Utilizing wastes of related industry branches in composition of water-containing fuel slurries

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A large number of various industrial wastes are generated annually in large and medium-sized cities. Technologies for their processing are not always widely used due to high economic expenditures. Direct combustion or storage of industrial waste is rather dangerous and leads to significant environmental pollution. Significant means are spent for the waste transportation and maintenance of industrial waste dumps. In addition, huge areas are allocated for the storage of waste, which can be used in a different way. In this situation, it is possible to utilize combustible industrial waste by involving them in the fuel and energy cycle.

The study addresses the involvement of combustible industrial waste in the energy sector as the main or additional components of slurry fuels for combustion in boilers. We focused on energy, environmental and economic parameters of the using slurries in comparison with traditional energy resources: coal and oil. Obtaining basic estimates of the energy, environmental, and economic parameters of the combustible waste utilization as a part of composite fuel slurries will create a scientific basis for: (i) large-scale waste utilization; (ii) obtaining an alternative energy source; (iii) a potential reduction in emissions of harmful oxides as a result of a decrease in the amount of coal dust that is combusted at high temperatures.

We considered the following potential components of fuel slurries: coal slime; coal flotation waste (filter cake); coal middlings; peat; solid residue of tire pyrolysis; sawdust; used turbine oil; heavy oil; rapeseed oil. The following fuel compositions were prepared: (1) 20% coal slime, 30% filter cake, 40% wet sludge deposits, 10% peat; (2) 15% coal slime, 25% filter cake, 10% sawdust, 50% wet sludge deposits; (3) 20% coal slime, 30% filter cake, 40% wet sludge deposits, 10% used turbine oil; (4) 15% coal slime, 25% filter cake, 10% tire pyrolysis waste, 50% sludge deposits; (5) 20% peat, 30% filter cake, 40% wet sludge deposits, 10% rapeseed oil; (6) 20% coal slime, 30% filter cake, 10% crude oil, 40% wet sludge deposits.

The method of fuel preparation, experimental method and experimental setup are similar to those described in (Kuznetsov *et al*, 2018). The experimental technique is based on heating a fuel sample in a model combustion chamber. A more detailed description of the procedures and errors of the used method is given in (Dmitrienko *et al*, 2018; Kuznetsov *et al*, 2018).

The ignition temperatures of slurries of different compositions lay in a narrow range of 430–460 °C. The maximum combustion temperatures of the solid residue for slurries of different compositions were ranged from 987 to 1080 °C. Heterogeneous ignition of the solid part of the fuel is realized after the intensive phase of the gas-phase flame burning. The duration of this phase depends on the amount of volatiles in the fuel organic mass and the rate of their combustion, which is determined by the calorific value. The energy released during the combustion of gas-vapor mixture contributes to the additional heating of the solid residue of the fuel. The droplet surface temperature increases and heterogeneous ignition of the fuel solid part is realized. Video frames of droplet combustion are shown in Fig. 1.

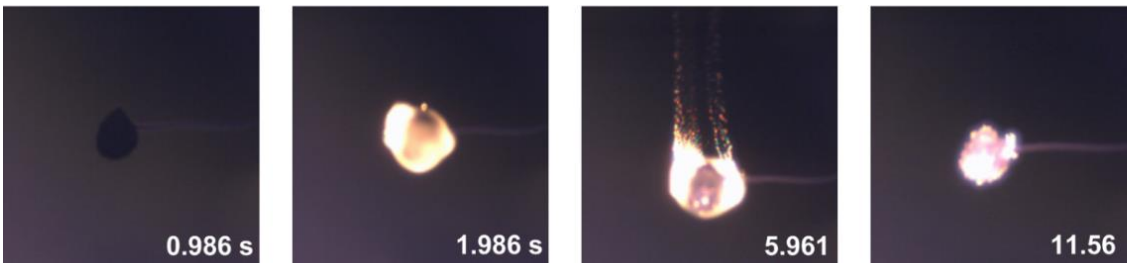

Fig. 1. Video frames showing combustion of fuel droplet (20% coal slime, 30% filter cake, 40% wastewater, 10% peat) at a temperature in the muffle furnace of ≈700 °C.

Fig. 2 shows the maximum concentrations of sulfur and nitrogen oxides in the combustion products of waste-derived slurries. Even the most unpromising composition (with the addition of crude oil) from an environmental point of view gives 6% less emission of NO_x and 29% less emission of SO_x compared with coal dust.

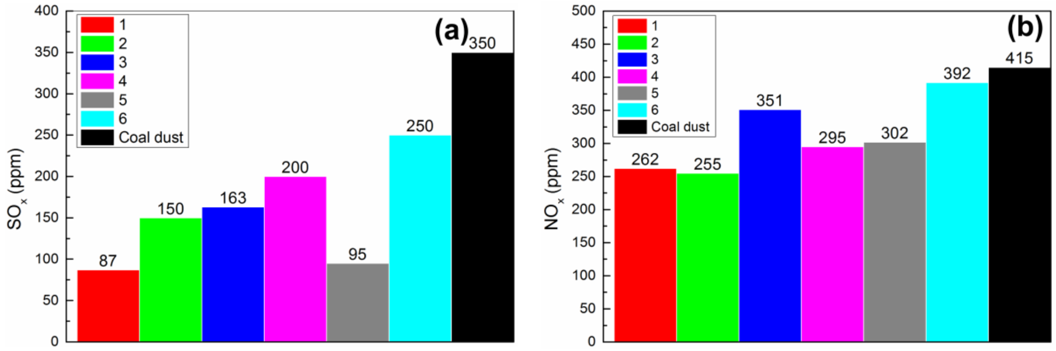

Fig. 2. Concentrations of sulfur (a) and nitrogen (b) oxides in the combustion products of waste-derived slurries and coal dust at combustion chamber temperature of 1000 °C.

To compare new waste-derived fuels and traditional boiler fuels (coal, fuel oil), a relative indicator was calculated (in accordance with the approach (Dmitrienko *et al*, 2018)), taking into account the combustion heat, cost, and environmental hazard of the fuel (by emissions of sulfur and nitrogen oxides). Fig. 3 illustrates the results of the calculation of this relative indicator ($D_{relative}$ is indicator of the use efficiency of composite fuel relative to coal or fuel oil).

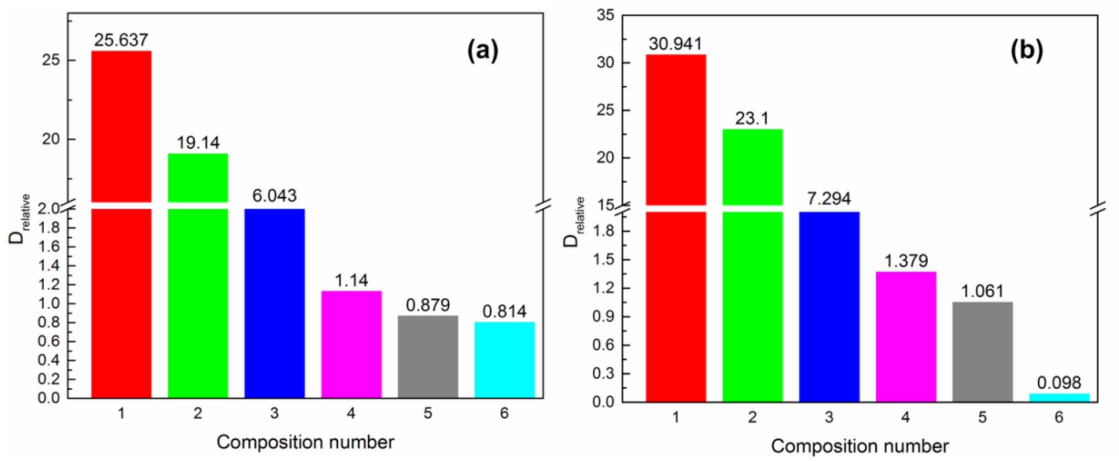

Fig. 3. Indicator of the use efficiency of composite slurry fuel relative to coal (a) and fuel oil (b).

According to the final relative indicator, two most promising compositions can be distinguished: (1) 20% coal slime, 30% filter cake, 40% wet sludge deposits, 10% peat and (2) 15% coal slime, 25% filter cake, 10% sawdust, 50% wet sludge deposits. These fuels are the best among the considered slurries by the set of the considered characteristics in comparison with coal and fuel oil (Fig. 1). Indicators of coal and fuel oil correspond to the 1. If the indicator of the fuel composition is greater than 1, this means that it is superior to coal or fuel oil, by the sum of its characteristics. Such high rates of fuel slurries are due to low emissions from combustion and the low cost of all components.

The results illustrate the great potential for conservation of natural resources and reducing anthropogenic effect of industrialized cities on the biosphere, because annually over 1,500 million tons of industrial waste can be utilized by combustion as a component of composite fuels. Globally, about 14–20% of coal and fuel oil can be saved by large scale combustion of waste-derived fuels. Despite a number of disadvantages (in particular, the ignition complexity and reduced combustion heat), the studied slurries can be recommended for the use in thermal power industry for large-scale waste utilization, reducing emissions (compared to pulverized coal plants) and expanding the resource base of the energy sector.

Acknowledgments

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References

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