Experimental study on flammability limits of fuel vapors at elevated temperatures in 20-L sphere

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1 Introduction

Safety engineering and prevention meaures of severe explosions require more fundamental knowledge on explosive characteristics of combustible substances used in the process industries [1]. Such characteristics are mainly maximum explosion pressure, flammability limits or minimum ignition energy and temperature. Data available in the literature may not always be adequate for the use in particular industrial application because there are many different testing methods giving variuos results and also they may have been obtained at lower temperature than is required in practice [2]. Such example could be the quantity of air which is required to decrease dangerous vapor concentration to a safe level in the particular process carried out at 200^0C should be based on flammability data at the same temperature [3]. When it's not available than some approximations can be done for risk assessment for the process being considered. Most flammable mixtures approximately correspond to the stoichiometric composition [3]. Flammability limits are mostly affected by pressure, temperature, direction of flame propagation and gravitational field. These limits are determined experimentally and the values obtained depend on particular testing method.

2 Experimental set-up

To investigate the explosion pressures and flammability limits for ethanol, methanol and 1-buthanol the experimental studies were performed in 20-litre spherical chamber made of stainless steel. The initial conditions of tested vapors were 1 atm and 40, 60 80, 100 and 120^0C. Tested vapors were ignited by a hot-wire which was located in the centre of chamber. By means of pressure measuring system with piezoelectric PCB transducer, the pressure-time curves which develop following the ignition were recorded. From the pressure-time plots the maximum explosion pressure, highest rate of explosion pressure rise and flammability limits are automatically determined by data acquisition system, including dedicated software. For all tested vapors at least three measurements were done and average value was calculated.

The experimetnal set-up consisted of 20-litre spherical chamber resistant to higher pressures and corrosion from the combustion products, equipment for preparing a tested mixtures, an ignition system as the hot-wire method, pressure measuring system, temperature measuring system, data acquisition system and necessary safety equipment. The chamber is also equipped with heating system allowing for testing vapors up to initial temperature of 120^0C. The pressure transducer is able to measure pressures up to 20 bar. Experimental data were recorded by an acquisition system with the samping rate of 100 kHz. Temperature monitoring system included a thermocouples for measuring flame temperatures in the chamber. The 20-litre spherical chamber used in this experimental study is shown in Figure 1.

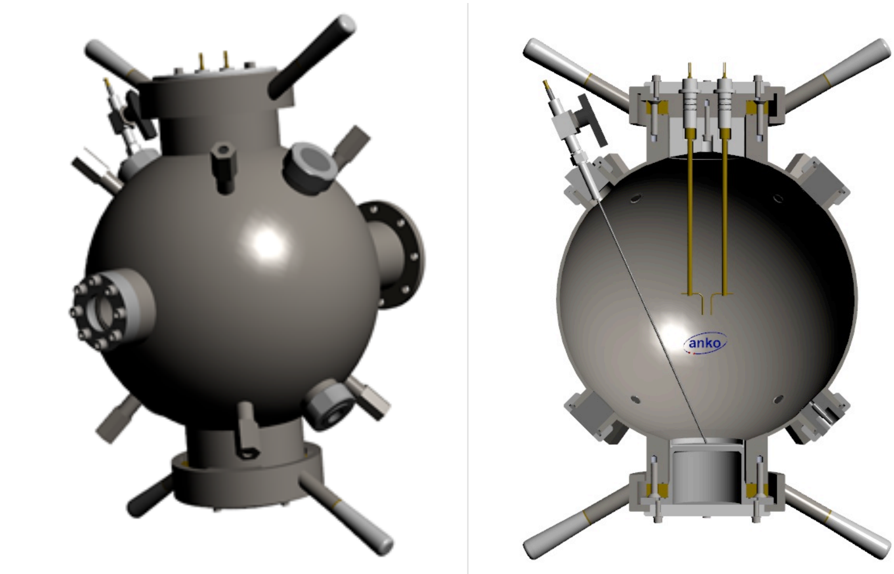

Fig. 1. 20-litre spherical chamber for testing flammability limits of vapors.

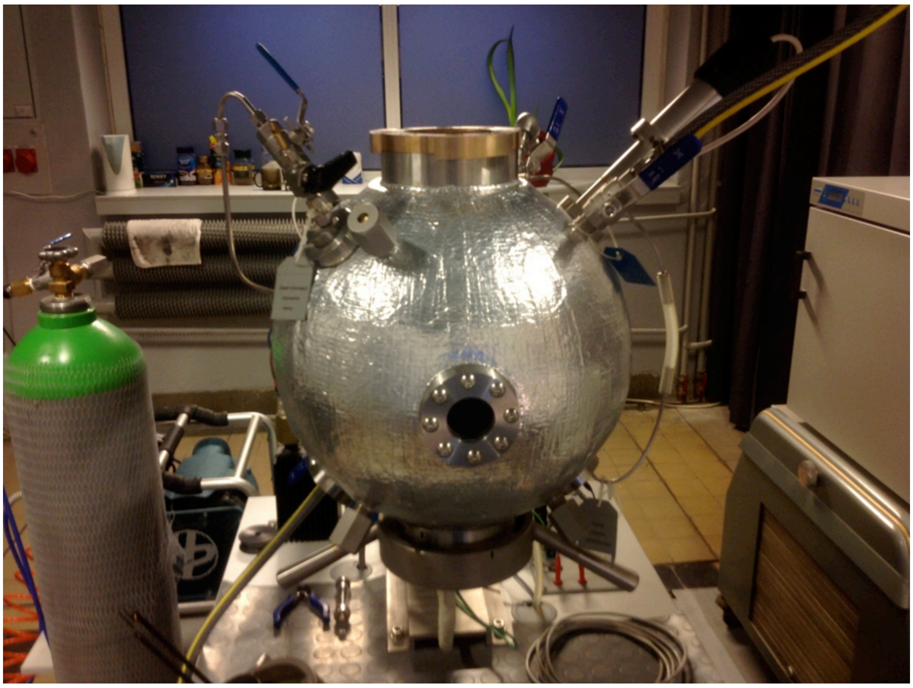

Fig. 2. An overview picture of experimental facility.

3 Results and discussion

Tested vapors of ethanol, methanol, 1-butanol and 2-butanol at different liquid volumes were introduced into the chamber and ignited. We used three values of initial temperatures for tested mixtures ranging from 40 up to 120^0C. Our data acqiusition system recorded a pressure profiles in time for every single shot. Figures 3, 4 and 5 show some experimental data on average flammabilioty liimits plotted as a function of vapor concentration for ethanol, methanol and 1-butanol at initial temperatures of 40, 60, 80, 100 and 120^0C respectively.

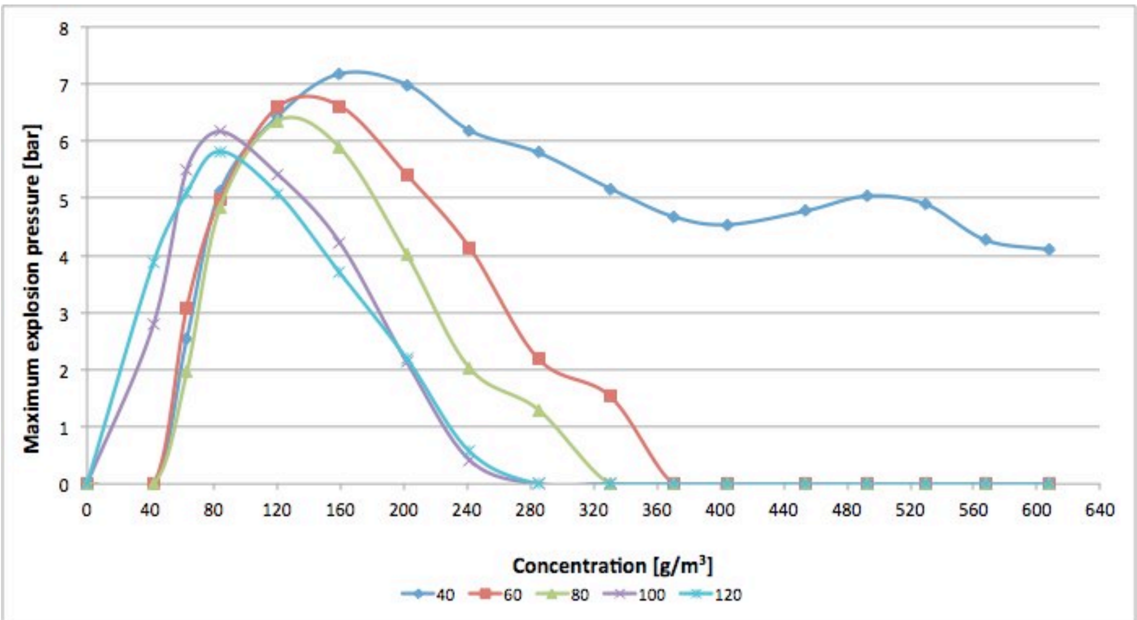

Fig. 3. Flammability limits for ethanol at initial tempertures of 40, 60, 80, 100 and 120^0C.

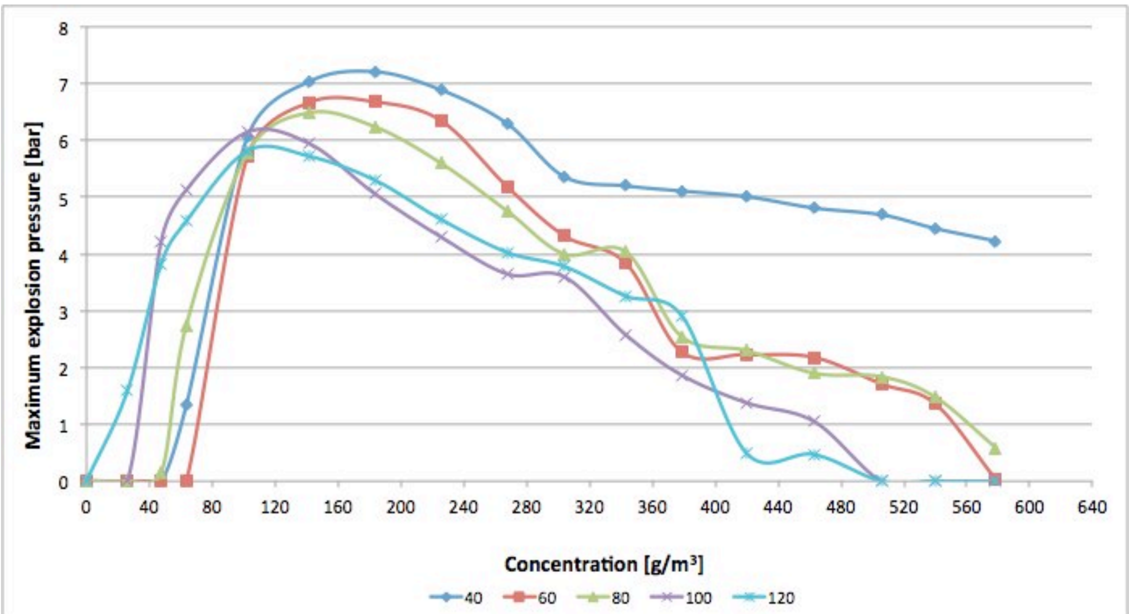

Fig. 4. Flammability limits for methanol at initial tempertures of 40, 60, 80, 100 and 120^0C.

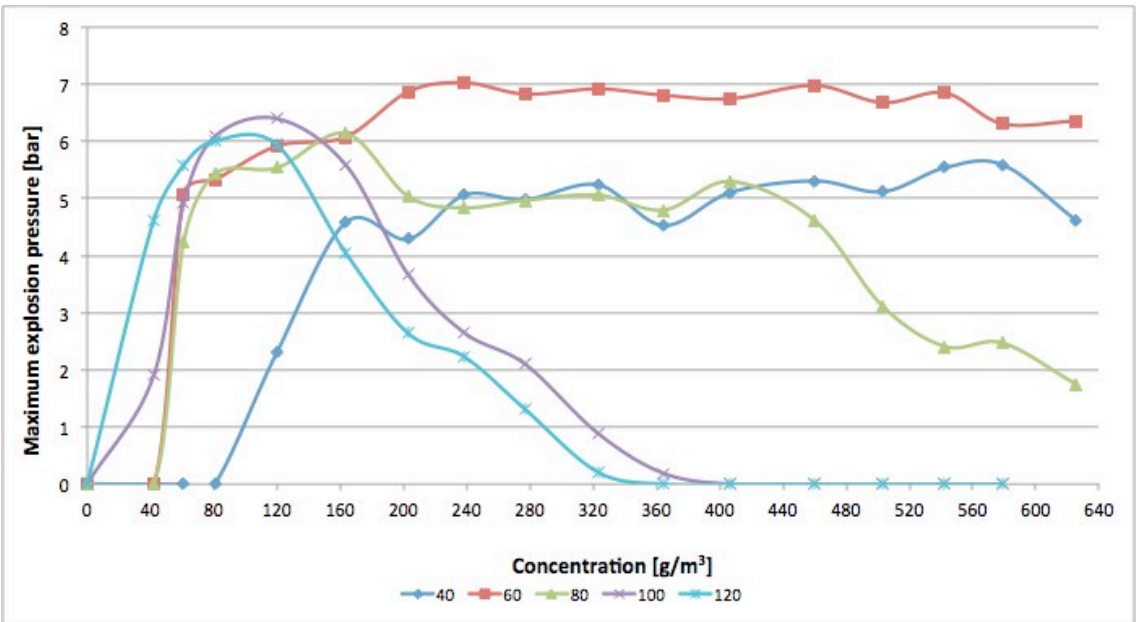

Fig. 5. Flammability limits for 1-butanol at initial tempertures of 40, 60, 80, 100 and 120^{0}C.

Lower flammability limits for tested fuel vapors were assessed based on maximum explosion pressure criterion, according to EN 1839. If the resulted pressure rise is equal to or greater than the overpressure created by ignition source alone in air then tested dust concentration is considered as inside the flammability limits.

For ethanol it can be obseved that increasing initial temperature makes the mixtires less sensitive for flammibility range. That means narrow flammabilitylimits for higher initial temperatures. For methanol we observed the decreasing explosion pressure with increasing initial temperatures. Considering 1-butanl we noticed that the lower flammability limit is decreasing with increasing initial temperature.

4 Acknowledgement

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References

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