

The fire hazard during combustion of some alternative fuels

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Alternative fuels are fuels which include: biomass fuel from waste and sewage sludge. Co-firing biomass with coal is now considered as an effective and financially attractive way the use of biomass for energy production. Perhaps in the future this new technology will replace co-efficient technologies, such as gasification in combination of the gas-steam systems, and the use of gas or ethanol from biomass to value highly efficient fuel cells [1]. The use of coal and biomass mixtures can also be a threat to the safe operation of the plant, including in particular the preparation and installation of the fuel supply. Organic matter in biomass (organic fraction) is a complex mixture of fats, proteins, carbohydrates, humic material-go and fatty acids [2–4]. Self-igniting the fuel can be the result of various factors such as chemical, physical or biological agents stored inside a large amount of organic matter. Self-igniting solid fuels storage depends on many factors such as particle size, nature and type of biomass, coal, the moisture content of the fuel, the storage method and the means of ventilation [5]. In order to determine the self-ignition temperature of coal and of biomass: straw pellets and wood pellets, the method called CPT (Crossing Point Test) [18] was used. Apart from this, the elemental composition of these biomass as well as of coal have been marked.

Key words: alternative fuel, biomass, SRF, CPT, fire hazard, self-ignition.

Background

One of the challenges for the energy sector in the coming years will be to reduce the consumption of fossil fuels in order to comply the strict limits on the environment. There are many legal obligations for which the power industry has to meet, such as: reduction of greenhouse gas emissions i.e. CO₂, energy conservation, improvement of energy efficiency and the promotion of energy production from renewable energy sources so. RES. One of the solutions being able to respond to this requirement is the use of alternative fuels [6]. Compared with the conventional fuels, the alternative fuels are fuel produced from waste, biomass and sewage sludge. Fuel produced from waste are under different names in the world i.e. U.S. legislation known as RDF (Refused Derived Fuel) or Opportunity Fuel (OF), the European legislation named them: SRF (Solid Recovered Fuel) [5]. SRF is a fuel produced from municipal solid waste or industrial use. This fuel can be produced exclusively with non-hazardous waste. These fuels in its composition cannot contain either fossil fuels or pro-mine waste. However, they are often found in the composition of residues from i.e. production processes, industrial waste or selective collection of trade and households, municipal solid waste or construction and renovation waste [5]. SRF can be used for combustion and co-firing with coal in suitable facilities that meet the environmental requirements for waste incinera-

tion plants and, in the legal sense because the fuel is treated as waste and are classified according to the specifications set out in standard EN15359 [7]. Sludges derived from wastewater treatment plants contains organomineral phase separated from the wastewater collected from septic tanks and other waste water treatment plant and other plants, which has a composition similar to the composition of the waste water treatment. Biomass is biodegradable material from plant or animal. The main sources of biomass are: wood from forests, orchards, specialty crops, and waste from the timber industry, vegetable products produced in the fields and pastures, straw and other plant residues forming the waste material in the production of agricultural and waste arising from agro-food sector.

Co-firing biomass with coal in Poland and other European Union countries is used in the power industry on an increasing scale. Currently, the co-firing is carried out with the increasingly higher proportion of biomass in the coal/biomass mixture [8]. The co-firing is conducted in large and small power plants, mostly in the framework of existing power-plant in the infrastructure and can be used in all existing combustion technologies such as in a stationary bed, a fluidized bed and pulverized coal stream. Although the co-firing does not contribute to the generation of additional power, the implementation it in a way that does not cause a drastic reduction of power, can be helped to achieve economic benefits and reduction of pollution [8]. In Poland there are a lot of power stations and

CHP which carry out tests leading to introduction in the future the implementation of new technology [9–11].

There are two ways of biomass co-firing with coal in power boilers: The first way is a direct co-firing which includes mixing the biomass with coal before the mixture is delivered to dispensing system of the boiler or mills and administration to the combustion chamber by the existing coal handling system and dust burners. Sometimes, in this way, biomass is preparation independently - fragmentation and burning takes place on the grill or dosage to the coal burners under independently stream [1]. The other way is the indirect co-firing, where the processes of heating volatilization and combustion are run separately, for which there is the pre-fire place allowing for delivering of combustion gases heat to the special combustion chamber. Then followed the initial gasification of biomass - into the combustion chamber is fed wet combustible gas [1].

The reduction of CO₂ emission by co-firing of biomass power generation technology is now easy and enjoys a lot of interest both in Poland and in the world [12]. However, the properties of the coal/biomass mixture may often increase the risk of self-ignition. The process of the fuel storage additionally complicates the SRF introduction into the system [3]. Perhaps too, fuel (SRF and coal) should be stored separately and mixed at the time of delivery to the mill. So far no laboratory standards, that can predict the behavior of the fuel during storage, have been established yet. Experiments and procedures used during the storage due to coal rather long-term observation and testing in real conditions than in the tests carried out on a laboratory scale.


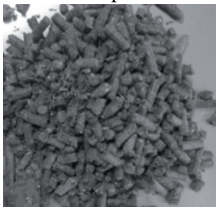
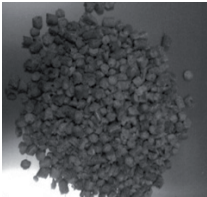
The use of coal and biomass mixtures can also be a threat to the safe operation of the plant, including in particular the preparation and installation of the fuel supply [13]. Safe operation may be due to differences in susceptibility to self-ignition and ignition of coal and biomass mixtures and from the differences in the formation of explosive mixtures of fuel and air. Moreover, the installations of close transport systems and mills in which there are transported mixtures of coal and biomass, must be protected against the effects of explosions [6,14–16]. In addition, the increases of the weight proportion of biomass fuel in the mixture increases the risk of fire in the installation. Occurrence of pollution due to explosions in the mill installation is strongly related to temporary conditions, such as working mill start-up, shutdown, or a sudden interruption in the supply of fuel. In order to ensure the safe work of the installation, a dual strategy of action should apply: to avoid (prevention) formation of fire (embers) and the use of systems to minimize the effects of explosions.

The combination of the weather and the properties of coal and biomass to the specification of large amounts of fuel storage causes local increase of the temperature of stored fuel to reach the ignition temperature, and further slow combustion of the fuel. Therefore, it is important to know the process of the low temperature reaction of organic fuels with air under the influence of the exothermic oxidation, which may lead to ignition [8]. This phenomenon is very undesirable, causing the loss and fire hazard for the entire facility. Self-igniting the fuel can be caused by various factors such as chemical, physical or biological agents stored inside a large amount of organic matter [17]. These reactions and the activity of the fuel itself spontaneously create fertile conditions for which is inherently an exothermic process. Regardless of the source of ignition three factors have an influence on the propensity for spontaneous combustion of fuel: 1) properties of storage fuel (particle size, particle shape, chemical composition and stored thermal conductivity of the material), 2) ambient conditions (temperature and oxidant concentration), 3) way of fuel storage (time, shape and volume of residual fuel layer) [17–20]. These factors interact with each other and result in the specific cases of non-uniform heating of the material or self-ignition of fuel. If the heat generation by the reaction occurring inside the material exceeds the amount of heat given off by the material, the temperature inside the material begins to rise and in consequences leads to an increase of reaction the rate taking place inside. This behavior of the material can lead to an increased heat transfer to the ambient or in the case of difficulty in heat transfer through the material, to the accumulation of fuel and risk of it self-ignition [17].

Materials and methods

Physical and chemical properties of coal and alternative fuels: straw pellets and wood pellets were determined using standard procedures [5]. The contents of volatile matter, moisture and ash content and the content of elements: carbon, nitrogen, hydrogen and sulfur was performed according to Polish standards [7]. Determination of elemental analysis were performed by auto-analyzer Leco TruSpec IHD according to *PN-G-04571 Determination of carbon, nitrogen and hydrogen by automatic analyzers. Macro Method, ISO 351 Determination of total sulfur content. Combustion at high temperature*. Elemental composition of coal, straw pellets and wood pellets is presented in Table 1. In order to determine the ignition temperature of the fuel samples, common laboratory test called CPT (Crossing Point Test) was used [17].

Table 1. Ultimate analysis of coal, straw pellets and wood pellets.

Sample	Sample state	C	H	N	S	O
		%	%	%	%	%
Coal 	as received	70,72	4,33	1,26	0,59	4,41
	air dry	78,70	4,82	1,41	0,66	4,91
	dry	79,22	4,85	1,42	0,66	4,94
	daf dry ash free	86,97	5,32	1,55	0,73	5,43
Straw pellets 	as received	40,54	4,62	0,53	0,07	29,30
	air dry	49,35	5,63	0,64	0,09	35,66
	dry	50,81	5,79	0,66	0,09	36,72
	daf dry ash free	54,01	6,16	0,70	0,10	39,03
Wood pellets 	as received	47,49	5,50	3,99	0,08	35,04
	air dry	50,15	5,81	4,22	0,09	37,00
	dry	50,85	5,89	4,28	0,09	37,52
	daf dry ash free	51,56	5,97	4,34	0,09	38,04

Crossing Point Test

The fuel ignition can occur on the site, the installation of the fuel supply, but the fire-hazard explosives may also arise during ground transport fuel to the burners in the lines of powdered fuel.. Low temperature reaction of organic fuels with air under the influence of the exothermic oxidation reaction may lead to ignition. To determine the characteristics of the fuel ignition in laboratory is used a test called CPT (Crossing Point Test) [17]. The test in-

volves the heating of the sample in a fuel filler wire basket that is placed in a furnace. The basket is made of steel mesh with the shape of a cube (side length of 50 mm, Fig. 1) [17]. The temperature of the furnace in which the temperature of the sample measured at the center starts to exceed the temperature of the sample measured at a fixed distance from the center of the sample (the intersection of the two temperature) indicates a spontaneous combustion of the sample. During the test the temperature of the furnace is measured T_0 , the temperature in the center of the sample and the temperature T_1 in the middle of the distance between the sample and the outer surface of T_2 .

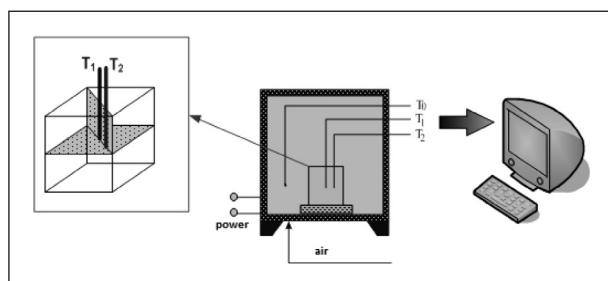


Fig. 1. Scheme of the measurement positions for self-ignition temperature determination [17].

Results and conclusions

Elemental composition of fuel respondents shows that there are significant differences between coal, alternative fuels: straw pellets and wood pellets [5]. The results of self-ignition temperature determination for coal, straw pellets and wood pellets have been shown in Fig. 2.

The analysis of the example graphs indicates that in the case of insufficient ambient temperature sample temperature is stabilized, and there is no oxidation. In the case of self-ignition conditions, the oxidation starts to rapidly with the secretion of large amount of heat. This leads as a consequence to the ignition of the sample and

its complete combustion. This is shown in the middle of the temperature of the sample begins to increase rapidly and crossing the external temperature of the sample. The results of auto-ignition temperatures of fuels are presented in Table 2.

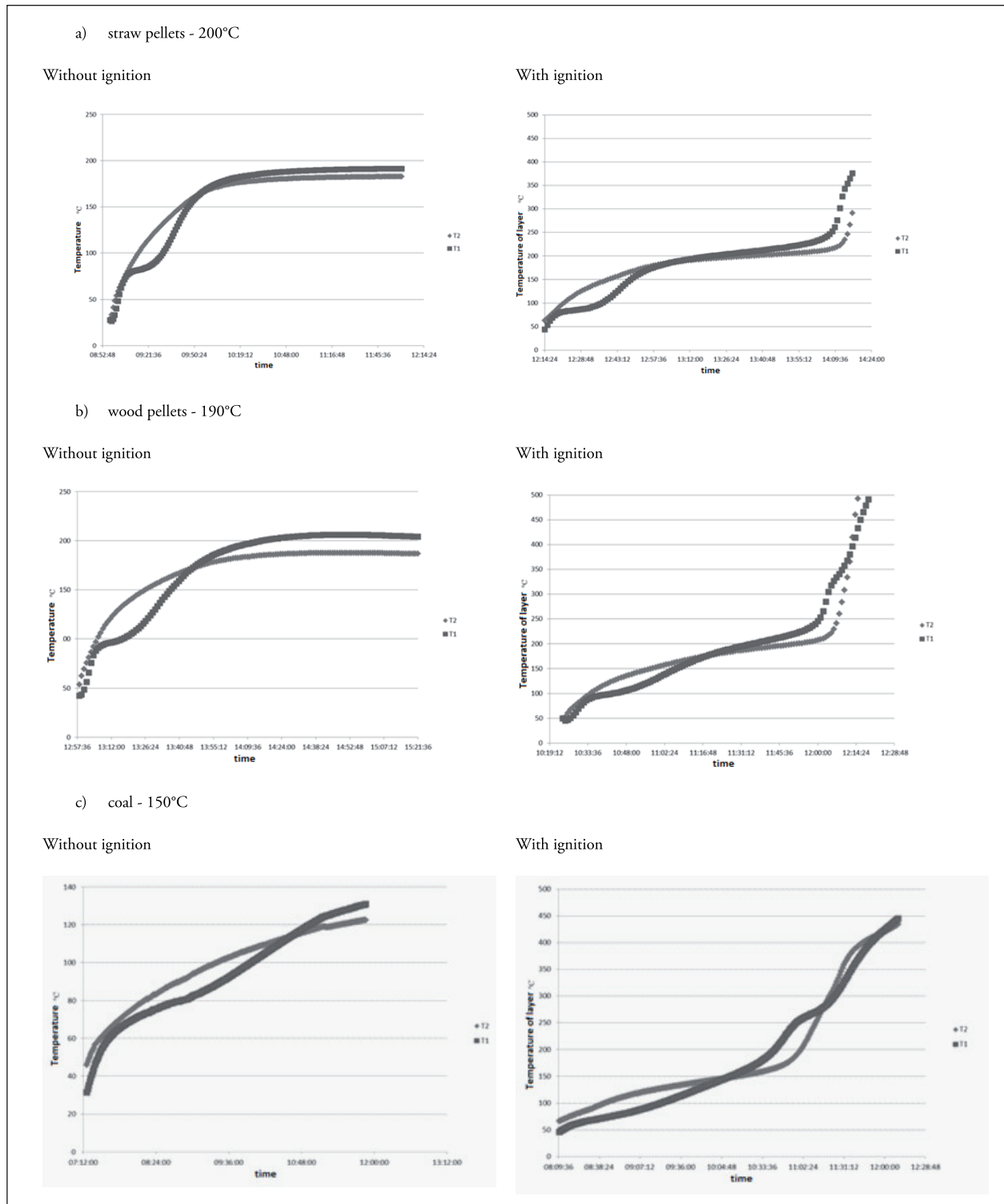


Fig. 2. The results of self-ignition temperatures determination by CPT method for: a) straw pellets; b) wood pellets; c) coal.

Table 2. Self-ignition temperature of fuels.

Sample	Self-ignition temperature [°C]
Coal	150
Wood pellets	190
Straw pellets	200

The results have shown that ignition temperatures should not be confused with the self-ignition temperatures, from which they are much lower. Furthermore, the self-ignition temperature of the coal was 150–155°C and was roughly 40°C, lower than the self-ignition temperature of wood pellets (190°C) and 50°C lower than straw pellets. Because of higher self-ignition temperature if straw and wood pellets than coal, these alternative fuels can be used as renewable energy source.

Summary

CPT method allows obtaining reproducible results.

The coal/biomass mixtures have a higher self-ignition temperature than the self-ignition temperature of coal during combustion of pure coal.

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