MATEC Web of Conferences **19**, 01004 (2014)
DOI: 10.1051/matecconf/ 20141901004

The mechanism of gas-phase ignition of solid fuel particles with local heating

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Abstract. The ignition of the dispersed wood by the heated to high temperatures single metallic particles of the fixed sizes are experimentally investigated. It is established that delay time the ignitions of sawdust insignificantly are differed from analogous values for the distillate fuel. The obtained results also make it possible to make conclusions about the high fire hazard of technological processes products of which they are the fine dispersed withdrawals of wood.

1. Introduction

Study of the ignition processes and combustion of solid dispersed flammable substances is the basis for engineering methods of fire protection of buildings and structures, processes and equipment, as well as ensuring the safety of people. Waste wood processing industries on the one hand are sufficiently promising energy [1,2], but on the other hand correspond flammable materials [3,4]. Eventual various scenarios of ignition such waste, the most dangerous of which are wood dry sawdust. One of the typical heat sources during ignition this condensed matter can be heated to high temperatures metal and non-metal particles formed, for example, during the repair work. Despite the high risk of fire wood waste to date, no models on the basis of which to formulate the conditions of ground wood fire and evaluate the ignition delay time depending on the initial temperature of the heat source. Mathematical models developed to describe the process ignition monolithic fuel compositions [5], wood, as well as liquid fuels [6], applied to the conditions unverified ignition dispersed flammable solids local heating sources. Also waste from woodworking industry are discussed in recent years as a promising technology for the thermal conversion of woody biomass to produce biogas and biofuels. Determination of temperature ranges and mechanisms of processes of thermal decomposition of different types of wood will improve the theory by termo-conversion of biomass processes and develop the most energy-efficient processing of biofuels.

The aim of this work - an experimental study of the laws of ignition dispersed dry wood heated to high temperatures (1000 K) metal and non-metal particles.

2. Experimental research methodology

Studies were conducted on the experimental setup [7] with the registration of the initial temperature of the particles (T_p) and the ignition delay time (τ_{ign}). As the local heat sources were chosen ceramic

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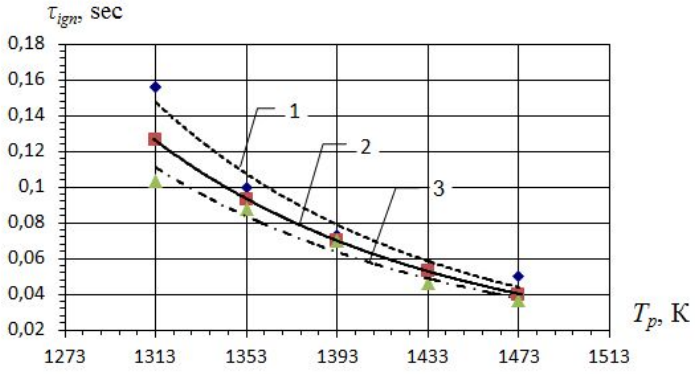
(alumina based (Al_2O_3)) and steel particles in the form of a disk with a fixed diameter (d_p= $6\cdot10^{-3}$ m) and thickness (h_p= $3\cdot10^{-3} \div 7\cdot10^{-3}$ m). Studied the conditions and laws of ignition of dry sawdust of pine. Dry sawdust had a characteristic size 1,5-$2\cdot10^{-3}$ m and matched typical sawmill waste process. Sawdust humidity was about 8-10%. Sample investigated material (≈ 20 g) was placed in a glass container of small dimensions so that the thickness of the timber layer was dispersed at 0,003-0,0035 m area of about 0,001 m^2. Heating the steel and ceramic particles held in a heating furnace of similarly [7]. When reaching the planned temperature, the particle discharged from the heating chamber at a fixed height of 0.15 m on the surface layer of the dispersed timber. Points of contact the hot particles with surface of the dispersed solid fuel and flame appearance were determined using High-Speed Video Camera. Carry out video footage of each experiment. The ignition delay time is determined after processing video recordings as time difference flame appearance and time to determination contact with the sample of the heat source crushed fuel. In order to assess the random errors of time-delay ignition experiments were performed under identical conditions (for fixed main factors affecting the process) at least 6 times in a row. Systematic errors measuring the initial particle temperature T_p and the ignition delay time τ_{ign} caused by errors of the means of measurements did not exceed 3% [6]. Found that during the fall of the surface temperature of the steel particles decreased by no more than 3-4 degrees. This deviation can be neglected in the analysis, as in the experiments of the metal particle temperature is not less than 1313 K.

3. Results and discussion experimental research

Figures 1-3 show the obtained values of the experiments performed τ_{ign} The curves are plotted as a result of approximation the experimental data. Approximation curves were obtained by least squares. Random error in determining τ_{ign} (relative mean-square deviations) were not more than ± 15% for the two fuels. The absolute values of the ignition delay times sawdust steel particle (Figure 1) were not significantly different from those values for diesel fuel (Figure 2). This result is probably due to a combination of factors. First - a significantly lower arrival rate of the fuel (for wood waste is gaseous products of thermal decomposition of the material) to the external environment oxidant (air) compared with the product of evaporation of liquid fuels. On the other hand for the gasification of wood spent a lot less energy compared to liquid combustibles and temperature pyrolysis gases significantly higher evaporation temperature of the products any liquid fuels. As a result, the concentration of combustible gases in the air during the thermal decomposition of the wood is less than the evaporation of liquid fuels, but the temperature of the gases above. It plays a big (compared to the concentrations) in connection with the role of the character according to the rate of chemical reactions on the temperature and concentration.



Figurte 1. Experimental dependences of the ignition delay of pine sawdust from the initial temperature of the steel particles: *1* – hot particle h_p=$3\cdot10^{-3}$ m, *2* – hot particle h_p=$5\cdot10^{-3}$ m, *3* – hot particle h_p=$7\cdot10^{-3}$ m.

It should also be noted that a comparison of the results of experimental studies of ignition dispersed pine steel (Figure 1) and ceramic (Figure 3) particles shows that the deviation from the values of τ_{ign} (under the same T_p) reach no more than 40%. One can conclude that the thermal and physical characteristics of the materials from heating source affect the characteristics of the ignition process of the dispersed wood such particles.

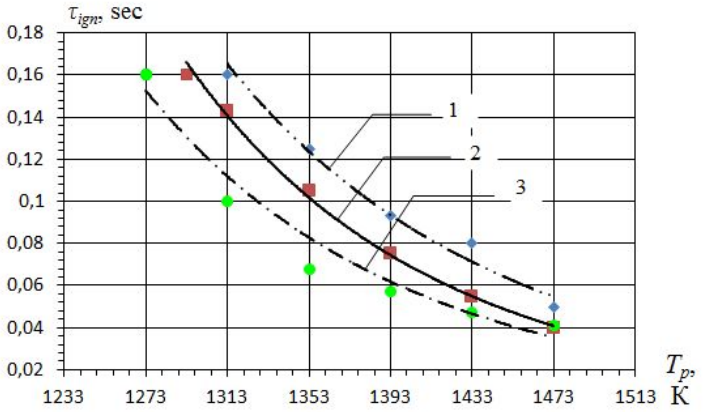


Figure 2. Experimental dependence of the ignition delay of diesel fuel from the initial temperature of the steel particles: *1* – hot particle $h_p=3\cdot10^{-3}$ m, *2* – hot particle $h_p=5\cdot10^{-3}$ m, *3* – hot particle $h_p=7\cdot10^{-3}$ m.

Based on the analysis of the experiments video can formulate a physical model of the ignition non-fire-rated substances dispersed with local heating. Sizes of single fragments sawdust significantly smaller than the characteristic dimensions of the heat source. A falling out heated to a high temperature particles on the surface of dispersed layer the wood intense heat supply is carried directly in the wood and the air gaps between the individual fragments of the bulk material. A occur rapid heating of a single fragment the wood and its thermal decomposition. Thus the energy of this fragment the draw aside bad - air enough good thermal insulator.

The structure of the porous layer of sawdust are usually such that the convective heat transfer in this layer is negligible. As a result, a rapid heating of the single fragment to a high temperature at which the wood is decomposed intensively release gaseous products (fuel for the subsequent reaction with an oxidizing agent - air). This result suggests the possibility of using gas-phase ignition models in mathematical modeling of this process for dispersed the wood.

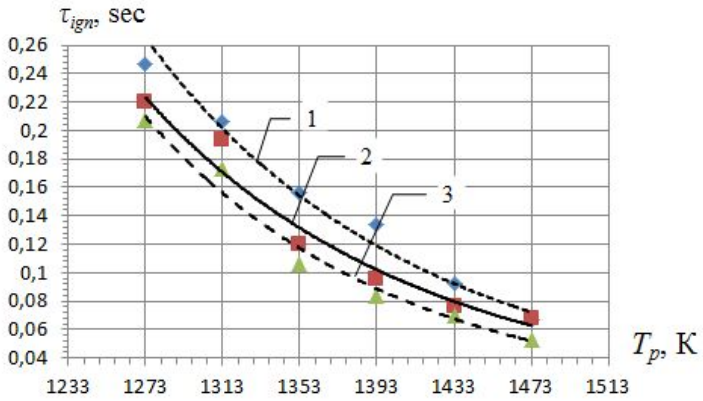


Figure 3. Experimental dependences of the ignition delay of pine sawdust from the initial temperature of the ceramic particles: *1* – hot particle $h_p=3\cdot10^{-3}$ m, *2* – hot particle $h_p=5\cdot10^{-3}$ m, *3* – hot particle $h_p=7\cdot10^{-3}$ m.

It should be noted that the extreme temperatures of ignition for all experiments considered in particle size corresponded to the value 1273 K. These temperatures correspond to the range of heating particles products produced during welding and cutting of metals in real processes. Therefore, we can conclude about the high fire hazard technological processes, direct or indirect products of which are finely dispersed wood waste, with the possible impact of metal particles generated during welding or cutting of metal structures.

The results are also possible, in particular, to assess fire danger fast pyrolysis technologies are addressed in recent years as a very promising technology for the thermal conversion of woody biomass to produce biogas and biofuels (motor and solid) [2]. Length of stay the wood particles in the reactor chamber fast pyrolysis is less than two seconds at a temperature of the surface of the reactor to 875 K. Within these ranges variation of temperatures and time ignition the dispersed wood does not occur, as shown by the experiments. Therefore, the technology of fast pyrolysis of wood at the above restrictions on the time and temperature of technological process can be considered fire safe.

4. Conclusions

The results of the of experimental studies illustrate the possibility ignition of layer dry pine timber dispersed single heated up to high (more than 1273 K) temperature ceramic or steel particles. Based on the results of experimental studies, may be concluded that a stable ignition wood sawdust single particles heated to a temperature above 1273 K. Found that the ignition delay time of sawdust steel particle is slightly different from similar values for distillate fuels. The obtained experimental results can be used in developing mathematical models of processes ignition dispersed non-fire-rated of condensed substances. The results also allow us to make conclusions about the high fire danger technological processes, products which are finely dispersed wood waste.

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