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THE DEPENDENCE OF SELECTED TECHNICAL AND COMBUSTION CHARACTERISTICS OF FIRE ON MOISTURE LEVELS IN ALTERNATIVE FUELS

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Research article

Abstract: The subject of this paper is to analyse the influence of moisture on selected technical and combustion characteristics of alternative fuels. The analyses are conducted on the basis of analyses of samples of alternative fuels simulating states of the fuel in expected operating conditions, focusing on the identification of potential operational risks. The final part consists of a set of recommended measures to ensure the operational safety of the practical use of alternative fuels based on the results of the analysis.

Keywords: Fire, combustion, risk, alternative fuels.

Introduction

This research and the presented results on this topic are directly related to the long-term cooperation between VVUU (specifically the Risk Analysis Division and Accredited Testing Laboratory No. 1025) and ČEZ Group in the area of research and development related to the risks of fire and explosion associated with alternative and mixed fuels that are suitable for use in conventional power plants in the ČEZ group.

This project, "fire-safety aspects of the use of alternative fuels" funded by ČEZ group a. s., can be divided into two parts, from the perspective of the tested fuel samples, namely:

- Alternative fuels based on biomass,
- Alternative fuels based on RDF.

Within the scope of this research, we will also deal with some solutions in the area of biomass (BM).

Materials and methods

During selection of fuels for the purpose of the project many requirements and selection criteria were considered to which the samples had to conform (operational-technological, environmental, financial, legislative, etc.). Based on the identification of the above-mentioned factors, each sample was passed through a selection process. These specific samples were selected for specific operating conditions and tested for various technical parameters of fire and combustion characteristics (TPFC).

The analyses aim at clarifying the behaviour of BM samples at different moisture levels that may actually occur in real-world conditions.

In general, it can be said that increasing the moisture content of the sample reduces the susceptibility to fire/explosion (Štroch, 2010).

Specifications of the test set of BM

Below are the specifications of samples that were selected for analysis, including the specifications of test conditions under which the TPFC analyses were performed:

Marking of the samples for testing: Sample Specification: Defined % moisture for testing TPFC: State:	**BM1** Wood chips (branches, roots and fibre) 20, 30, 40 [% wt.] Dust
Marking of the samples for testing: Sample Specification: Defined % moisture for testing TPFC: State:	**BM2** Pellets from purpose grown plants 10, 15 [% wt.] Dust
Marking of the samples for testing: Sample Specification: Defined % moisture for testing TPFC: State:	**BM3** Sunflower plant pellets (husk and seeds) 10, 15 [% wt.] Dust

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Marking of the samples for testing: Sample Specification: Defined % moisture for testing TPFC: State:	**BM4** Grass Pellets 10, 15 [% wt.] Dust
Marking of the samples for testing: Sample Specification: Defined % moisture for testing TPFC: State:	**BM5** Briquettes 10, 15 [% wt.] Dust
Marking of the samples for testing: Sample Specification: State:	**BM6** Palm Husks (15 wt. %) + Black Coal (85 wt. %) Black Coal - Dust, Palm Husks - Ground

Fig. 1 BM1 - Wood chips/ dust

Fig. 2 BM2 - Pellets from purpose grown plants/dust

Fig. 3 BM3 - Sunflower plant pellets (husk and seeds)/dust

Fig. 4 BM4 - Grass pellets/dust

Fig. 5 BM5 - Briquettes/ dust

Fig. 6 BM6 - Palm Husks/ ground + Black Coal/dust

Dust is defined [EN 14034-1:2004+A1:2011] as a collection of small solid particles in the air that settle under their own weight, but can remain dispersed in the air for some time. (average size of the dust below 500 micron).

Specifications of the analysis of TPFC

To ensure the necessary accuracy of the results, all analyses were performed by Testing Laboratory No. 1025 VVUU accredited by the Czech Accreditation Institute (CAI), according to the harmonized European normative test code (EN, 1999; EN, 2011; EN, 2008; EN, 1998).[1]

The specifications of the TPFC analysis, together with the indicated regulation norms that define the test procedure and defined specifications of the selected tests from the perspective of operational experience and practical solutions for the prevention of explosions during operation in industrial plants are shown in Tab. 1.

Results

During the course of the project, a wide range of results characterizing the parameter changes in TPFC for BM when moisture content is changed was observed. For the purposes of this contribution, the conclusions of the sample values of TPFC and the important comparisons of the selected samples that take place are, concretely:

- Ignition temperature of dust clouds for part of the samples of BM - Fig. 7,
- Induction period for part of the samples of BM - Fig. 8,
- The speed of the spread of fire upon a sample layer of settled dust for part of the samples of BM - Fig. 9.

Setting and verification of the moisture level

The sample was dried in a drying oven at 103 ± 2 [°C] to a constant weight. Drying was verified through basic chemical analysis. On the basis of the results, the estimated amount of water was added and the target moisture level of the sample was verified using basic chemical analysis.

Summarization and comparison of the observed values of TPFC

In Fig. 7, 8 and 9 is a summarization and comparison of the observed results.

1 Test procedure from the requirement ČSN 015140-3 that was eliminated 1. 2. 2003 without a replacement (ČSN, 1985; Damec and Šimandl, 2005).

Tab. 1 TPFC analysis/norms/comments

Flashpoint/Ignition temperature of powder (EN 50281-2-1)	The flashpoint of settled powder is the lowest ambient temperature at which an external ignition source is able to ignite the gasses of the thermal decomposition. The ignition temperature of the settled powder deposits is the lowest ambient temperature at which the in the absence of an external source of ignition spontaneous ignition of the gaseous pyrolysis products is possible.
Ignition temperature of dust clouds (EN 50281-2-1)	The lowest ambient temperature at which gaseous products from thermal decomposition ignite even in the absence of an external ignition source. This value is important in determining the risk that a mixture of dust and air would ignite on the hot surfaces of equipment.
Lower Explosive Limit (EN 14034-3+A1)	The lowest concentration of a combustible dust in air, at which the mixture is explosive. The value of the lower explosive limit for powdered materials is given in the unit [g.m^3].
Maximum Explosion Pressure (EN 14034-1+A1 EN 14034-2+A1)	The maximum pressure resulting from an explosion of explosive dust in a closed container under specified test conditions where the dust/air mixture is at optimal levels. This is the maximum pressure that the substance is able to create in a closed vessel during an explosion. The value of this parameter is important for the proper design of explosion protection equipment (relief diaphram, flaps and valves).
Maximum speed in rise in pressure (brisance) (EN 14034-1+A1 EN 14034-2+A1)	The maximum value of the rise in pressure per unit of time resulting from the combustion of a range of flammable dust substances in a closed vessel under specified test conditions.
K_{St} Constant (EN 14034-1+A1 EN 14034-2+A1)	The cubic constant. It expresses the brisance of a dust air mixture regardless of the volume in which it was established. According cubic constants, dust is classified St1 to St3, the St3 class explosion is the most dangerous.
Limit Oxygen Concentration (EN 14034-4+A1)	The limit of oxygen content is the experimentally determined concentration of oxygen, which does not allow an explosion of the mixture of fuel, air and inert gas. It is used in the area of equipment protection by rendering the environment inert.
Determination of susceptibility to spontaneous combustion (EN 15188)	The self-ignition temperature is defined as the lowest temperature at which a substance ignites itself without the application of an external ho[t exothermic processes. The heat required to ignite the substance arises from the substance itself as a result of chemical, physical or biological processes. The term self-ignition is to be understood not only the ignition of the substance, but the aggregate on-going process from the first temperature increase (= self-ignition temperature), until reaching the ignition temperature.
Minimum Ignition Energy (IEC 1241-2-3)	The minimum ignition energy is the lowest possible energy an ignition source needs to ignite a substance in the optimal concentration.
Rate of the spread of fire of a layer of dust	The rate a fire spreads is determined by the amount of time it takes to transfer combustion in the opposite direction of the flow of oxygen from a predetermined distance.

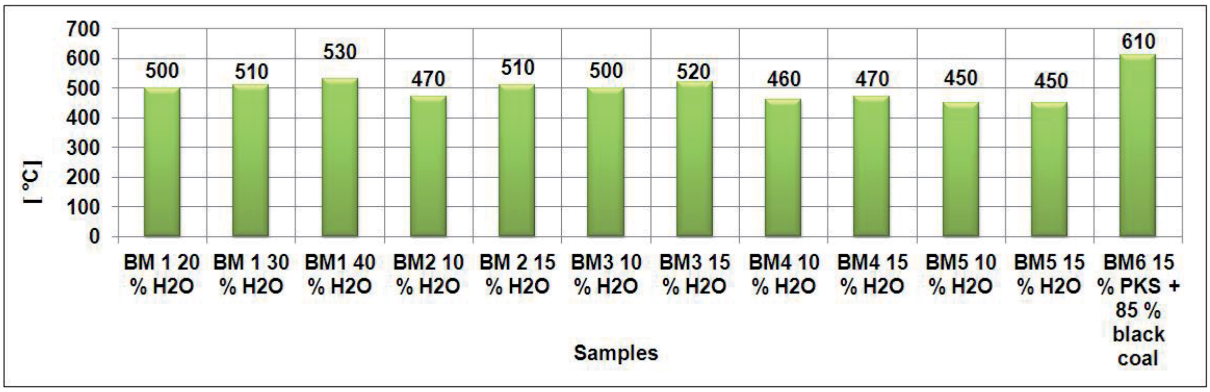

Fig. 7 Ignition temperature of dust clouds

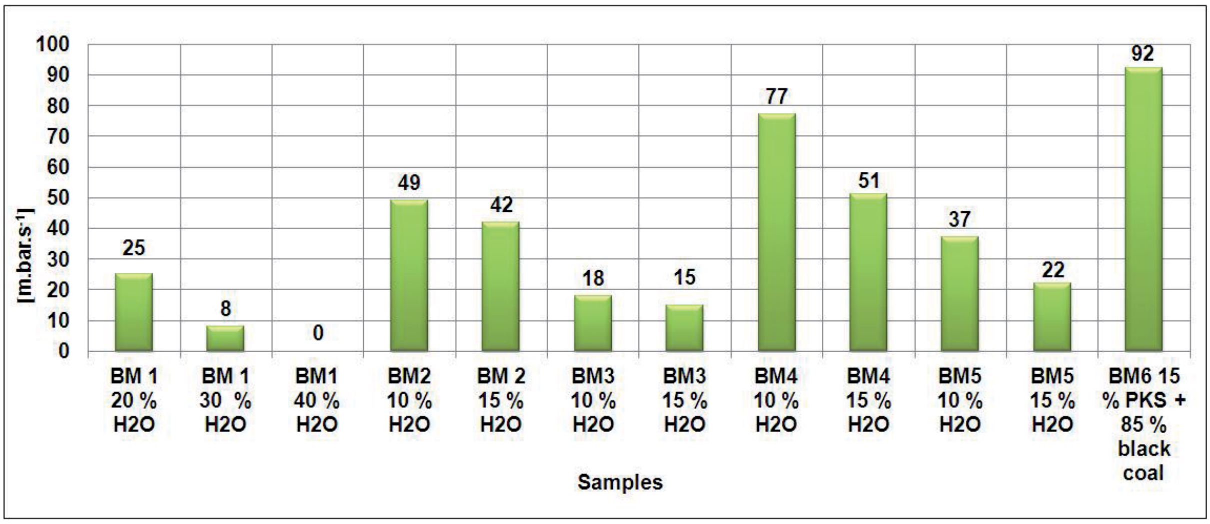

Fig. 8 The Cubic Constant, K_{St}

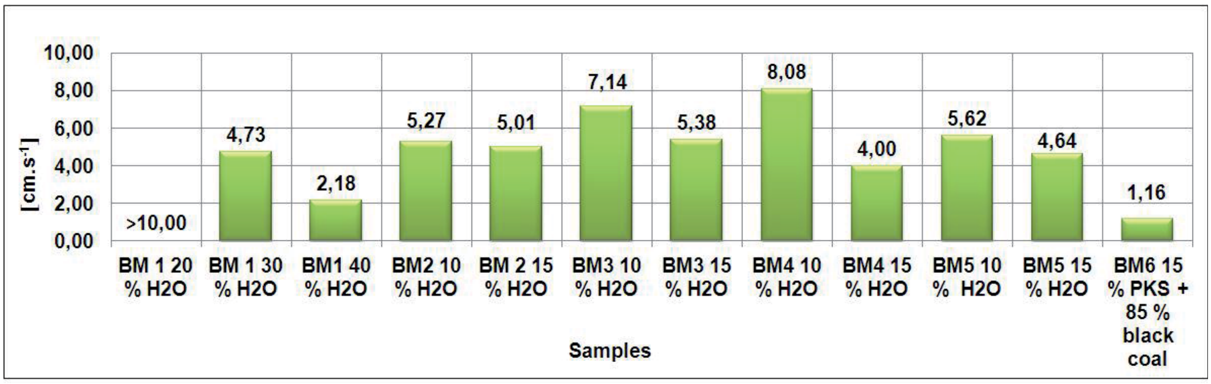

Fig. 9 The rate of the spread of fire on a layer of dust

Conclusion

Before drawing conclusions from the analysis of TPFC carried out within the project, it is necessary to point out some important facts.

In order to comply with the requirements of the test procedures (thus, among other things, ensuring the reproducibility of individual tests) it is often necessary to test samples before the start of the analyses to adjust to the condition, which is required by the individual test procedures and methodologies.

One of the essential steps in the process of preparing samples for the analysis of TPFC itself is often to modify the characteristics of the grounds, drying, etc., so that the tested samples were observed at the most critical (most dangerous) values for each factor of TPFC. Knowledge of the "maximum" value is particularly important in the design and implementation of industrial explosion protection.

The values TPFC and the resulting conclusions apply only to the tested set of fuels. Based on the results of the tests performed it is clear that it confirms the assumption that with increasing moisture content of the test sample the BM, there is a decrease in the susceptibility of samples to ignite and initiate in general (increasing ignition temperature when settled and when in the form of dust clouds). It also shows that a higher percentage of water content results in the need for higher dust concentrations for the formation of explosive atmospheres (higher /lower explosion limit) and significantly reduces the intensity of an explosion event (which gives us values such as p_{max}, brisance, K_{St}).

This behaviour can be derived not only on the sample BM1 but it can be safe to assume that at a water content of > 40 %, the fuel already displays this characteristic and does not exhibit explosive properties - it can then be concluded that this will be the case in response to varying moisture levels of the samples when these conditions occur in real industrial environments.

Another important finding is that all the tested samples in all test conditions (i.e. different humidity levels) exhibited susceptibility to spontaneous combustion, which is essential information especially in terms of their long-term storage in large piles. The result of the susceptibility of the test set of alternative fuels to auto-ignite corresponds with what is currently known on this issue (Balog, 1999).

The burning of alternative fuels, and their co-incineration in equipment that was originally designed for the combustion of classic fuels, is not, especially in energy higher levels, anything unusual. Alternative fuels have specific characteristics which, in turn can cause security risks in the various stages of storage, transportation, treatment and combustion itself.

In the cases of incineration, co-incineration and a modified fuel base, it is always needed to analyze and evaluate the risks, and not only in terms of explosion prevention. In the area of explosion prevention the basic regulation Government Regulation No. 406/2004 Coll. (Government Regulation, 2004), which in § 4 point d) imposes on the operators the requirement for the processing and maintenance of written documentation of explosion prevention. This regulation can be understood such as rule, by means of which the Czech Republic is implementing the requirements of the European Parliament and Council Directive 92/99/EC (Directive, 1999) (often known under the name of ATEX 137).

One of the pillars of the risk analysis of any technology is thorough knowledge of the material properties - in the form of fire and explosion characteristics that will occur in the technology (in this case, the fuel or fuel mix). The requirement for technical knowledge of fire and explosion characteristics of processed and stored materials is also defined by the Decree of the Ministry of Interior No. 246/2001 Coll (Decree, 2001).

Finally, proper risk analysis must always be clearly and unequivocally based on whether the technology can be considered safe for its operation with a new fuel base, and/or what technical or organizational measures must be taken to do so.

Quality and comprehensive risk analysis and the application of technical and organizational measure that are defined in it, in the past, has been proven many times to go beyond the protection, safety and health of workers at the workplace as well as saving much in the form of the value of equipment and downtime.

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