STATISTICAL ANALYSIS OF CONSEQUENCES CAUSED BY THE COLLISIONS OF SOARING DROPS OF ORGANIC COAL-WATER FUEL

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Abstract. The paper examines the processes of collision of the soaring organic coal – water fuel (OCWF) drops in the specialized combustion chamber in case of direct injection of suspension with the subsequent crushing, decay and coagulation. High speed video registration is used. The fuel composition is prepared with the use of a coal conversion waste (filter-cake "G"), turbine oil waste, water and a plasticizer. The statistical analysis of consequences of impingement of OCWF drops at their movement in an oxidizer flotation (temperature is about 800-840 K) with their following deformation is carried out. The conditions when the processes of coagulation, disintegration or crushing of drops are dominated are established.

1 Introduction

More and more growing interest in creating and applying organic coal –water fuel (OCWF) [1] on the basis of numerous waste oil products, waste oil, low-grade coal, the filter-cakes and others. Effective utilization of waste by incineration in thermal power plants is an urgent task at present. The basis for the creation of OCWF was the use of coal-water fuel [2] .Now accumulated a large amount of experimental research data [3, 4, 5].

To determine the characteristics of ignition particles OCWF (or groups of particles) without the use of holders developed an experimental technique that provides its wool-oxidant environment using specialized combustion chambers [6]. For the aggregate, group, set or stream of droplets soaring to play a decisive role droplet collision processes (crushing, coagulation, decomposition). It is therefore of interest in experimental research of factors the effects of collisions drops OCWF flying at them in the oxidant flow. Consequences of collisions of drops of fuel were studied by the statistical analysis of experimental data. Assessments of results allow predicting to what share of probability these events can happen.

The purpose – establishment and registration of characteristic consequences of collision of drops of OCWF with each other soaring in a flow of an oxidizer and their subsequent ignition in the combustion chamber as a result of statistic analysis of the obtained experimental data.

2 Experimental setup and study technique

The technique is similar to the experimental studies described in the paper [6]. Organic coal – water fuel were prepared using the following components (with the indicated concentrations of mass) filter-cake grade "D" (89 %), the exhaust turbine oil (10 %) and a plasticizer (1 %). To a suspension of the fuel injection flow (7) unused T-mixer (5), one of which is fed the compressed air channels (4), and in the second – OVUT (6). The air pressure was 200 kPa. The amount of fuel used was 4 ml. This system made it possible to generate fuel droplets of different sizes. The average droplet size of the injected OCWF R_d varied in the range of 0.1-1 mm.

The specialized combustion chamber from optically transparent quartz glass (Fig. 1) was used to a research of processes of crushing, coagulation and decay of drops of OCWF with characteristic formation of agglomerates. The mechanism (3) by rotating speed about 400-600 RPM, causing oxidizer flow turbulence, set in the lower part of the combustion chamber was used to support of optimum conditions of a flying, speed of movement of particles and agglomerates of organic coal –water fuel rotational propeller. Processes of crushing, coagulation and decay of the soaring OCWF particles, and also their sizes registered using system the high speed Phantom video camera with a frequency of 500 frames per second.

The initial rate of motion of the drops and the speed of the oncoming stream of the oxidant varies between 2.5-3.3 m / s and 3.2 m / s, respectively. The average temperature T_g oxidizer into the combustion chamber was about 820 K. The

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oxidizer temperature measurement is carried out by two chromel-alumel thermocouples (range 273-1373 K, accuracy ± 3 K, the inertia 3 sec.), through the technological hole (10).

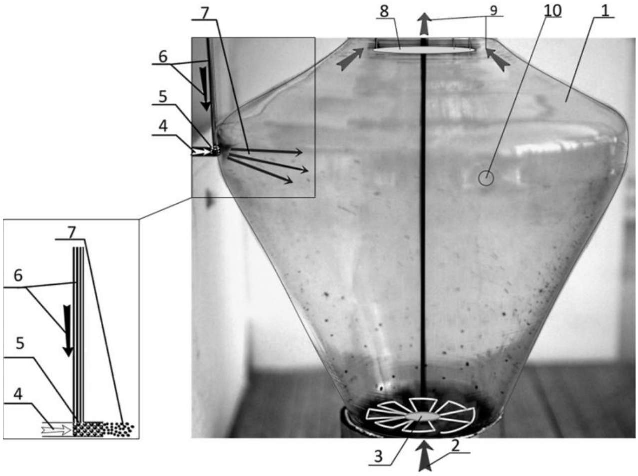

Fig. 1. Specialized combustion chamber: 1 – chamber wall heat-resistant optically transparent quartz glass; 2 – initial oxidant stream; 3 – rotary vane mechanism; 4 – Compressed air supply channel; 5 – T-mixer; 6 – channel for supplying OCWF; 7 – OCWF stream of particles; 8 – oxidant flow restrictor; 9 – oxidant stream at the outlet from the chamber; 10 – technological hole for temperature measurement.

3 Experimental results

As a result of processing and statistical analysis of the experimental data set three possible consequences of a collision soaring drops OCWF: crushing drops into smaller drops, coagulation (clumping OCWF particles agglomerate formation) and the decay of particles (collision of coagulated particles without substantially changing the size) for a certain interval time. The processes of fragmentation and coagulation were reported from the beginning of the injection of fuel into the combustion chamber suspension until its completion, the duration of which was about 8 sec. During the collapse of the agglomerates formed OCWF observed before the start of steady particle ignition. Typical effects of the collision and deformation of two drops of fuel are shown in fig.2, fig. 3 and fig. 4. All figures are depicted sequence of video frames (a, b, c) with the large-scale increase in the area of the collision in the inset on the left.

The next stages of phase transformations are the ignition and combustion of the fuel. From fig. 5 (a) shows that the two particles are of irregular shape with the local region are moving towards the ignition. Further, these particles collide (fig.5, b), there is an intensive volatile products with the formation of a common flame front. After the collision, the particles scatter OCWF (fig. 5, c) in the part and the process can be repeated. These effects largely depend on the size and configuration of the particles, as well as associated aerodynamic forces. To intensify the ignition and combustion processes it is important to consider the consequences of colliding drops incendiary. The main mass of the particles at the same time are lit separately.

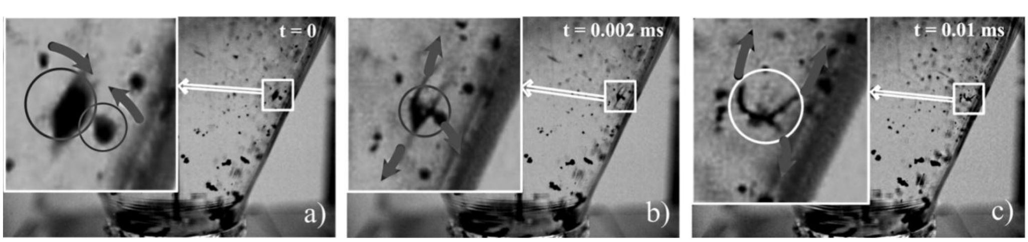

Fig. 2. Chipping OCWF drops.

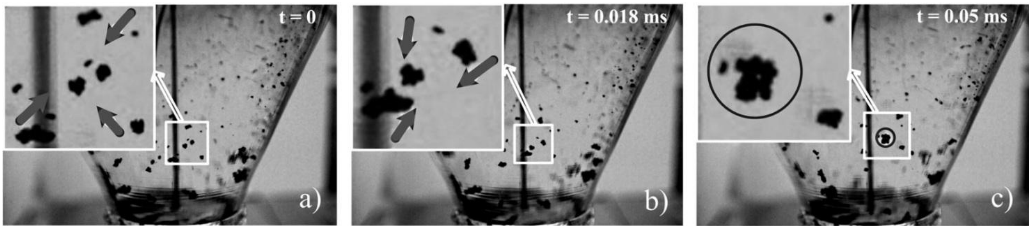

Fig. 3. Coagulation OCWF drops.

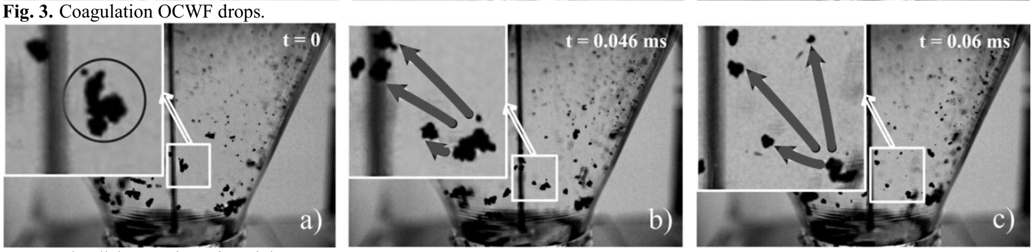

Fig. 4. The disintegration of particles OCWF.

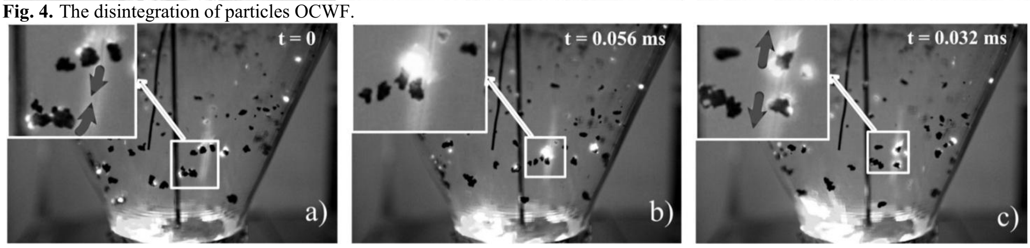

Fig. 5. Collision incendiary particles OCWF.

On the basis of experimental data is a bar graph fig. 5 probability P_1 (crushing), P_2 (decaying), P_3 (coagulation) of occurrence of the collision of two or more OCWF drops in the wool-oxidant stream. It was found that all these processes take place at different vibrations R_{d1} and R_{d2} particle size, defined their ratio, respectively, for the crushing of 0.2-1.7 mm, the decaying of 0.2-1.9 mm, the coagulation of 0.1 - 2.3 mm. Probability values of P_1, P_2, P_3 was evaluated by treating the amount of 50 collisions.

At calculation of values formulas have been applied:

$$P_1=N_1/(N_1+N_2+N_3),\ P_2=N_2/(N_1+N_2+N_3),\ P_3=N_3/(N_1+N_2+N_3),$$

where N_1, N_2, N_3 – number of collisions as a result of which three options of events are implemented: crushing, decaying and coagulation.

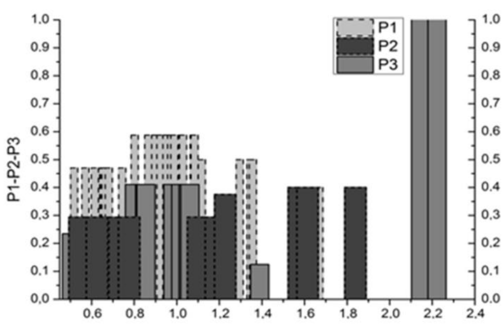

Fig. 6. Statistical analysis of the consequences of the collision of two drops OCWF in their wool-oxidant stream, depending on their size.

The analysis of the histogram shows that probabilities of emergence of crushing (P_1) and coagulation (P_3) of drops of OCWF at a ratio of the R_{d1}/R_{d2} sizes from 0.2 and 2.2 are made by about 50 % and 30 %, respectively. About 20 %

fall to the share of probability of disintegration of agglomerates. While a ratio of the R_{d1}/R_{d2} sizes of two pushing together drops fuel suspensions it is close to 1, probabilities of crushing and coagulation are almost comparable, 60 and 40 %. At the same time at the same time at a stream of an oxidizer there are damp and dry particles of fuel. As viscosity of drops of OCWF at a stage of injection of fuel suspension rather big, is observed domination of processes of crushing and coagulation. With parallel oxidant effect of temperature decreases the viscosity OCWF drops and an increasing number of dehydrated particles. Therefore there is a high probability of the formation of agglomerates. But it is not ruled out the probability of disintegration of agglomerates formed during their combustion chamber flying. In the intermediate case (R_{d1}/R_{d2} between 1.5 and 2) the probability of coagulation is practically not observed, and the likelihood of fragmentation and disintegration of the same. Once the ratio R_{d1}/R_{d2} size increases to 1/1.5, the coagulation of the droplets become quite rare. When the ratio of fuel particle sizes larger R_{d1}/R_{d2} = 2 the probability of coagulation rapidly increased to P_3~1 and the process begins to dominate.

4 Conclusion

The analysis of singularities collision OCWF hovering particles can be concluded that for efficient ignition and combustion nozzle unit OCWF structure should provide optimum ratio of air flow rate and uniformity of droplet size. This will lead to a decrease in coagulation factors that respectively increase fullness and reduce fuel burn incomplete combustion. In the experiments carried out, the ratio R_{d1}/R_{d2} size was not more than 1/1.5. It is important to note that the probability of droplet collisions OCWF processes not only depends on the droplet size and the velocity of their movements, the amount of fuel particles per unit volume of the chamber, and defined oxidant parameters.

The study was performed by a grant from the Russian Science Foundation (project 15-19-10003).

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