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Analysis of pyrolysis gases from dust and powders

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Combustible dust and powder are flammable and can explode when in the form of a dust cloud exposed to an energy source and at critical concentration. The risk is known and the desire to minimize the risk is seen in the extensive research and studies within the area. Research is carried out to clarify the risk and to be able to set guidelines that can prevent accidents [1].

The ignitability of a specific dust or powder are defined by several parameters. Among other parameters describing the specific chemical properties of the dust-air mixture, parameters describing explosion sensitivity to the flow properties and to the heat transfer of the dust cloud. Explosive sensitivity is tested in laboratory tests from powder samples taken directly from the production. This method presupposed that these laboratory test data are comparable to or a conservative view of the actual conditions at the factory and in the production areas - this even though a dust cloud in the production is likely to be different from a dust cloud created in the laboratory with powder sampled from the industry [1-2].

The current study focuses on the analysis of the chemical compounds released by pyrolysis of combustible dust. Knowledge in this field is scarce and data therefore few, despite the properties of the pyrolysis gases are essential for the reaction and energy of dust explosions. The aim is to identify the pyrolysis gases from dust and powders at different temperatures.

When heating powders, the ambient oxygen will react with the gaseous substances released from the powder in an exotherm reaction. There will also be reactions between gas and liquid and between gas and solid. Although all three reactions are relevant, the homogeneous reaction will create the highest energy. Thus, it is this reaction gas to gas, that is the controlling step in a dust explosion while the other reactions are assumed to be very fast [2].

This study focuses on powders and dust from the food industry (milk powder, corn starch, cocoa powder etc.), the furniture industry (in the form of dust and other by-products) and the wood industry (dust and other by-products). In total, nine different dust and powders have been analyzed.

In the experiment the powder sample is placed in a reactor heated at temperature controlled on demand. The atmosphere in the reactor is 100% nitrogen to prevent oxidation products. For each temperature interval, two samples of the pyrolysis gases are withdrawn from the reactor. The samples are subsequently analyzed in a gas chromatography – mass spectrometry (GC-MS) with helium and argon as carrier gas in two columns.

The powders begin to release gases by pyrolysis at temperatures of 200-300 °C. At higher temperatures, a further degradation and a deeper release of pyrolysis compounds will occur, and the yield will increase.

The results from the GC-MC analysis show that hydrogen, carbon monoxide, carbon dioxide and methane are the primary gases identified in the pyrolysis gases. The initial pyrolysis gases formed is CO_2 and H_2, where the concentration of CO_2 is proportionally high.

Concentration of H_2 is low at intermediate temperatures but has a steady incline. In opposite to the concentration of CO_2, where the concentration is high (up to 14,1 %) with a corresponding steep incline. Most dust samples have a maximum concentration of CO_2 at 400 °C. At intermediate temperatures the concentration of CO is low for most samples.

At 600-700 °C the concentration of CH_4 peaks with a concentration of almost 50 % in all samples.

At temperatures above 600 °C, the measurements show high concentration of H_2 (10,8 - 31,2 %) and CO (13,8 – 39,0 %), which seems unusual, but is consistent with other studies of pyrolysis at high temperatures [3]. The concentration of CH_4 follows a decline matching the incline at low temperatures. It was possible to make a correlation between the concentration of methane and a Gaussian distribution with a very good fit, for all tested dusts and powders.

The study should be seen in connection with a longer study at RISE [4] regarding the determination of combustion and explosion properties for dust clouds composed of biomass materials.

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