OPTIMISING
DUST EXPLOSION VENTING

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FLACS
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- **Objectives**
  - Determine the reduced overpressure ($P_{red}$) inside a silo after an explosion
  - Determine the vented effects externally on buildings and in occupied areas
  - Investigate the effects of different relief vent areas, vent designs and vent locations
  - Determine the optimum venting design for the silo

- **Challenges**
  - A large enough total vent area needs to be used to ensure the reduced overpressure inside the silo does not exceed the silo design strength
  - To evaluate the additional consequential effects of external vent relief
  - Simultaneously, the total vent area needs to be as small as possible to reduce cost, maintenance and risk of water ingress

- **Software**
  - FLACS-DustEx v10.3r2

- **Solution/Added Value**
  - Run varying dust cloud/ignition location explosion simulations with varying relief vent areas to determine the reduced overpressure for each case. These results can be used to create a curve of reduced overpressure against vent area, allowing the optimum total vent area to be chosen. Details of overpressure on external structures are also provided.

- **Introduction to the case**
  - Biomass power-generation schemes often require very large storage areas. Silos can have capacities exceeding 60,000 tonnes and 100,000 m³. International standards for dust explosion protection determining overpressures in enclosures protected with explosion relief panels (e.g. EN 14491:2012, NFPA 68) are based on empirical data. In particular, they are only proven for vessels with volumes less than 10,000 m³ and are generally not suitable for massive bulk-biomass stores. If used, these methods often impose excessively conservative explosion protection requirements with the associated economic penalties. As an alternative to the empirical formulations presented in the standards, computational fluid dynamics (CFD) codes may be used. FLACS-DustEx is a CFD tool developed to simulate dust explosions.

  Here, large silos are planned to be installed amongst structures at an existing facility. To reduce the maximum pressure realised during an explosion event, and to minimise the risk of escalation to ALARP (As Low As Reasonably Practicable), provision is made for an array of 4 m high explosion relief vents (set to open when the pressure increases above $p_{stat} = 0.1$ bar) to be installed around the circumference of the silo near its top. FLACS-DustEx explosion modelling has been performed to evaluate a conservative (worst) case explosion originating within the silo from an ignition source at the base. This has evaluated the efficacy of explosion-relief burst membranes to provide sufficient vent area to allow the rapid combustion from a deflagration to continue to expand externally thus achieving the required reduced explosion pressure ($P_{red} = 0.3$ barg) within the silo.
Modelling with FLACS-DustEx

The case is set up with a range of dust clouds so as to determine a realistic worst-case scenario. This is ignited at the bottom of the silo, to give the longest possible flame path. Explosion relief vents are defined on the silo with a static opening pressure of 0.1 barg. This simulation is repeated with varying total vent areas.

The reduced overpressure inside the silo, as well as overpressures on other surrounding buildings and structures, are recorded. Similarly, the predicted flame envelopes are predicted in order to highlight areas of risk to personnel.

For the case illustrated herein, EN 14491:2012 significantly overpredicts the explosion relief vent area required. For the allowable maximum pressure (here $p_{max} = 0.3$ barg), EN 14491:2012 requires a vent area of 521 m$^2$. The most conservative FLACS-DustEx simulation suggests that a vent area of 350 m$^2$ would be sufficient (see Figure 4). Hence, EN 14491:2012 overpredicts the required vent area by around 1.5 times. This could represent an additional cost of proprietary explosion vent panels alone of over £50,000 (estimated £300/m$^2$ vent area), taking into consideration installation costs and future maintenance this figure could easily be £150,000 difference. Note that, for this case study, the most conservative scenario is counter-intuitively the 33% dust cloud. This highlights the importance of considering a wide range of scenarios in the analysis.

At the detailed design stage, the above study could be expanded for value-engineering purposes to predict the consequence of a dust explosion for a wider range of scenarios. For example, multiple ignition locations might be considered. The filling of the silo might be explicitly modelled to determine the likely dust cloud size and concentration and the resulting turbulence levels. By considering a representative sample of all the possible scenarios, the probability that the overpressure in the silo will exceed its design value can be estimated and suitable explosion protection can be determined on an economical basis with the justification recorded within the Risk Assessment Methodology thus achieving a robust basis of safety while demonstrating ALARP.

Added value for the project

- Standards typically suggest using a stoichiometric homogeneous cloud volume equal to 100% of the silo volume, resulting in very conservative results. Simulations undertaken with FLACS-DustEx helped reduce this excessive conservatism.

- Aided in development of a robust basis of safety while demonstrating ALARP.

- Optimum vent area determined.

- Visualization of explosion events highlighting high risk areas.

- Input for structural analysis.

- Potential to determine likelihood of secondary explosions, fires, risk to personnel, etc.

- Reduced vent area reduces probability somewhat of water ingress and thus reducing probability of fire from smouldering combustion which has a higher probability than that of an explosion.
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Figure 1: Flames from an explosion showing impingement on a neighboring building

Figure 2: Dust cloud defined inside the silo before the explosion simulation is begun

Figure 3: Pressure contours on surrounding buildings and structures from a dust cloud explosion inside the silo

Figure 4: Comparison of FLACS-DustEx Simulations with EN 14491:2012
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