Maximizing the Safety Production of Energo Gas - Determination of Explosion Characteristics

Jan Skřínský[1,*], and *Jan* Koloničný[1]

[1]Energy Research Centre, VŠB-TU Ostrava, 708 33 Ostrava - Poruba, Czech Republic

Abstract. The article is focused on the determination of explosion characteristics of energo gas produced from an industrial scale, biomass gasifier. The results underline that the composition of energo gas from industrial technology has a significant impact on the gas explosion characteristics. The gas explosion experiments were carried out in the spherical 20-L explosion vessel. The Real gas was sampled into the 50-L Tedlar bags, introduced into the vessel and mixed with air by a partial-pressure method. Absolute explosion pressure for energo gas air mixture was higher than 6 bar for the energo gas optimum concentration close to 30 vol. % of fuel. The maximum rate of pressure rise and the deflagration index have been determined. Obtained explosion characteristics could be used to describe the explosion process and to rate the effects of an explosion.

1 Introduction

1.1 Previous studies

Biomass is considered as a renewable resource because of its short life cycle, and biomass-derived biofuels are potential substitutes to fossil fuels [1]. Gasification is a process that converts solid fuel into gas, which could allow the wider implementation of biomass to produce electricity on a small and commercial scale. However, in many cases, such units would have to operate within a single system with intermittent energy sources, thus having to cope with new flexibility requirements [2]. Maximizing the cleaning efficiency of energo gas is attractive in the worldwide challenge for low emission technology and in chemical process intensification. However, this opportunity raises several issues not only in terms of costs, but also in terms of safety. Indeed, in the case of loss of control, explosion consequences can be dramatic [3]. One way is to study these processes by mathematical computational fluid dynamics (CFD) modelling. CFD has sufficient accuracy and a much higher potential for being optimized if based on currently used experimental methods [4-5]. The primary aim of this contribution is maximization of technical safety experimental data of energo gas produced from a pilot scale, biomass gasifier working under low equivalence ratio regime [6].

* Corresponding author: jan.skrinsky@vsb.cz

1.2 Interest

The novelty and added value of the article is to enable fundamental explosion characteristics, namely maximum explosion pressure, maximum rate of pressure rise, lower explosion limit and upper explosion limit that may help to improve the future safe production of this material. By gathering such information, we can start step-by-step decision-making process resulting in the selection of the as low as reasonably acceptable safety measures. The obtained experimental results of the explosion modelling should be expanded with CFD models.

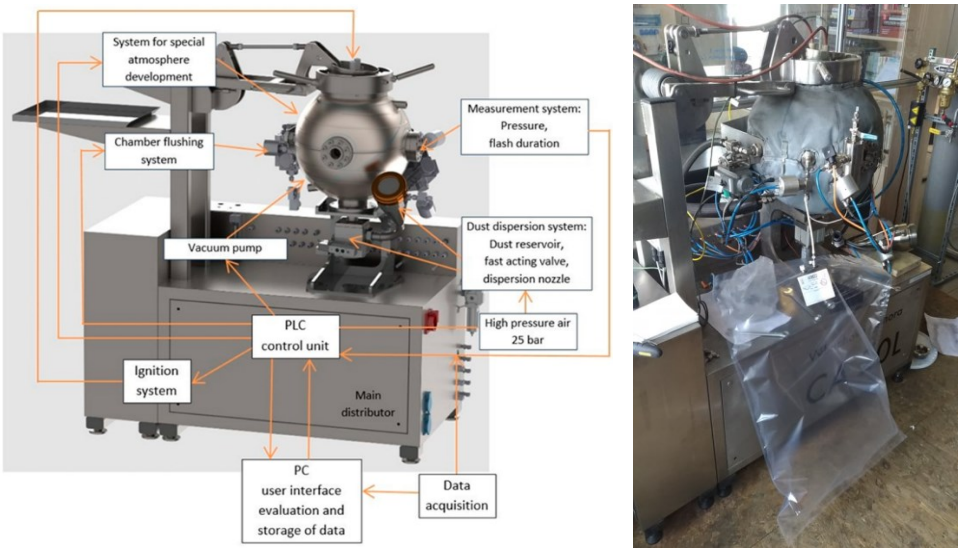
2 Experiment

2.1 Experimental Setup

To record pressure–time curves the 20-L oil-heated spherical vessel was used. The 20-L apparatus incorporated a digitally adjustable external control device Presto A30 that heated the oil in the instrument to the specified temperature range. The experimental set up is described in Figure 1a. The dynamic explosion pressure in the vessel was measured by a pair of quartz pressure sensors. The data acquisition sampling period was 0.02 ms with a sampling frequency 50 kS/s. Programmable logic controllers connected to a PC were used with the interface to automatically control the whole testing procedure [7-8].

2.2 Experimental procedure

Explosion characteristic values of the energo gas were determined experimentally according to the EN 15967:2011. First, the procedure started with evacuation to the initial conditions under a pressure of 0.40 bar in the 20-L. Second, the sample was blown into the evacuated chamber from the 50-L Tedlar bag. The sample bag is shown in Figure 1b.



a) **b)**

Fig. 1. Experimental setup a) the 20-L spherical vessel, b) gas sampling from Tedlar bag.

3 Results

3.1 Explosion characteristics

The safety of a gas explosion depends on four fundamental explosion parameters. One of the most important is the maximum explosion pressure (p_{ex}). The p_{ex} was determined as the highest value of the pressure–time curve divided by the initial pressure for the actual equivalence ratio. The p_{max} is the highest explosion pressure for all equivalence ratios [9]. Upper explosion limit, UEL, and lower explosion limit, LEL, evaluation is based on the highest and lowest concentrations, respectively, at which the material is explosive by using the 5.0 vol.% criterion [10].

Figure 2-3 illustrates the effects of initial concentration on the explosion pressure and the explosion rate of pressure rise of energo gas-air mixture at the initial concentration range from 10 to 50 vol. % and atmospheric pressure of 1 bar. With increasing concentration, the explosion pressure value increased up to the optimum concentration of 30 vol. %. After reaching the optimum concentration, the explosion pressure decreased slightly with the minimum value close to the 50 vol. %.

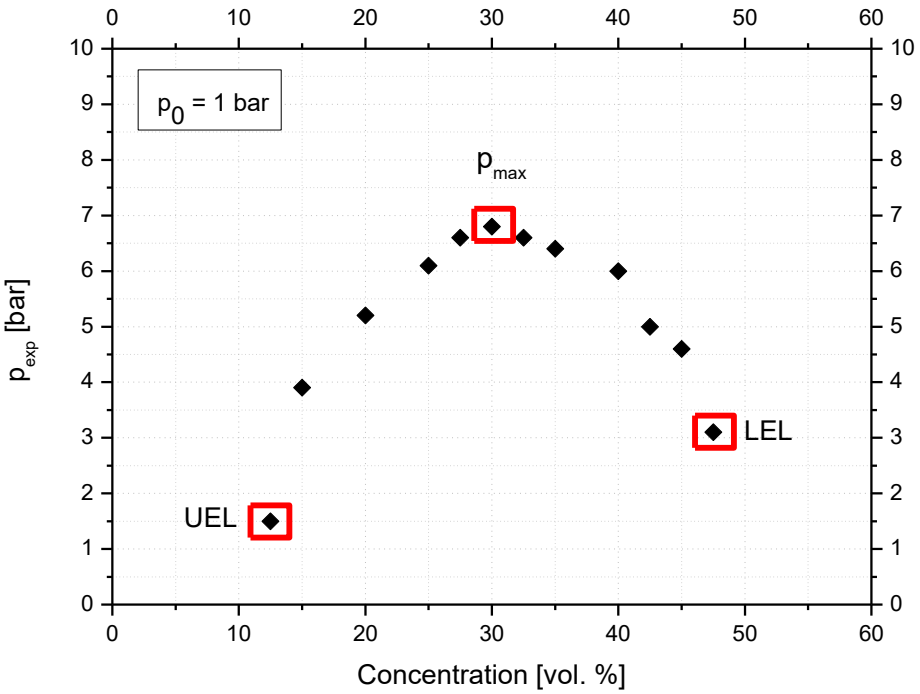


Fig. 2. Explosion pressure versus concentration.

One of the most important is the deflagration index, KSt, directly connected to the maximum rate of pressure rise $(dP/dt)_{max}$ through the so-called "cubic root law" relationship [11]. The maximum explosion pressures and deflagration indexes were obtained from pressure time records. Maximum rate of explosion pressure rise is for 0.02 m^3 recalculated to a vessel volume of 1 m^3, using Equation (1) for the deflagration index:

$$K_G = V^{1/3} \cdot (dp/dt)_{max} \quad (1)$$

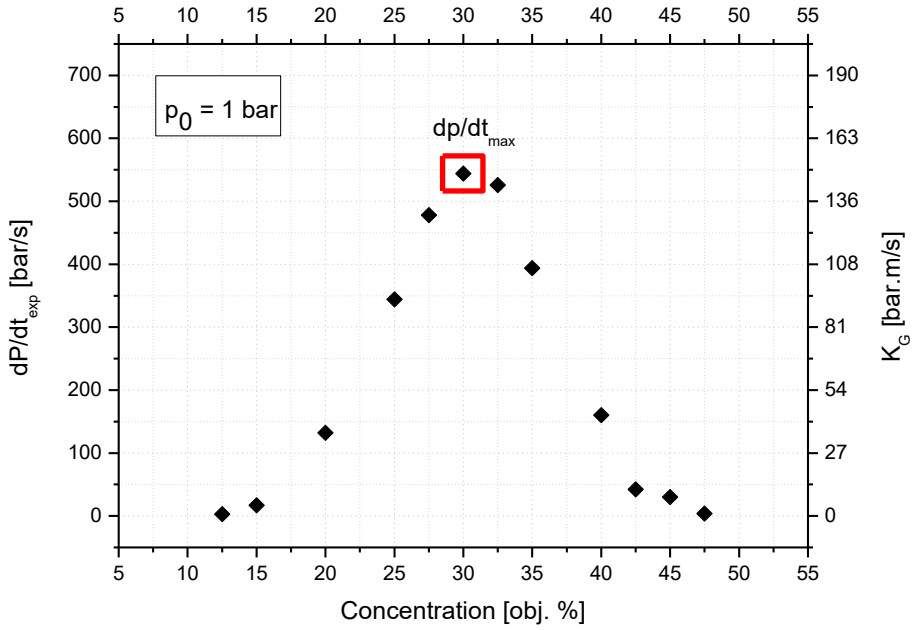


Fig. 3. Explosion pressure rise versus concentration.

Based on the knowledge of $(dP/dt)_{max}$ we can evaluate K_G to design deflagration vents. The design of safety protection is reviewed and the new techniques it presents are examined and explained in [12]. The K_G parameter is used both as an input parameter for vent sizing, according to "NFPA 68, Standard on Explosion Protection by Deflagration Venting" and for explosion hazard classification for combustible gas explosions.

Table 1. Hazard classes for combustible dust explosion, K_G [bar m s^{-1}].

Range	**Group**	**Explosibility**
$K_G = 0$	K_G0	Non-explosible
$0 < K_G < 200$	***K_G1***	**Weak**
$200 < K_G < 300$	K_G2	Strong
$300 < K_G$	K_G3	Very strong

Accordingly, the estimation of the deflagration index gives the value in the interval $0 < K_G < 200$ corresponding to K_G1 and weak classification of explosibility. However, particular attention has to be paid to the conditions connected to the gasification process.

4 Conclusion

The first part provides a clear introduction to the dangers of technologies dealing with the explosion characteristics of man-made gases. The following part describes the experimental equipment, the measurement procedure and the substances used for the experiments. A definite set of basic explosion characteristics was obtained. In the following experiments, these values will be used as approximate initial values for explosion experiments carried out in heated 1 m^3 explosion apparatus built by OZM Research s.r.o. at Energy Research Centre, VŠB - Technical University of Ostrava.

This study was carried out as part of the project: 'Maximizing the efficiency of energy gas cleaning' (identification code SP2020/113).

References

1. W. H. Chen, K. T. Lee, H. Ch. Ong. *Energies* 2019, 12, 290
2. J. Čespiva, M. Wnukowski, L. Niedzwiecki et al. *Renewable Energy* 2020, 159, 775-785
3. A. Basco, F. Cammarota, V. Di Sarli et al. *International journal of hydrogen energy* 2015, 40, 8239-8247
4. V. A. Smetanyuk, A. A. Skripnik, S. M. Frolov et al. *Combustion and detonation* 2005, 1, 37–43
5. S. M. Frolov, V. Y, Basevich, V. A. Smetanyuk et al. *Journal of Loss Prevention in the Process Industries* 2007, 20, 562-569
6. J. Koloničný, K. Borovec, J. Skřínský et al. Ostrava: Report n. SP2020/113
7. J. Skřínský, J. Vereš, K. Borovec. MATEC Web Conf. 2018, 168, 07014
8. J. Skřínský, T. Ochodek. *Energies* 2019, 12 (8), 1574
9. EN 15967: Determination of Maximum Explosion Pressure and the Maximum Rate of Pressure Rise of Gases and Vapours; European Committee for Standardization: Brussels, Belgium, 2011
10. EN 1839: Determination of the Explosion Limits and the Limiting Oxygen Concentration (LOC) for Flammable Gases and Vapours; European Committee for Standardization: Brussels, Belgium, 2017
11. A. Fumagalli, M. Derudi, R. Rota, S, Copelli. *Journal of Loss Prevention in the Process Industries* 2016, 44, 311-322
12. NFPA 68. *Guide for Venting of Deflagrations*, 1st ed.; National Fire Protection Association: Quincy, MA, USA, 2000