Diagnostics on aluminium dust explosion ignited by spark discharge

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Several companies are using flammable dusts in their manufacturing process and are sometimes faced with the risk of explosion that can cause tremendous catastrophe with human and material damage. Dust explosions can have many ignition sources but static electricity represents the largest cause of ignition. In this context we use spark discharge to ignite dust explosions for studying conditions and characteristics of dust explosions in order to prevent them. The main goal of this work is to provide ignition experimental data usable for combustion modelling such as the minimum ignition energy (MIE), the burning temperature, the ignition delay, the variation of electron density and the spark temperature.

1. Experimental device

To inflame aluminium powder we used a Hartmann tube which is a polycarbonate transparent cylinder fitted with two tungsten electrodes that are cerium doped, having a cylindrical shape with a diameter of 2.4 mm whose ends are tip shaped with an angle of 40°. Compressed air blower spreads the deposited metallic dust and the spark generator provides the discharge which inflames the dust.

2. Minimum Ignition Energy (MIE)

The spark discharge energy is correlated with the discharge duration and the Langlie test [1] is used to determine the inflammation probability of a dust cloud with the spark discharge energy. The determined MIE of 350 mg of aluminium powder with a mean particle diameter between 15 µm and 25 µm is equal to 15.13 mJ.

3. Pyrometric and spectroscopic temperatures

Pyrometric measured temperatures are close to 2600 K and correspond to the burning particles temperatures in the Hartmann tube. However spectroscopic measured temperatures using vibro-rotational lines of AlO are about 3000 K and correspond to gas molecules temperatures and are certainly representative of temperature in flame front.

4. Ignition delay

The spark discharge interacts with the flammable medium through an ignition delay during which all the chemical processes of heat transfer from the spark to the inflammable product take place. The ignition delay follows a parabolic evolution versus the dust mass concentration. The average value is around 25 ms.

5. Spark temperature

To evaluate the discharge energy, it is necessary to determine the spark temperature. The spark discharge duration is fixed to 100 µs. Optical emission spectroscopy is used for the acquisition of the WI emission lines from different zones of the arc. An Abel inversion was performed to set up a radial distribution of the measured emissivity by defining a cylinder of radius r whose axis corresponds to the inter-electrode axis. Spatial-time evolution of WI excitation temperature is given assuming excitation equilibrium and using Boltzmann plot.

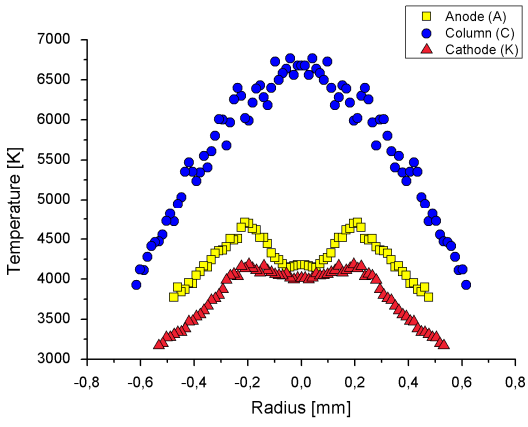

Figure 1 : Excitation Temperature at 50 µs

6. References

[1] S. Bernard & al. Statistical Method for the Determination of the Ignition Energy of Dust Cloud-Experimental Validation, Journal of lost prevention in the process industries, 23-3 (2010), 404-411.