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Editorial

Research into Energy Production from the Combustion of Waste-Derived Composite Fuels

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The most prominent issue of using solid fossil fuels is their high anthropogenic emissions. This limitation can be overcome by implementing technologies aimed at using composite fuels consisting of more environmentally friendly components than coal. The most promising components are coal slime, used oils, filter cake, etc. Water in the composition of composite fuels has a significant effect on the integral characteristics of their ignition and combustion. While reducing the energy indicators of fuel combustion in boiler furnaces, it substantially cuts nitrogen and sulfur oxide emissions.

The Special Issue "Sustainability of Fossil Fuels: Properties, Preparation, Transportation, Spaying, Combustion" generalizes the findings of recent studies addressing global environmental, energy, and economic issues by increasing the efficiency of fossil fuel combustion. The research fields of interest for the Special Issue include:

- ✓ Industrial and municipal waste recovery (specific aspects of combustion, emissions, and the economic effects of switching combined heat and power plants to composite fuels);
- ✓ The ignition of slurry fuel droplets with different heating conditions;
- ✓ The effects of pyrolysis temperature and retention time on the fuel characteristics of food waste feedstuff and compost for co-firing in coal power plants;
- ✓ The interaction of liquid droplets in aerosols under conditions corresponding to high-potential gas-vapor technologies;
- ✓ Using natural gas hydrates as an alternative energy source.

It is important to generalize the findings of fundamental and applied studies published in the Special Issue. The practical applications and methods of research in the Special Issue papers are presented in Table 1.

Glushkov et al. [1] experimentally investigated the combustion characteristics of droplets of composite fuel consisting of wet coal processing waste, municipal solid waste, and used turbine oil. The comparison of the ignition delay times and emission concentration ranges from the combustion of a filter cake and composite fuels revealed that the latter are characterized by lower ignition times and the emission of harmful substances. A strategy was proposed for the combined recovery of industrial and municipal waste that suggested burning it together with composite fuels. Switching three typical coal-fired thermal power stations to composite liquid fuel was put forward. The conducted feasibility study concluded that the economic effect of implementing the developed strategy of industrial and municipal waste recovery for 25 years will make up 5.7 to 6.9 billion dollars.

At the same, time Li et al. [2] suggested using pyrolyzed food waste (compost and feedstuff) as fuel additives. The temperature and time of the pyrolysis were shown to affect the higher calorific value of compost and feedstuff. A high content of calcium in the examined samples had a negative effect on the slagging and fouling indices. It was concluded that salt should be removed from pyrolyzed food waste for it to be used as a co-firing fuel.

When studying the ignition and combustion of liquid fuel droplets [3], four methods of heat supply were considered: a muffle furnace providing radiant heating; a hot surface

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to reproduce the conditions of conductive heating; a high-temperature channel with convective heating; chambers with floating processes, i.e., when the fuel is in a combustion chamber. It was established that the most efficient method for minimizing the ignition delay times and threshold temperatures of initiating combustion is convective heating of the fuel. The maximum ignition delay times were recorded in radiant heating. Three regimes of coal slime particle ignition and combustion were identified: flame combustion, smoldering, and micro-explosion.

Table 1. Practical applications and methods of research in the Special Issue papers.

Work	Application	Methodology
[1]	Industrial and municipal waste recovery	Muffle furnace, high-speed video recording
[2]	Fuel technologies	Heating of the fuel particles on the hot surface; heating of a fuel particle on the holder in the flow of heated air; heating of the fuel particle in the conditions of intense radiation heating on the holder
[3]	Fuel technologies	Pyrolysis equipment; technical analyses; elementary analyses; Fourier transform infrared (FTIR) spectroscopy; combustion ion chromatography
[4]	Gas-vapor-droplet technologies, fuel technologies, spray drying	High-speed video recording under model conditions corresponding to promising gas-vapor-droplet applications
[5]	Fuel technologies	High-pressure reactor

Wang et al. [4] considered gas hydrates as an alternative energy source. The effect of the size of particles on hydrate dissociation and sediment deformation was experimentally studied. A setup was designed to explore sand production and sediment deformation during the thermal decomposition of gas hydrates. Gas, water, and sand production behaviors during the hydrate dissociation were analyzed. The decomposition rate during heating was shown to be proportional to the particle size of the sediment: a decrease in the sediment size led to a lower heat transfer rate and energy efficiency. Wang et al. attributed it to the fact that an increase in the particle size of the sediment caused higher permeability. It was concluded that sediment deformation should be taken into consideration in the dissociation of hydrates during thermal impact.

It is possible to enhance the ignition and burnout completeness of composite fuels, as well as reduce the anthropogenic emissions and cover a larger area with water by using their specialized atomization during spraying. Sprayed fuel enters the furnace as a droplet flow. Demidovich et al. [5] investigated the interaction of liquid droplets in a gas flow. A statistical database with the characteristics of droplet collisions in aerosols was created. It takes the ratio of droplet sizes, relative velocity, and impact angles, surface area and shape of droplets, angular and linear impact parameters, as well as typical similarity criteria (the Weber, Reynolds, Ohnesorge, Laplace, and the capillary number) into account. It was established that droplet collisions in a gas environment can increase the surface area of a liquid by 1.5–5 times. Such substantial changes to the surface area of liquid can significantly enhance the heat exchange and phase transformations in energy systems.

Most of the papers in the Special Issue emphasize an important scientific objective showing the need for the development of solutions for the rapid primary and secondary atomization of composite fuel droplets that may contain two to five–seven substances in their composition. These fuels are highly viscous compositions. Their atomization can ensure improved ignition and burnout completeness. It is unreasonable to raise the pressure at the nozzles, as it increases the mechanical wear of surfaces due to friction. Thus, it appears relevant to develop the technologies of the secondary atomization of droplets and particles as a result of their collisions with each other, with heated walls, and with a gas jet, as well as superheating them to the water boiling. These objectives dictate worldwide trends in the area of composite fuels consisting of several components [6–14].

When conducting research into the integral characteristics of composite fuel spraying, it is especially important to study the collisions of droplets with particles making up these fuels. Controlling the collisions of droplets with particles to achieve a particle size of the droplet flow specific to each of the applications during the secondary (additional) atomization of the liquid using nozzles enhances the heat and mass transfer in several industrial applications: fuel systems, firefighting, sprinkler systems, and heat exchange units [1–5]. In particular, the efficiency of capturing particles in dust-collecting equipment can be improved by including additional impacts facilitating the agglomeration of particle droplets (i.e., conditions when their steady merging occurs) [5]. Creating conditions that lead to the additional atomization of liquid droplets due to their collisions with particles increases the efficiency of cool spraying of high-power equipment due to an increase in the free surface area of cooling and reduces the ignition delay times of fuel droplets [15–17].

The secondary atomization of composite fuel droplets makes it possible to cut the time and energy expenditure on the generation of a droplet flow with a required particle size. However, there are some challenges associated with the technologies of spraying liquids with significantly inhomogeneous compositions. For instance, spraying fuels consisting of particles of different sizes and properties may clog the flow channels of nozzles. This prevents the continuous and even supply of fuel to the combustion chamber. In this respect, the technologies of particular interest are the ones that imply the preparation of composite fuels directly in a combustion chamber, when their components are supplied separately by the intersection of the flow of droplets and particles. A special science and technology problem is presented by the studies focusing on the conditions of the interaction of droplets with particles and with other droplets containing particles of different shapes, sizes, concentrations, and those possessing different properties.

In practical terms, an important objective is to build up an information database of the key characteristics of the collisions of droplets containing solid particles from different materials of different shapes, sizes, and concentrations in high-temperature gas-vapor-droplet flows. These characteristics include interaction regimes, numbers, shapes, sizes, velocities, trajectories, and the component composition of secondary fragments. A group of parameters (sizes, shapes, velocities, impact angles of droplets and particles, properties of the materials of particles (density, porosity, hydrophilic, and hydrophobic properties, etc.) and liquid droplets (density, viscosity, surface, and interfacial tension), and the ratio of the concentrations of liquid and solid particles) are to be varied in the ranges typical of fuel technologies. It is also necessary to establish the effect of the above factors on the ignition and combustion behavior of composite fuels.

Five papers on the properties, spraying, and combustion of fossil fuels and fuels derived from waste and biomass were published in the Special Issue "Sustainability of Fossil Fuels: Properties, Preparation, Transportation, Spaying, Combustion". These proposed different ways of solving environmental, energy, and economic problems by increasing the efficiency of fossil fuel combustion. This paper generalizes the findings obtained in [1–5]. The presented results will be put to good use in practical applications, helping to reduce anthropogenic emissions and improve the efficiency of burning composite fuels based on different waste, hydrocarbons, alternative fuels, and additives.

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