A new approach based on an open source code for modelling dust explosions and future challenges

Chen Huang and Andrei Lipatnikov

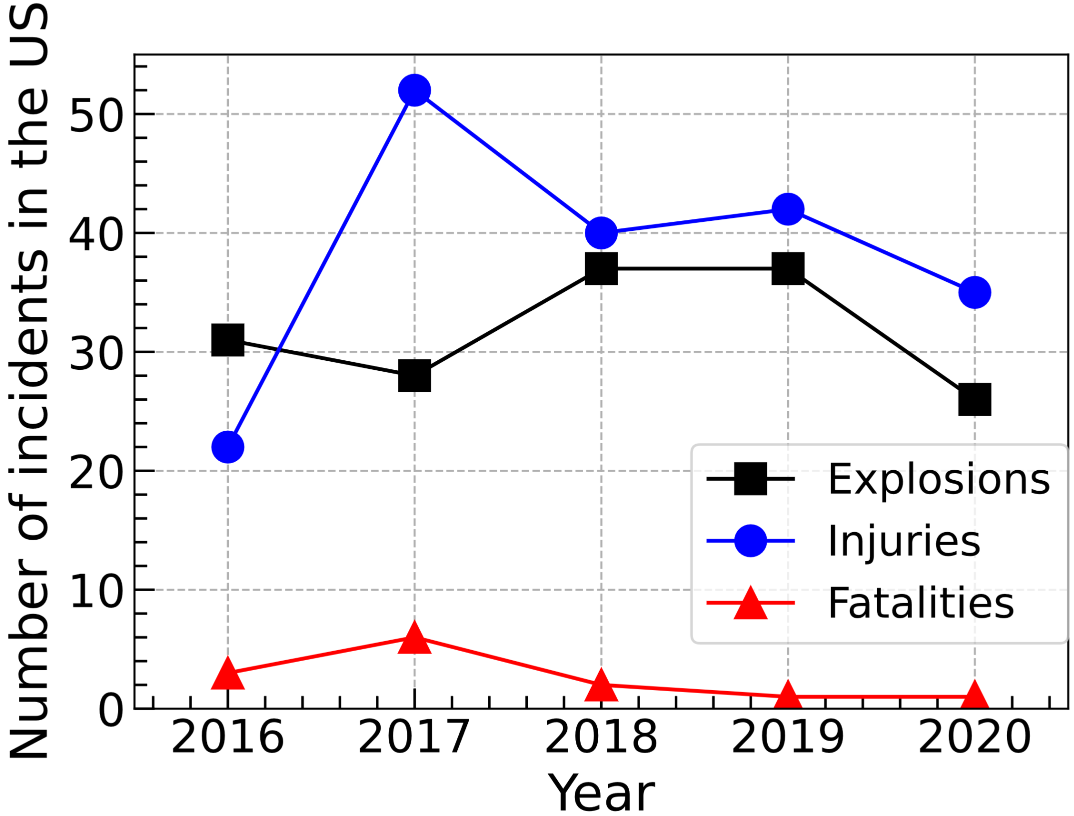
RI. SE CHALMERS

Brandfarlig vara 2021, webbinarium 25 November

Outline

- Background
- Goal
- Method
- Results and discussions
- Future challenges

Background



"One dust explosion occurs in each industrialized country every day."

Christophe Proust

Cloney, C.,. 2020 COMBUSTIBLE DUST INCIDENT REPORT.

Background

Flera bränder har drabbat foderfabrik i Lidköping, 2021-10-21; 2020-10-19

Dammexplosion i stålindustri, Falköping, 2021-11-03

Open source

- Commercial companies: Adobe, Facebook, Google (Android), GitHub, IBM, Intel, LinkedIn, Microsoft, Netflix, Redhat, Twitter, … …;
- ”Open source”: freedom to share source code, freedom to change, freedom to distribute;
- Advantages: easier and faster collaboration;
- Disadvantages: steep learning curve, users responsibility, business model for private code developers.

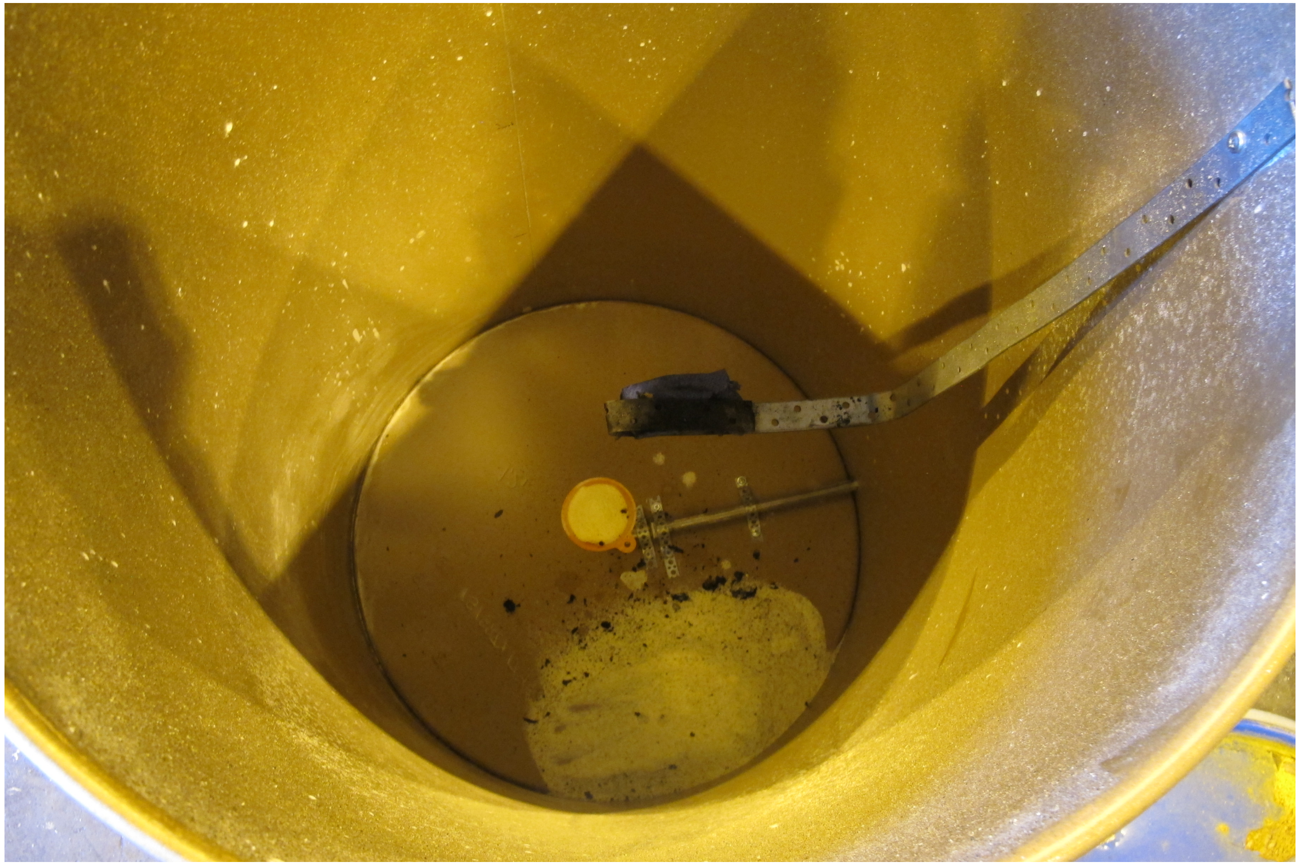
CHALMERS

RI. SE

Goal

- Present a new method based on open source code
- Practical usage of the method
- Future work and challenges

Demonstration



Demonstration

Method

- Computational Fluid Dynamics approach: the governing equations for mass conservation, momentum, species transport, flame propagation are solved in many controlled volumes using proper models and numerical schemes.
- Dust explosion resembles a gas explosion for fine dust particles and high volatile content (Bradley et al 1988, 1989).
- A gas explosion is a premixed turbulent flame.

Method

- Flame Speed Closure model focusing on flame propagation in a turbulent premixed flame
- FSC model was quantitatively tested for laboratory gaseous turbulent premixed flames from different groups with different conditions (Lipatnikov 2002).

Lipatnikov, A.; Chomiak, J., *Progress in energy and combustion science* **2002,** *28* (1), 1-74.

Results and discussion

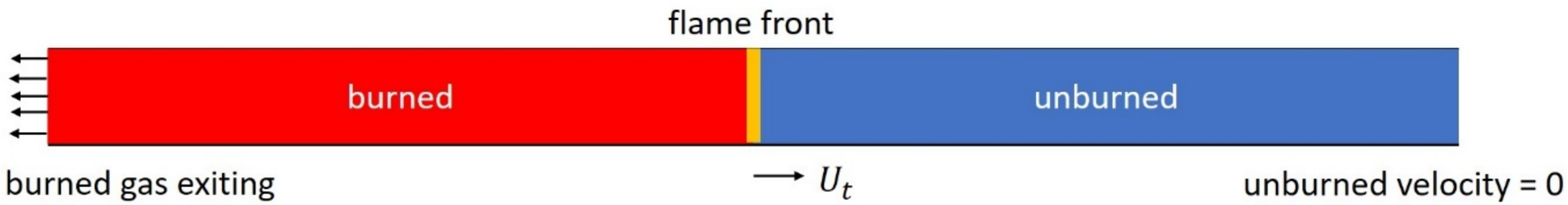
- Verification
- Validation
- Industrial application

CHALMERS

RI. SE

Verification

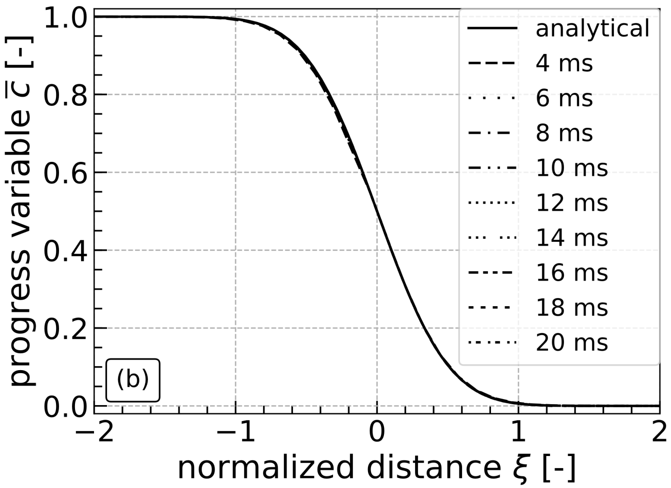
1-D planar flame in “frozen” turbulence

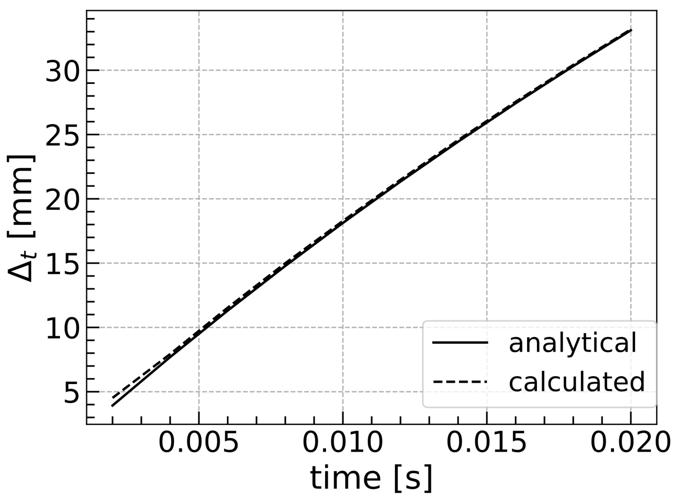


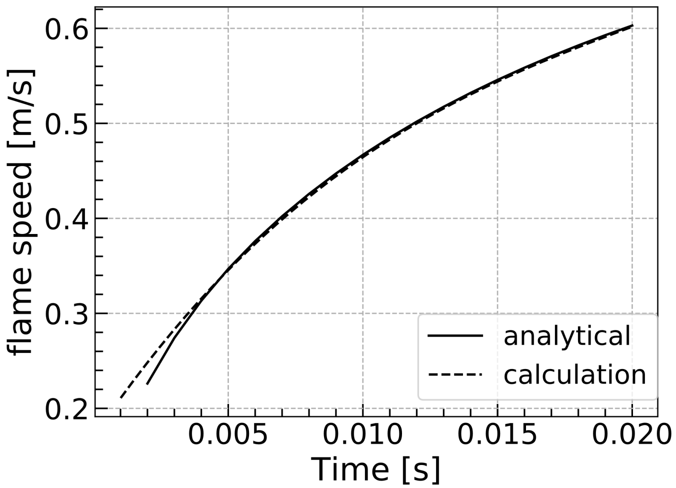
CHALMERS

RI. SE

Verification





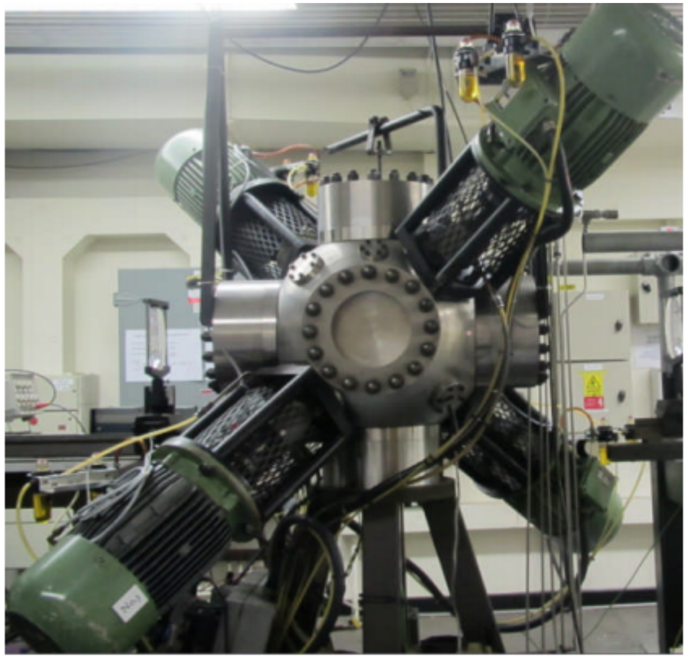


CHALMERS

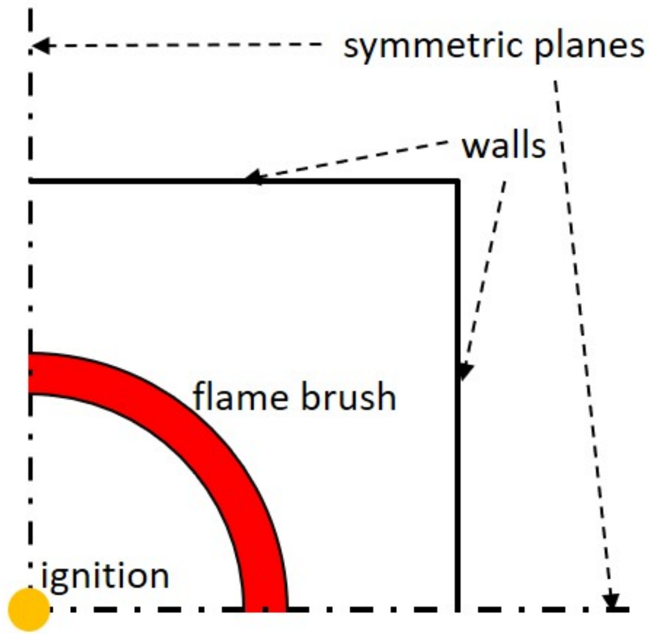
RI. SE

Validation

Leeds fan-stirred vessel for corn starch explosion



Leeds fan-stirred vessel by Anggono et al. (2013)



Schematic illustration of dust explosion model

Validation

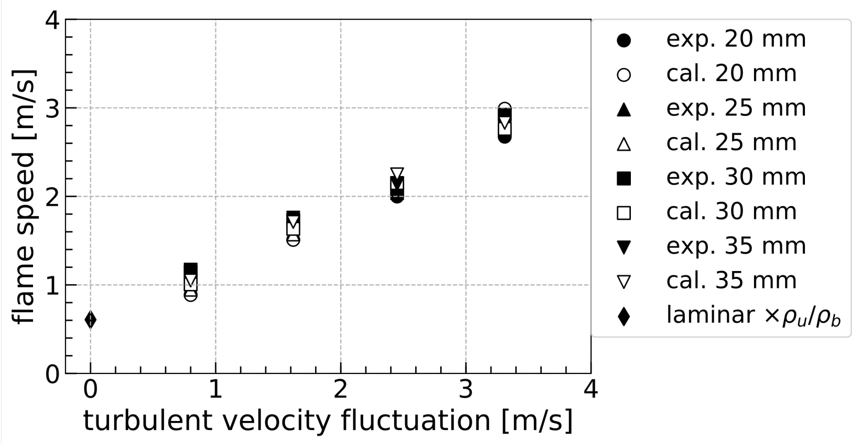


Fig. 3. Comparison of computed (open symbols) and measured (filled symbols) mean flame speeds. The diamond symbol represents the laminar flame speed multiplied with the density ratio.

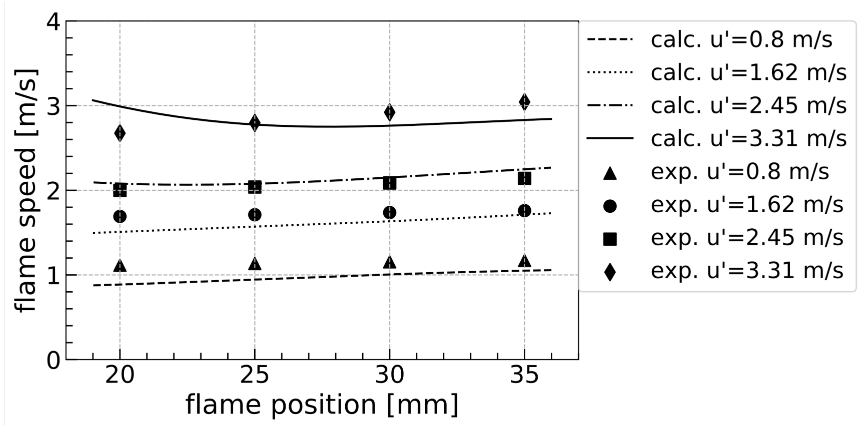


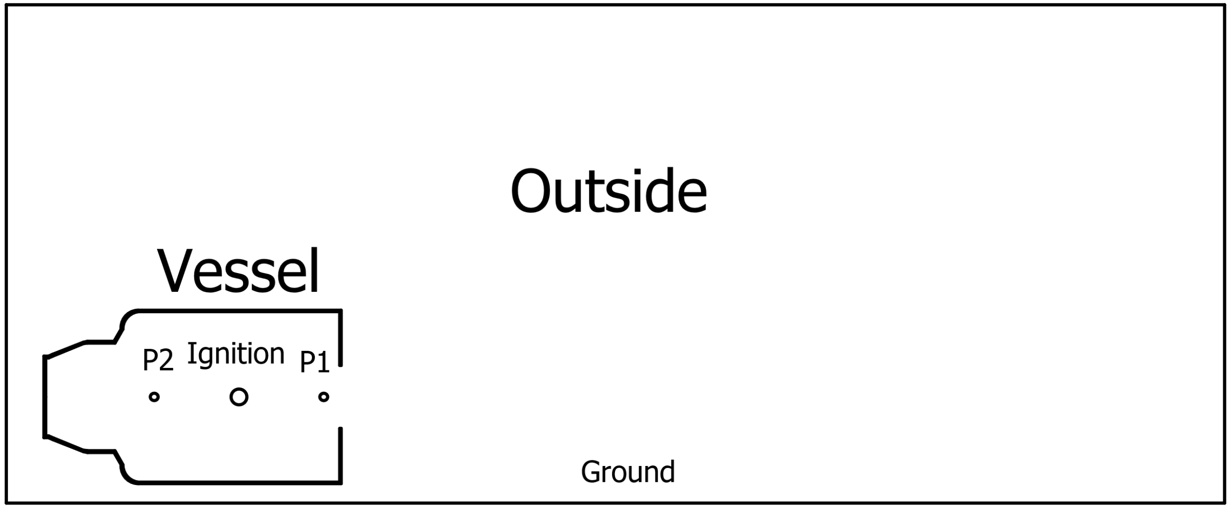
Fig. 4. Computed (lines) and measured (symbols) mean flame speeds vs. mean flame position.

Huang, C.; Lipatnikov, A. N.; Nessvi, K., *Journal of Loss Prevention in the Process Industries* **2020,** *67*, 104237.

Industrial application

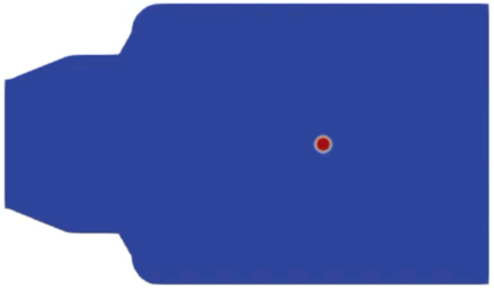
Vented dust explosion in an 11.5 m^3 vessel

Vented dust explosion



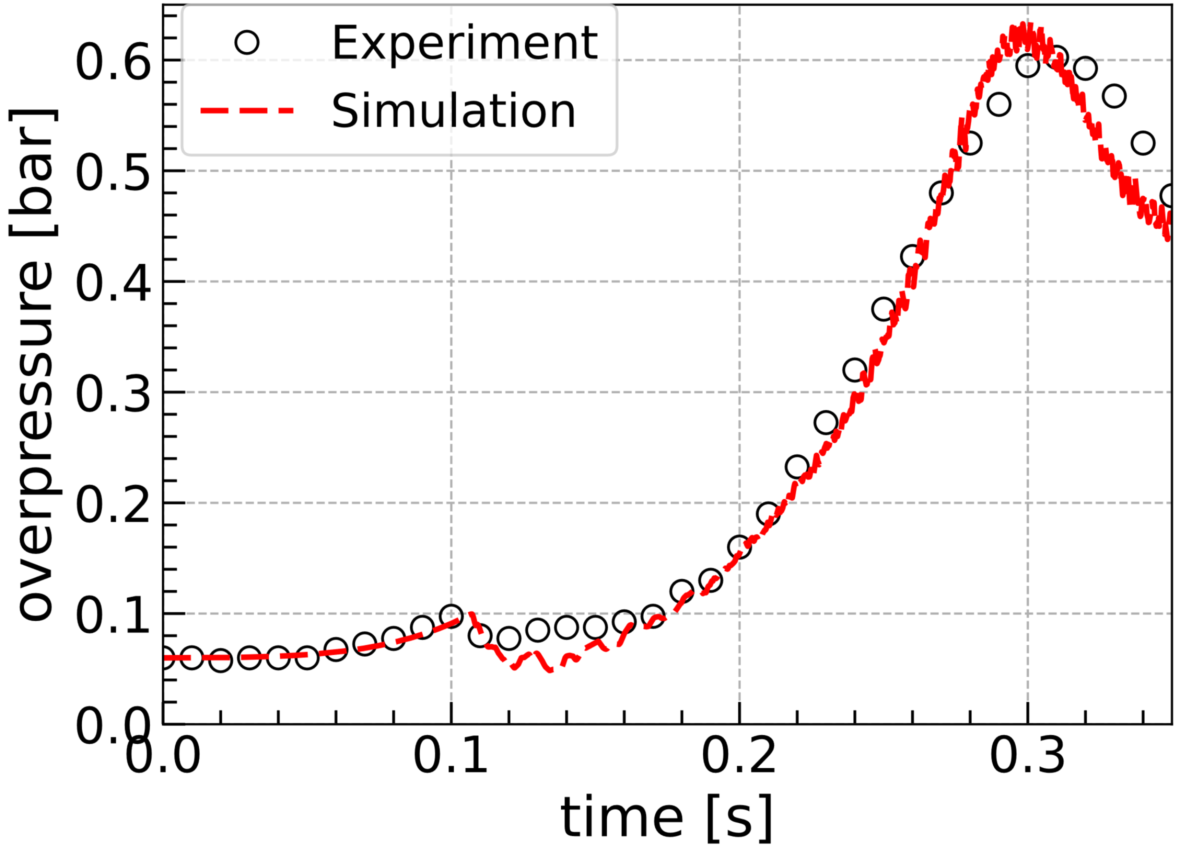
CHALMERS

RI.
SE

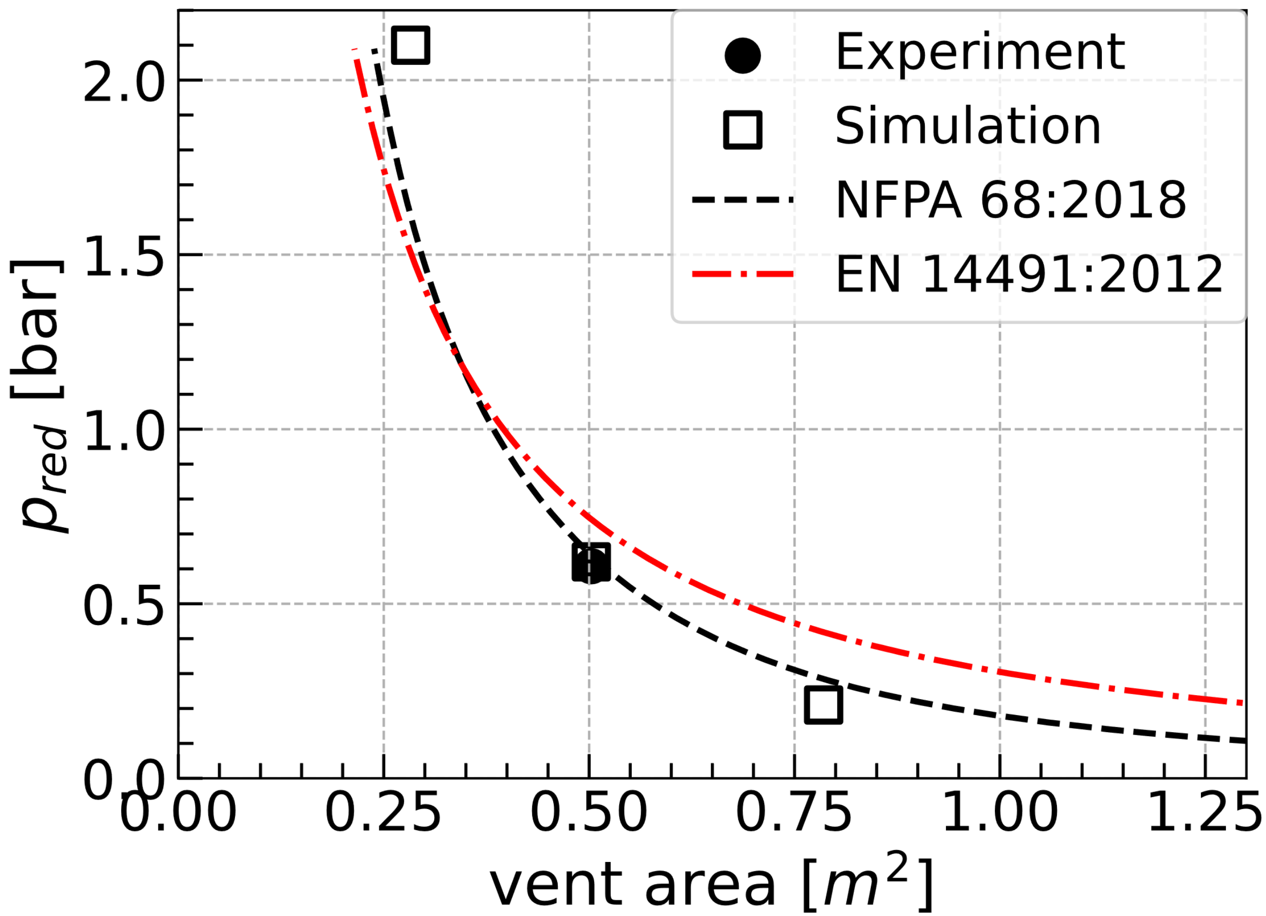


CHALMERS

Industrial application



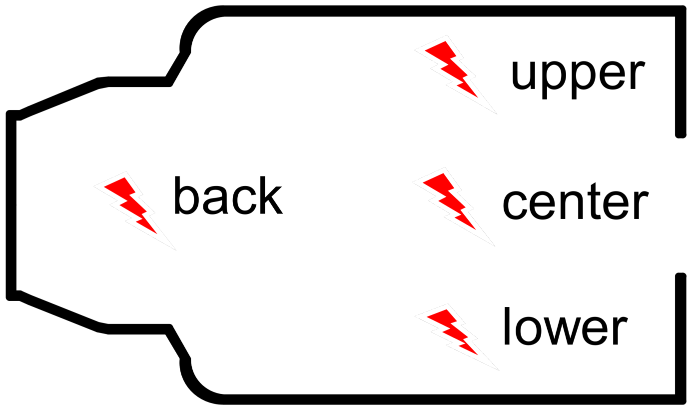
Vented dust explosion

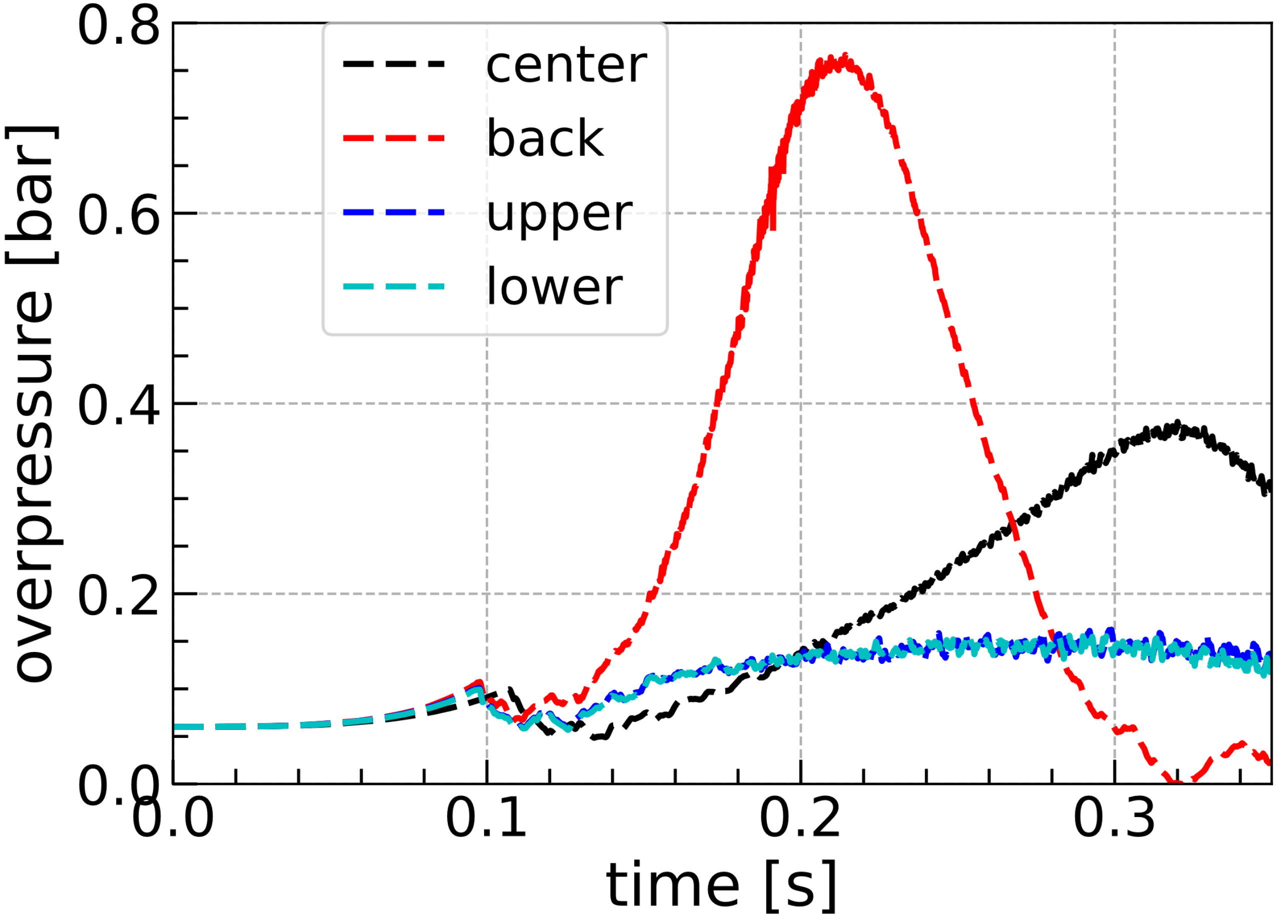


CHALMERS

RI. SE

Ignition location





CHALMERS

Conclusions

- A new approach (model and code) of modelling dust explosions was developed using an open source code;
- The model and code were verified and validated;
- The model and code were compared to large-scale industrial applications with reasonable agreement.

Future research challenges

- Fundamental knowledge about dust explosion, i.e. laminar burning velocity.
- Better treatment of turbulence modelling.
- Metal dust.
- Incidents analysis.
- Education.
- Collaboration and communication.

CHALMERS

RI. SE

Thank you!

"FIRE MODELING WON'T REPLACE FIRE TESTING. IT WILL ALLOW US TO DEVELOP A BETTER TEST, LEARN MORE FROM THE TEST RESULTS AND APPLY THOSE RESULTS TO A WIDER RANGE OF FIRE SCENARIOS."

FM Global's Dr. Sergey Dorofeev, research area director,
fire hazards and protection.