Combex 2013

Numerical simulation of continuously rotating detonations in an annular combustor with a wide gap at separate feed of fuel and oxidizer

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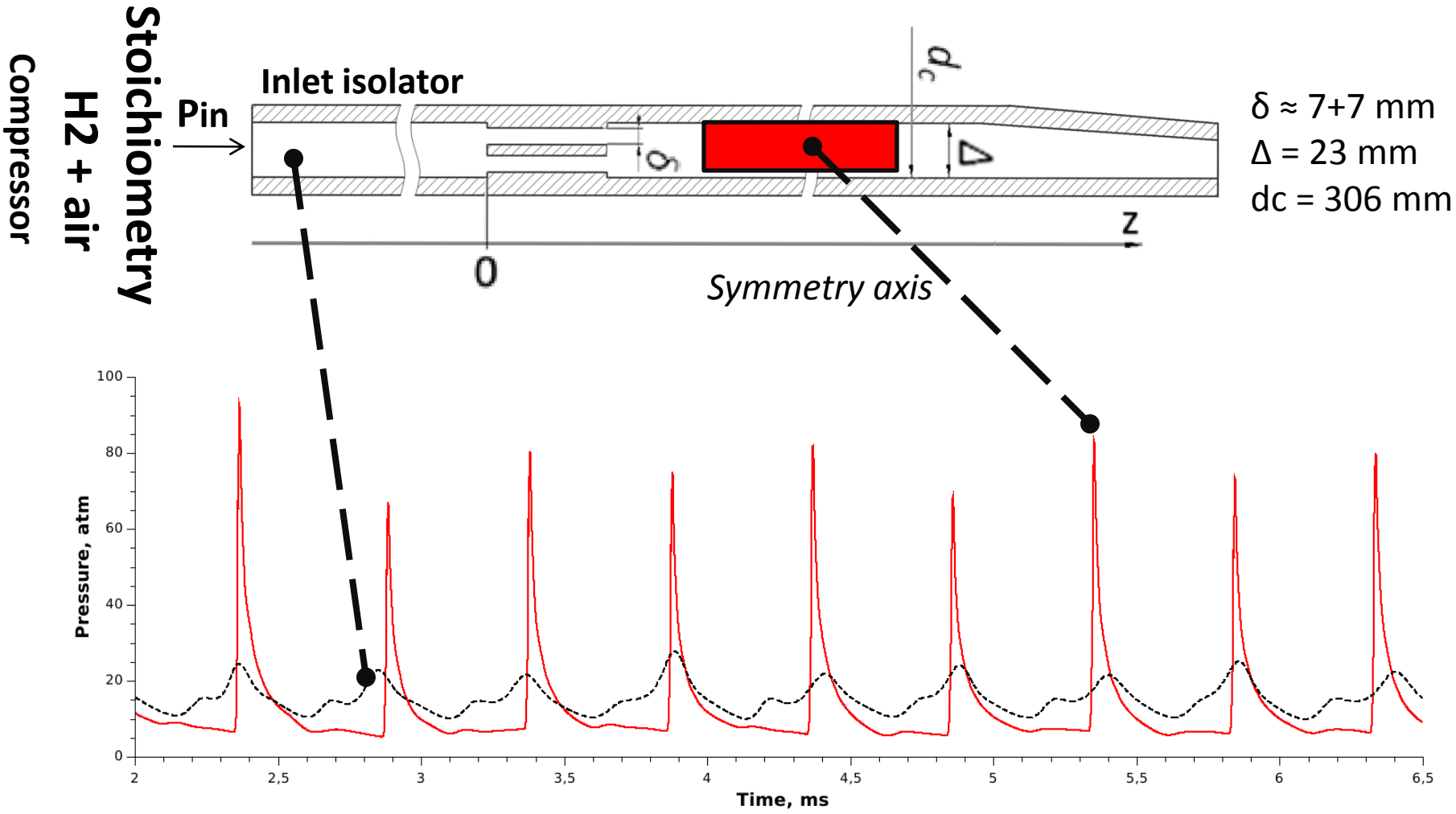
Introduction

Zel’dovich

Wojciechowski

In previous works



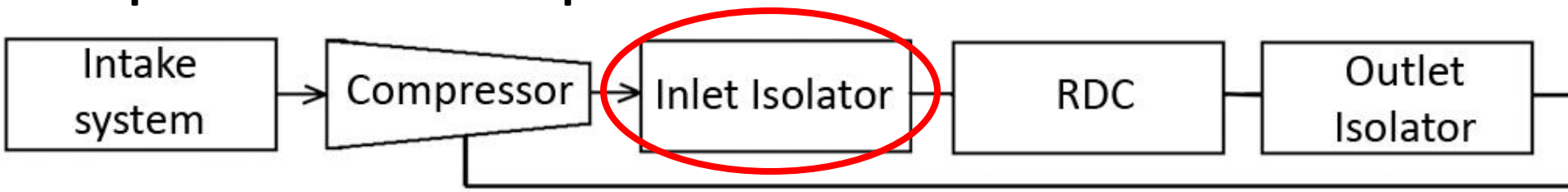
Pressure pulsations in the inlet isolator reach 40÷45 % Pin

Objective

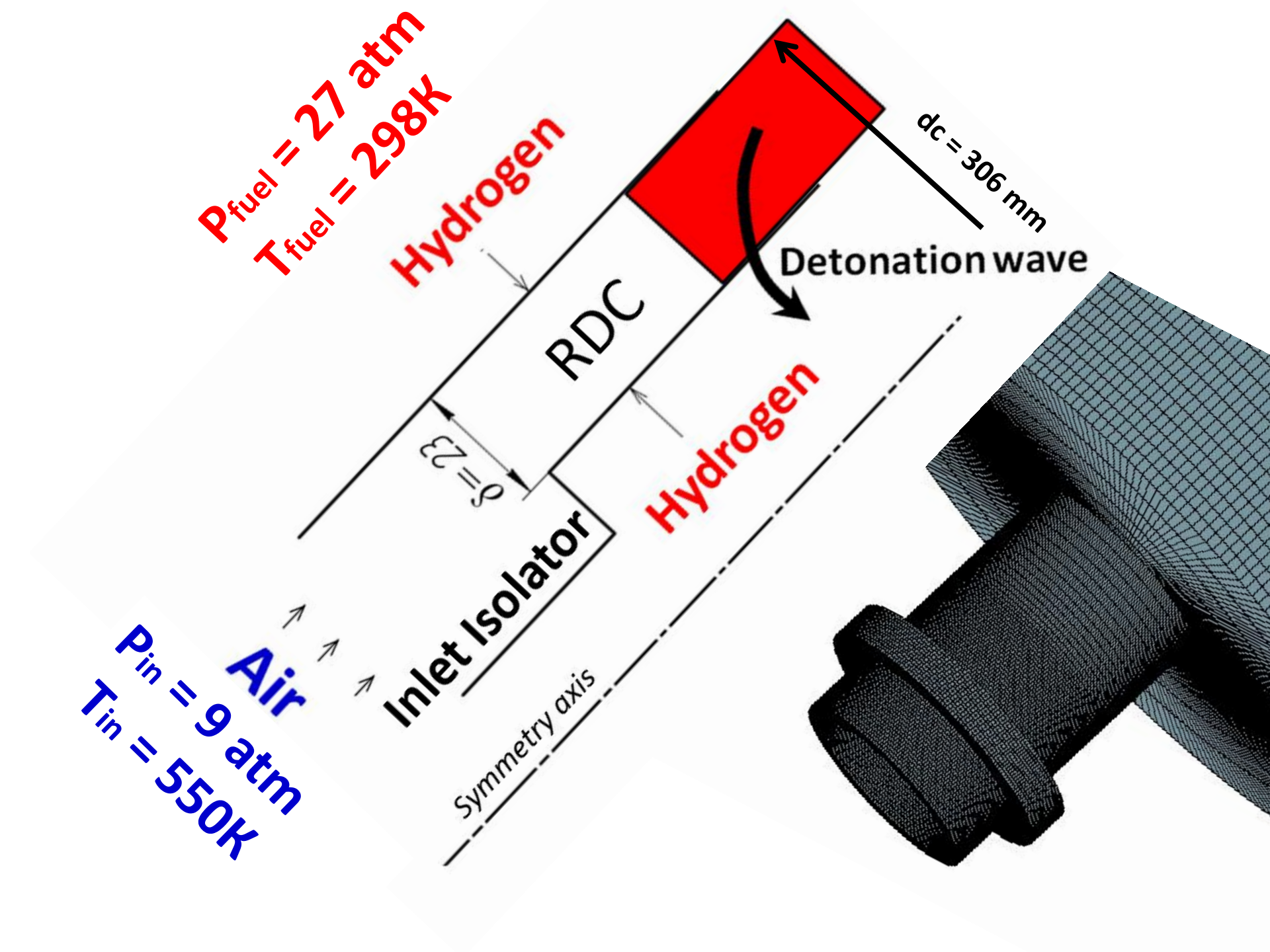
Demonstrate the ability of integration of rotating detonation chamber (RDC) into gas turbine installations (GTI) using numerical simulations, i.e. prove the possibility of the working process in the annular combustion chamber with a wide gap (comparable to the height of the last stage of the compressor blades) at separate feed of fuel and oxidizer.

Provided that RDC is a chamber with total pressure gain.

Design geometry of inlet isolator to prevent the unstable operation of the compressor.

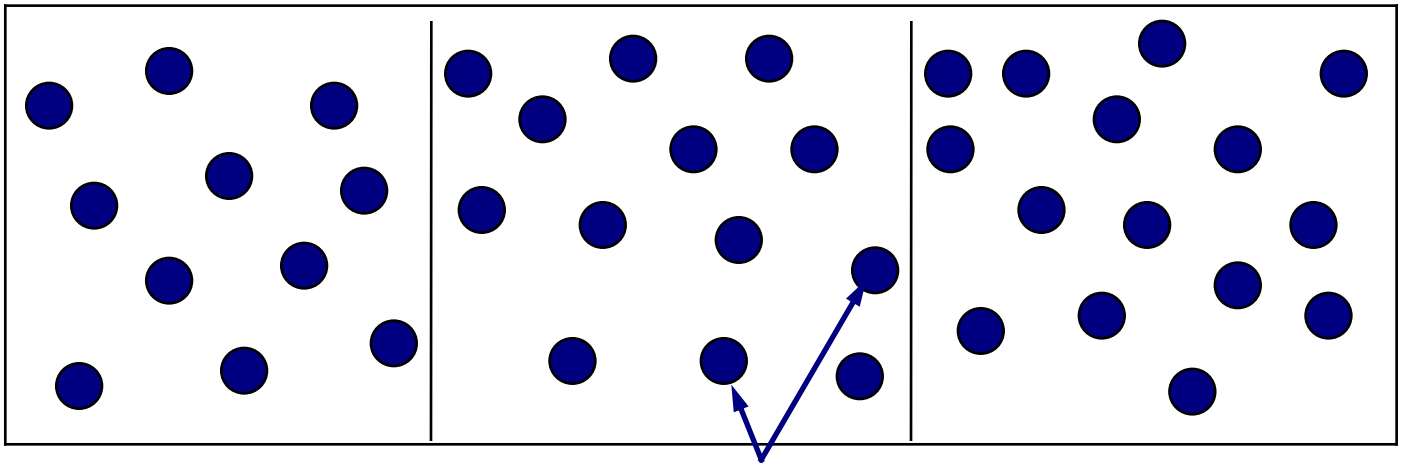


The statement of the problem


P_{fuel} = 27 atm
T_{fuel} = 298K
Hydrogen
RDC
dc = 306 mm
Detonation wave
δ = 23
Inlet Isolator
Hydrogen
Air
P_{in} = 9 atm
T_{in} = 550K
Symmetry axis

Numerical approach

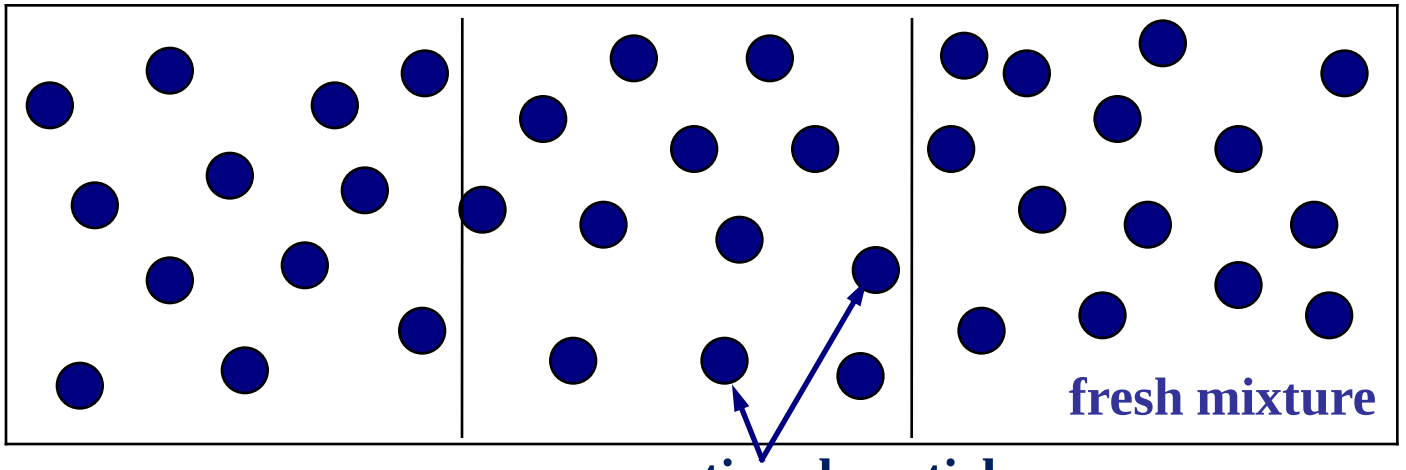
- 3D URANS equations
- Turbulence model (k-epsilon)
- Multicomponent reactive mixture
- Ideal-gas thermal and calorific equations of state
- Particle method for modeling micromixing and combustion



notional particles
(10 particles in cell)

neglect frontal combustion

Combustion model: Particle method



Monte-Carlo particle

Trajectory equation (particle displacement in space and time)

Mass conservation equation (molecular diffusion, **chemistry**)

Momentum conservation equation (**stochastic pressure force,** viscosity)

Energy conservation equation (molecular conductivity, **chemical energy release**)

Each particle has its own composition, velocity, and temperature

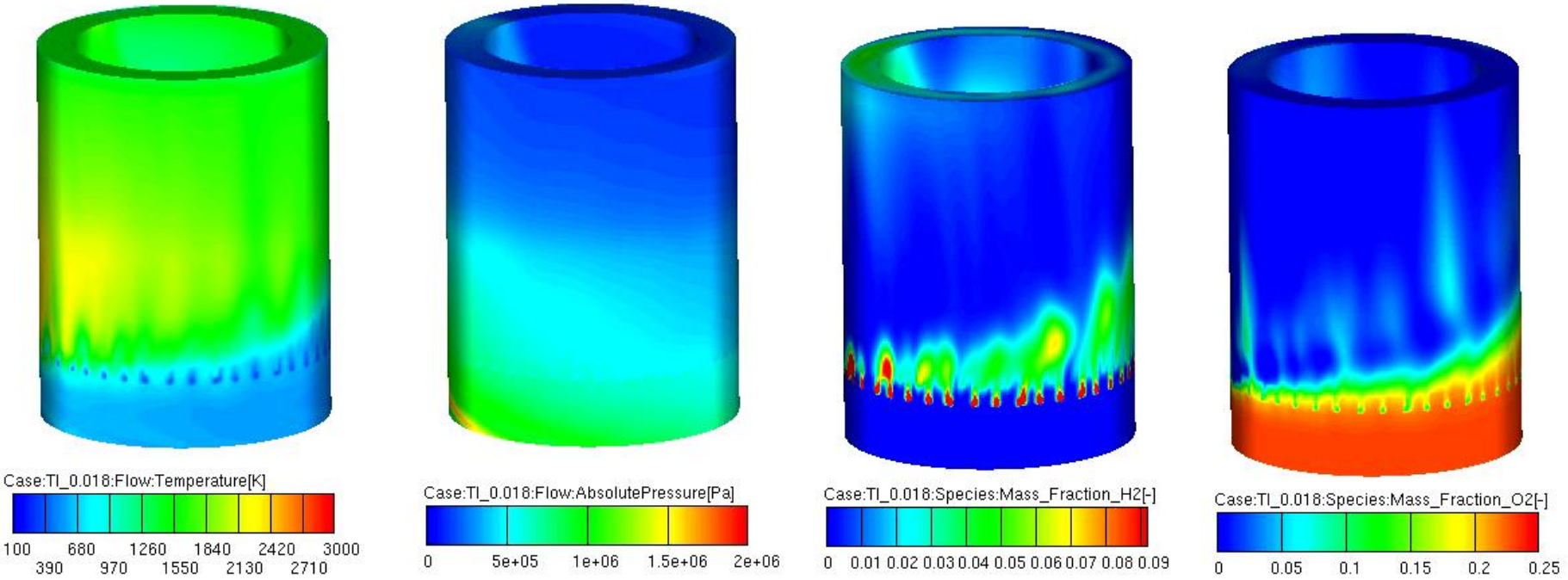
Particle represents a state realization in turbulent flow field

Results of calculation

Detonation propagation in RDC

Turbine

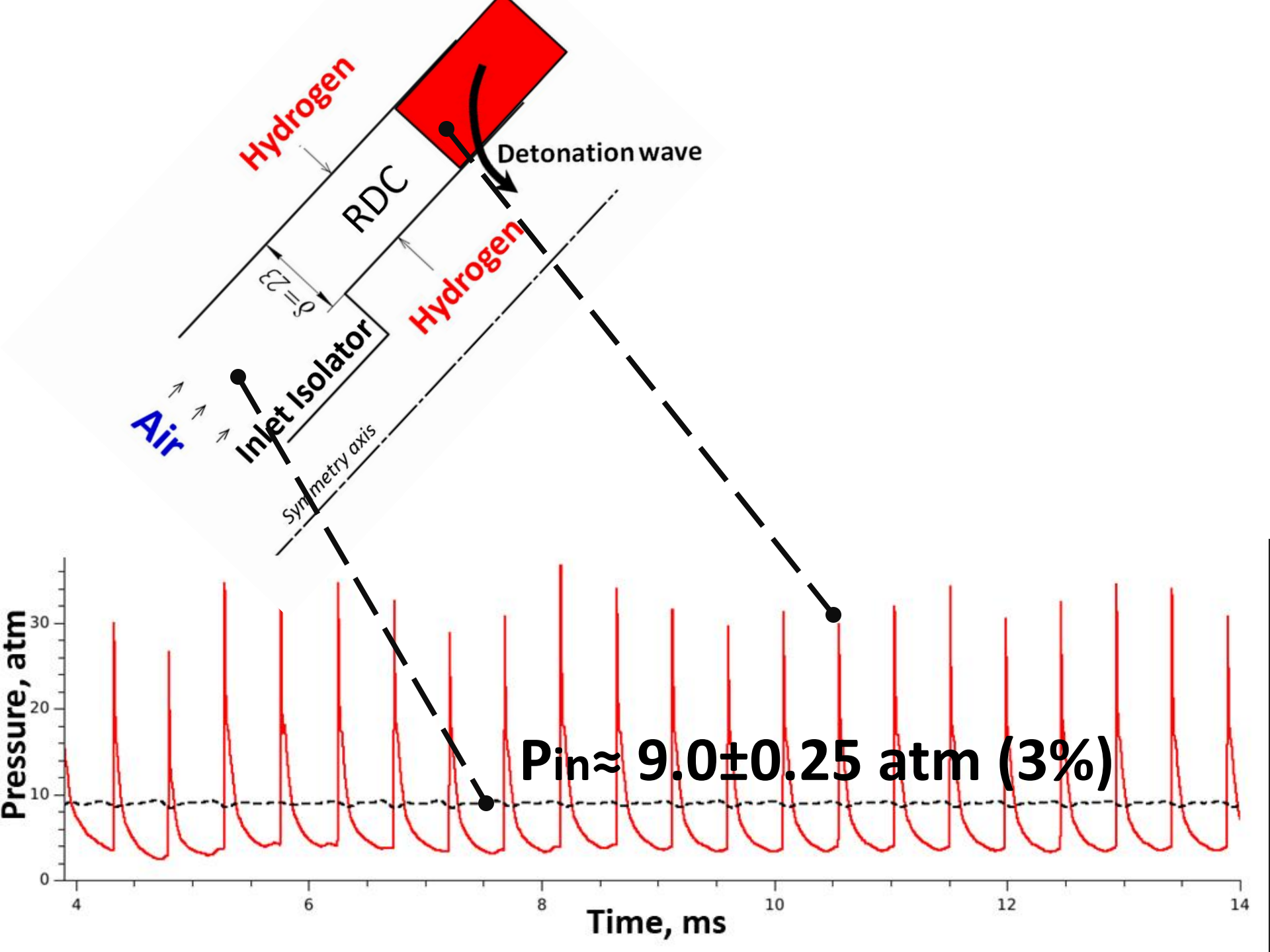
Outlet Isolator



Temperature **Pressure** **$y(H_2)$** **$y(O_2)$**

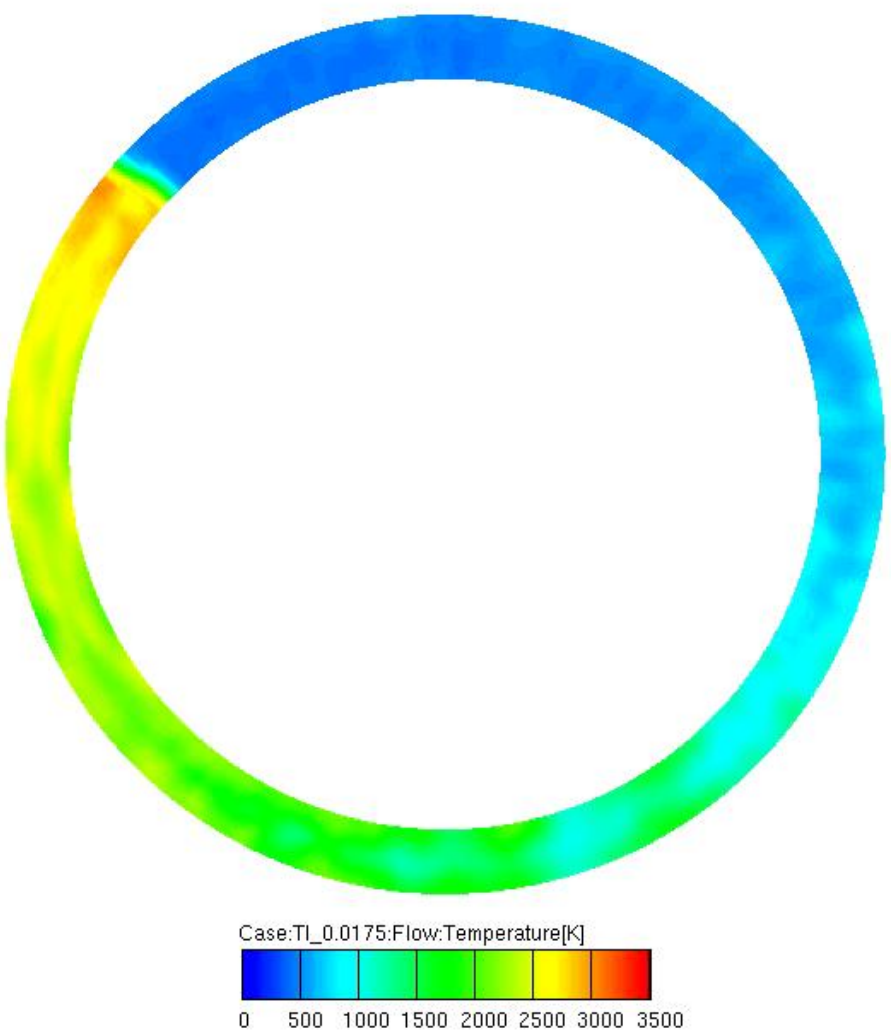
Inlet Isolator

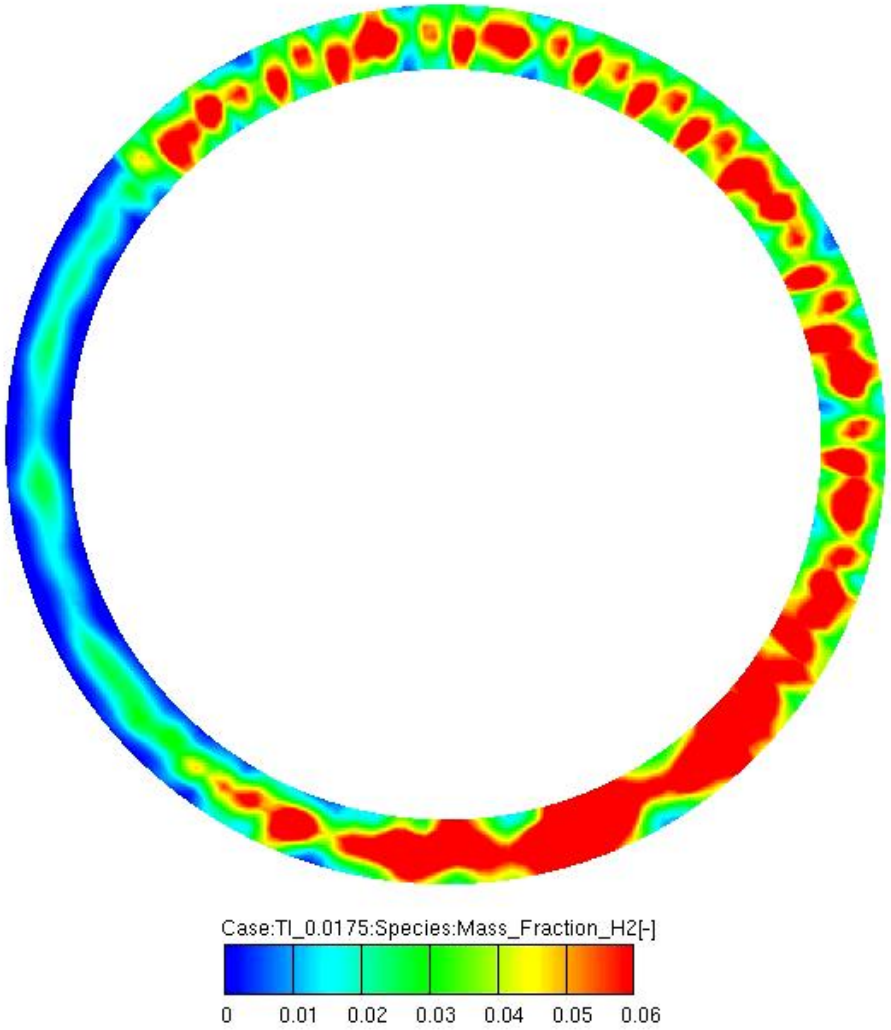
Compressor


Hydrogen
RDC
Detonation wave
Hydrogen
δ=23
Inlet Isolator
Air
Symmetry axis
Pressure, atm
0
10
20
30
4
6
8
10
12
14
Time, ms
Pin≈ 9.0±0.25 atm (3%)

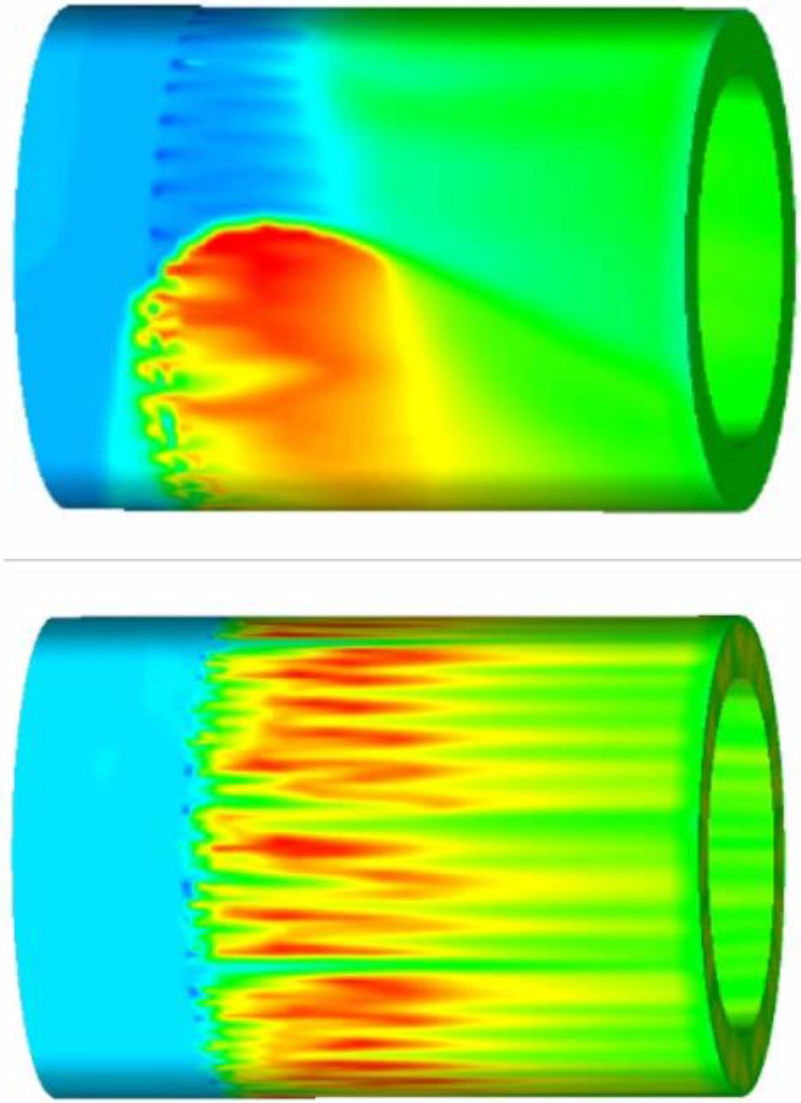
Detonation propagation in RDC

(horizontal cut)

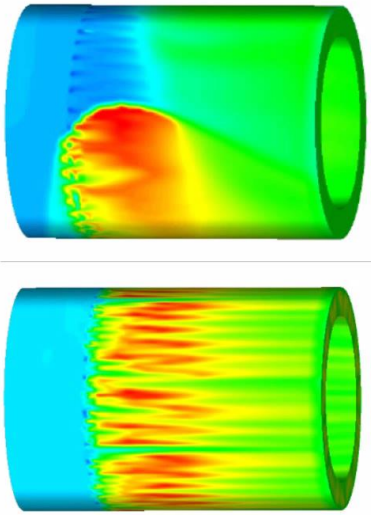


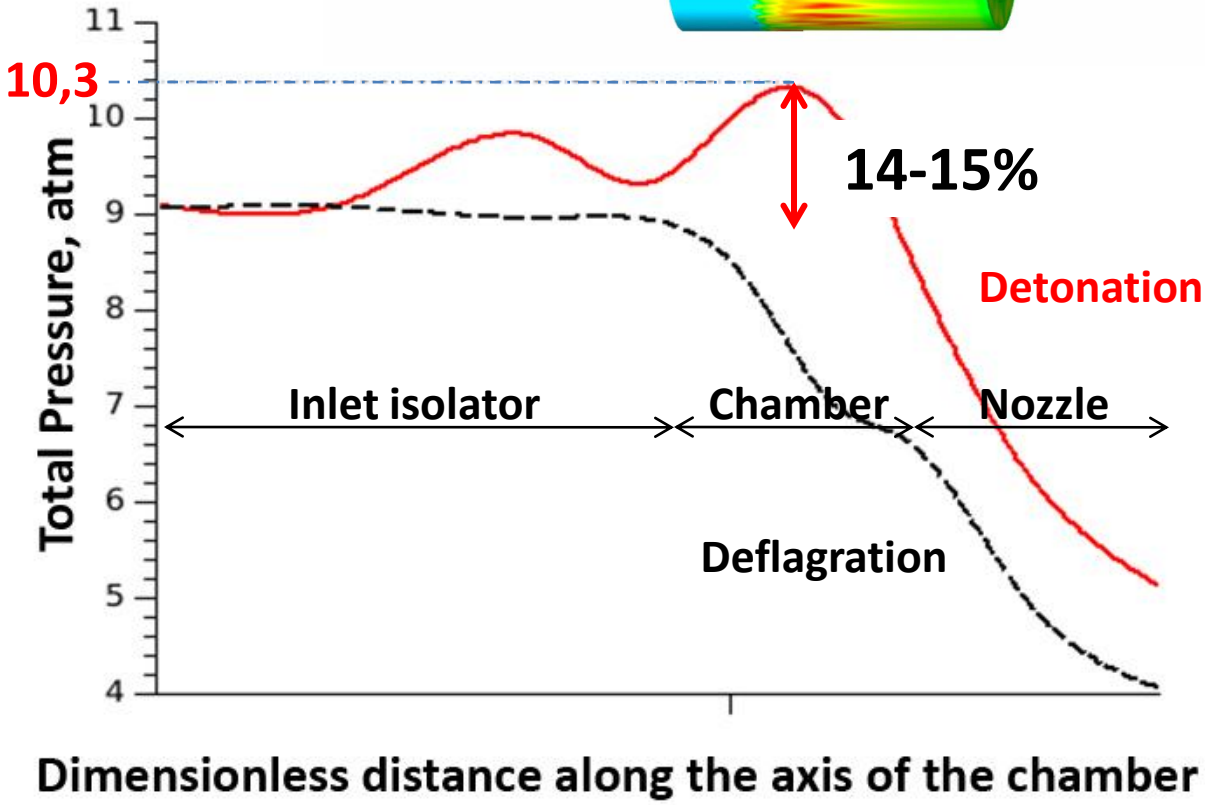


Detonation vs Deflagration

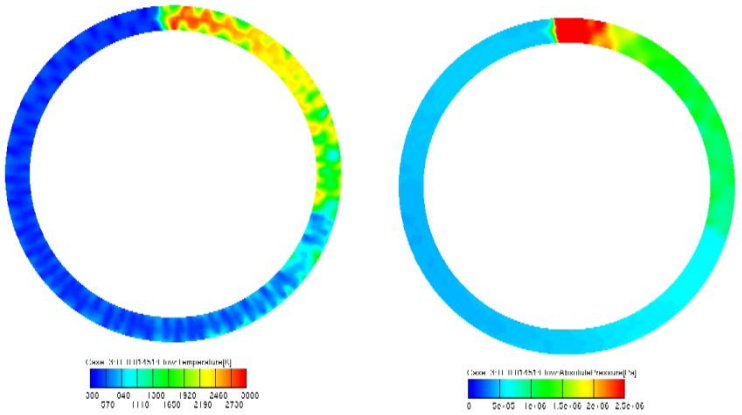


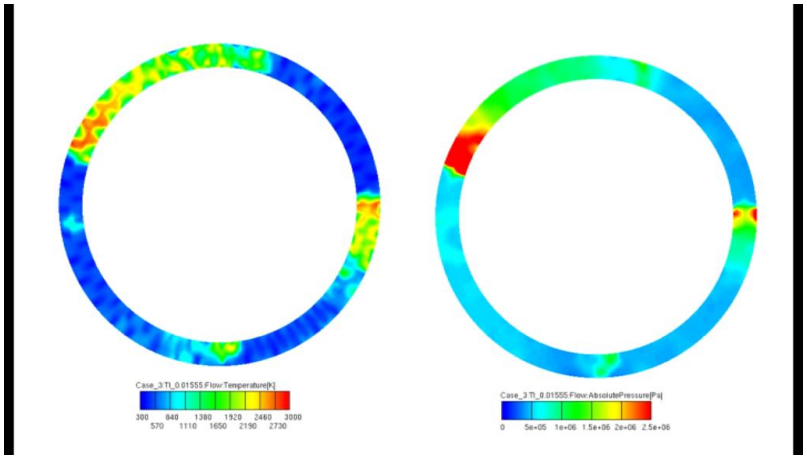
Detonation
vs
Deflagration

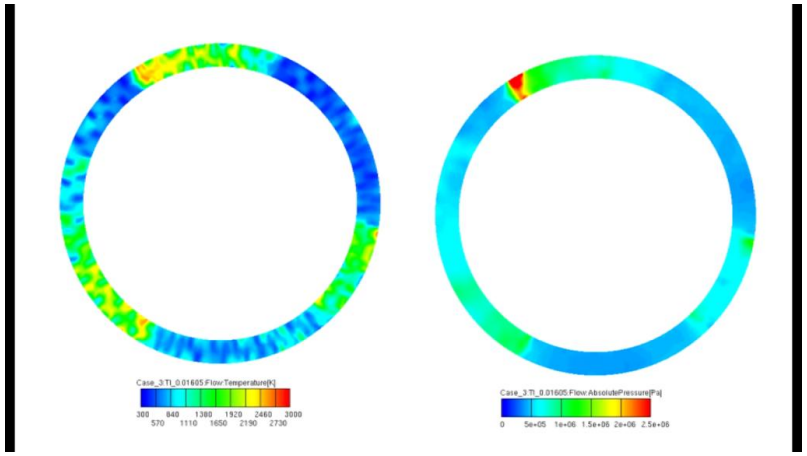


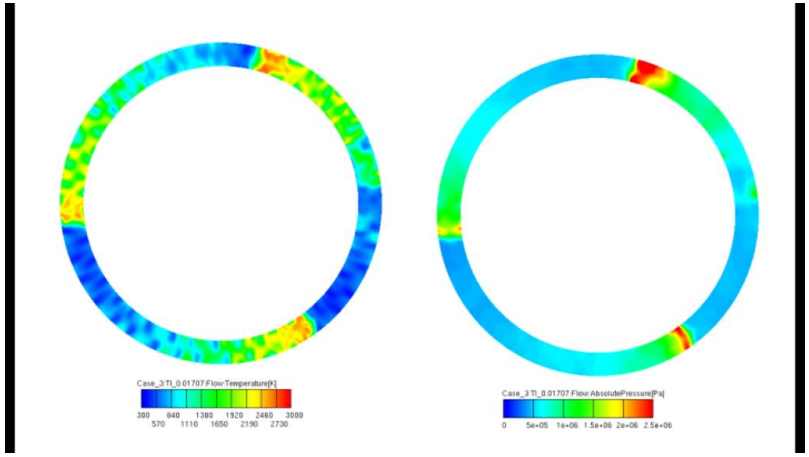


Multiple DW
(other initial conditions)









Conclusions

- **Efficient tool and technique for transient 3D numerical simulation of the operation process in an RDC with separate delivery and in-chamber mixing of hydrogen and air with a wide gap has been developed.**

- **RDC is a chamber with total pressure gain.**

- **New geometry of inlet isolator damps pressure pulsations.**