

As heat-stress of furnace decreases, low-temperature carbon-black emission occurs accompanied by yield of benzapirene.

Study of this problem shown that the temperature of decomposition of benzapirene molecules is not less than 1100 ^{0}C, curing time is 10 sec, which also requires well-organized mode of fuel combustion.

At the stage of experimental research in ACP of Voronezh we conducted researches on estimation of content of organic impurities and evaluated the efficiency of wet dust collectors.

Significant amount of sulfur oxidants in furnaces of ACP (maximum values of mass emission of sulfureous anhydride is 4.75 g/sec) poses the problem of use of gas as ecologically clean fuel instead of mazut.

Content of organic impurities was determined by ignition of dried specimen at 600 ^{0}C and measured 1.31—2.01 % of fuel amount (Table).

Table

Content of organic impurities

Setup	Time of sampling	Content of organic impurities, % of mass			Mean value, % of mass
		I	II	III	
Mixer Д-508-2 (dry and wet purification)	May (I)	1,62	2,01	1,31	1,98
	June (II)	1,87	1,81	1,81	1,83
	September (III)	1,58	1,64	1,66	1,63
Mixer Д-117-2К (dry purification)	September (IV)	1,87	1,87	1,74	1,83

Tabulated results shows that content of organic impurities reaches 2 % in spite of the fact that heating of raw materials is performed by gas. This will serve to increase in content of hydrophobic dust and reduction in efficiency of the systems of aftertreatment of emissions (wet stages of dust collectors).

It should be borne in mind this content can increase several times when using liquid hydrocarbon fuels and especially mazut.

Considerable amount of suspended particles contents in their surface products of fuel incomplete combustion.

To increase efficiency of dust collecting in “wet” stage of purification, we conducted full-scale tests on mixer Д-508-2 adding penetrating agent ОП-7 (ПАВ) to water of dust collector. Dust collector of the mixer consists of two stages: the first stage is 4 cyclones СДК-ЦН-33; the second stage is the cyclone-washer СИОТ.

It was established that use of washer ОП-7 in СИОТ makes it possible to increase the efficiency of “wet” stage, which is important in respect of hazar dust of size less than 10 mcm [2].

Figure shows the dependence of dust collecting efficiency on concentration of penetrating agent ОП-7 at “wet” stage.

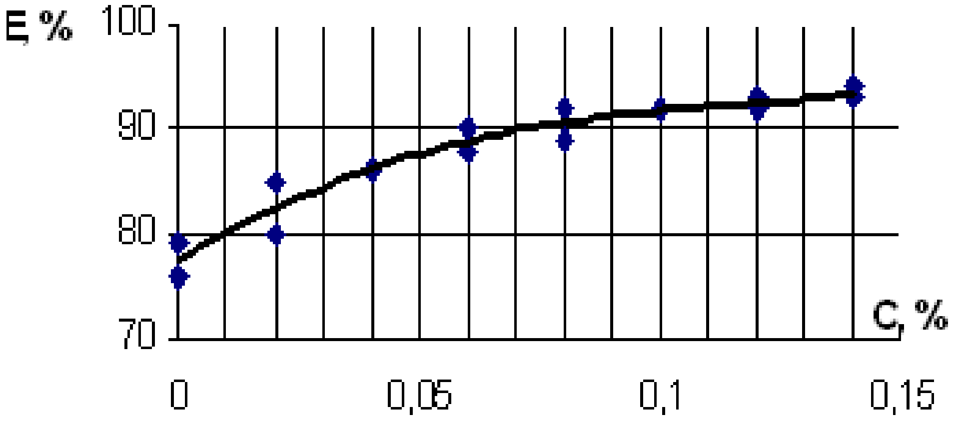

Fig. Dependence of dust collecting efficiency ε on concentration C of wetting agent ОП-7

It is obvious that satisfactory value of efficiency is obtained at concentration of penetrating agent C=0.1 % (ε=92.7 %), which determines minimal cost for ОП-7 when fulfilling standard requirements to the purity of gases proceeding from ACP.

Conclusions. Reduction in mazut viscosity in heating up to 100—110 ^{0}C facilitates increase in efficiency of fuel combustion, improve heat-stress of furnace, leads to reduction in emission of harmful substances, including benzapirene, decreases the amount of hydrophobic dust.

References

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