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CFD simulations of vented dust explosions in large biomass storage silo

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Combustible dust is a recognised hazard that is present in many industrial facilities that handle or storage biomass materials. This dust can generate explosible atmospheres in silos and other equipment. The mitigation of unacceptably high explosion overpressures in silos is commonly achieved by venting devices. Many industrial storage facilities for wood pellets consists of silos of large volume, typically around 20,000 m3, while standards for designing vent areas (EN 14491 and NFPA 68) state a range of application for the vessel volume of up to 10,000 m3. Moreover, standards do not consider all the different possible scenarios that could occur in reality. For these reasons, developing and applying alternative venting sizing procedures is necessary. In this sense, numerical simulations are a powerful tool that can be applied to this kind of problems.

In this study, explosion simulations have been carried out for a 18,500 m3 silo, 32 m in diameter and 33 m in total height (20 m of cylinder plus 13 m of conical roof) using a uniform grid composed of cubic cells measuring 1 m in size. The CFD code applied was the FLACS-DustEx by Gexcon, using a fuel file with the combustion characteristics obtained from a pine wood sample (Pmax = 7.9 bar and KSt = 131 bar·m/s). A set of 16 different simulations were calculated in order to perform a 2k factorial analysis involving four factors (venting area, ignition location, initial turbulence and dust concentration) and two levels. In all scenarios, the dust cloud occupied the 75% of the volume of the silo –a quite conservative scenario– and was located in the upper part; this corresponds to a situation during the loading process of the silo, when a dust cloud is mainly formed into the conical roof and upper part of the cylinder of the silo.

The results from the whole set of simulations were studied and analysed to detect trends and the most influential effects. Turbulence was the most influential factor, followed by the dust concentration and the venting area. The ignition location hardly had any effect. These results imply that controlling the turbulence during loading operations is of great usefulness to avoid large explosion overpressures; this requires gentle conveying systems and low operational velocities. Although the results are very dependent on the values adopted for each factor, this kind of approach could be useful to address explosion risks assessments in complex industrial scenarios.