FACULTY OF ENGINEERING AND ARCHITECTURE

DEPARTMENT ELECTRICAL ENERGY, METALS, MECHANICAL CONSTRUCTION & SYSTEMS
SUSTAINABLE THERMO-FLUID ENERGY SYSTEMS GROUP

ENGINE SIMULATIONS

Gilles Decan

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POLITECNICO MILANO

PRETREF

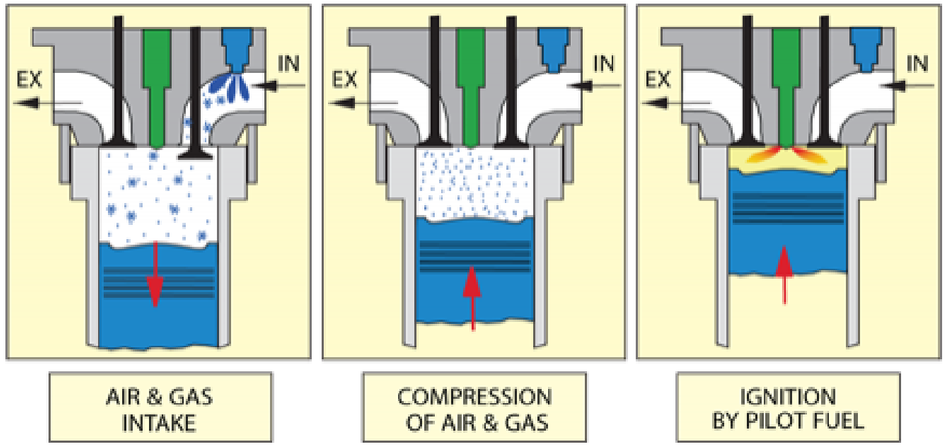
ANGLO BELGIAN CORPORATION
We power your future

FROM DIESEL TO DUAL FUEL

ANGLO BELGIAN CORPORATION

We power your future

- Replace 90 – 95% of diesel by low-carbon alternative
  - CH_4 / CH_3OH / H_2
  - Reduce emissions and CO_2
  - Retrofit
  - Introduce renewable fuels (bio, e-fuels)



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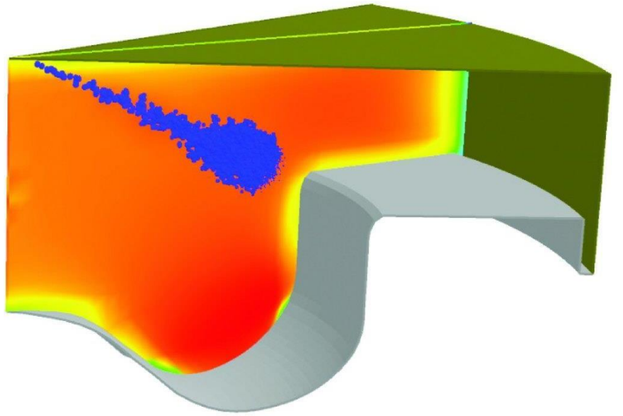
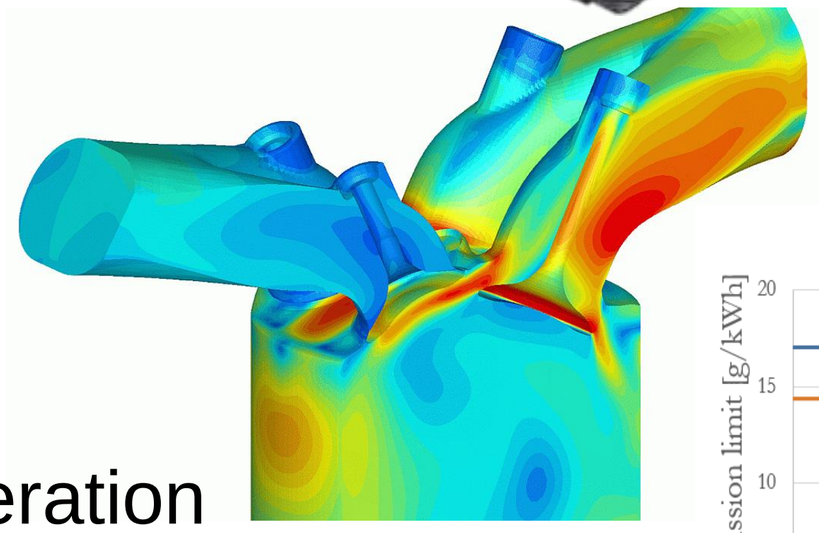
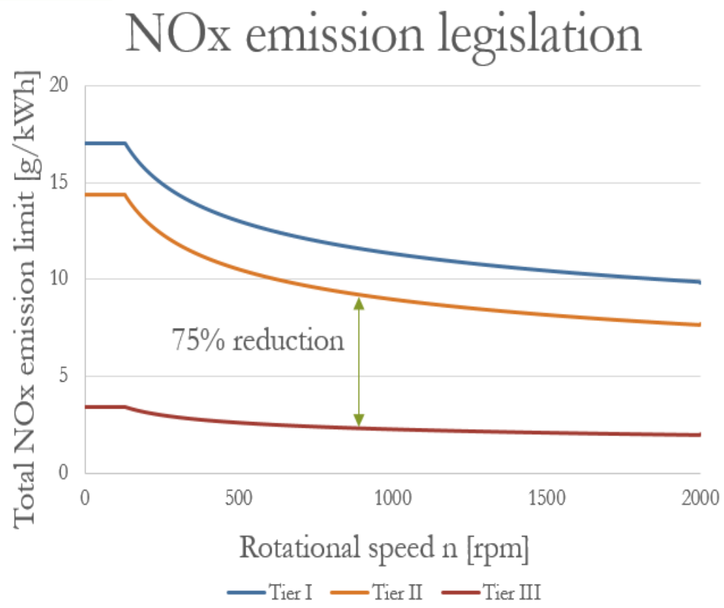
ENGINE DEVELOPMENT

- Development trough simulations
  - Emission prediction
  - Flow behaviour
  - Heat transfer
  - Spray modeling
  - Combustion modeling





- Optimization of engine operation
  - DF specific: ensure good combustion!
    at entire operating range



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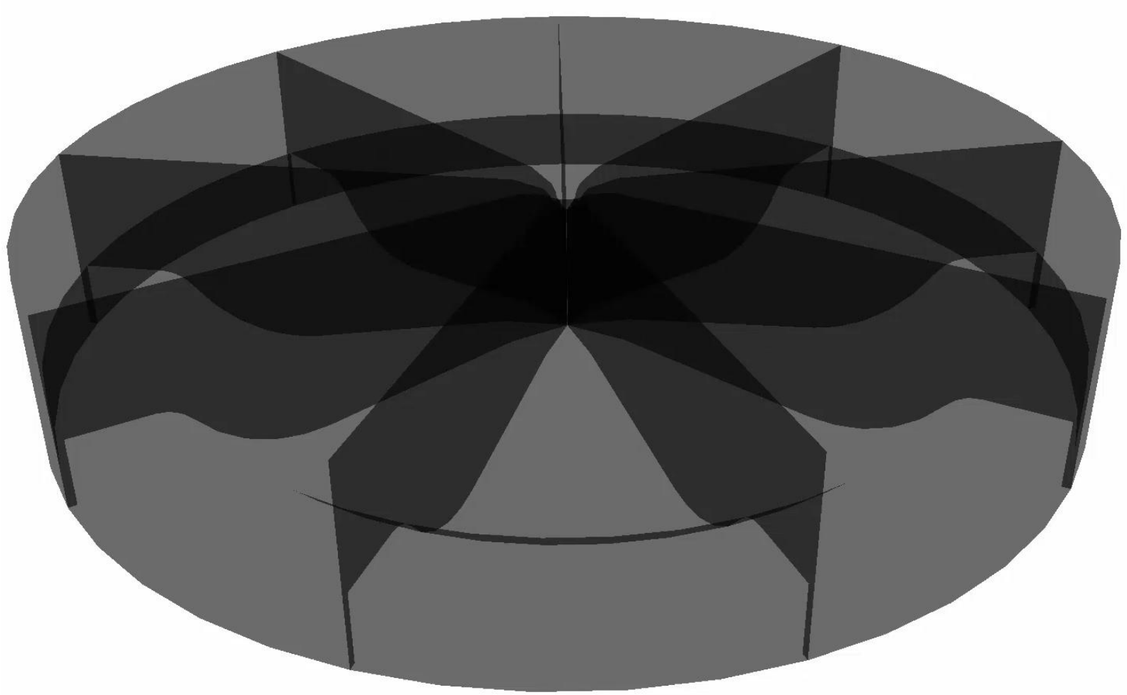
OPENFOAM UTILITIES

- Engine simulations
  - Piston movement
  - Spray injection
  - Auto-ignition, chemistry modeling
  - Flame modeling and propagation



OF2.2.x: own solver (dual-fuel)

OF6: engineFoam (diesel only)

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DIESEL ENGINE TUTORIAL

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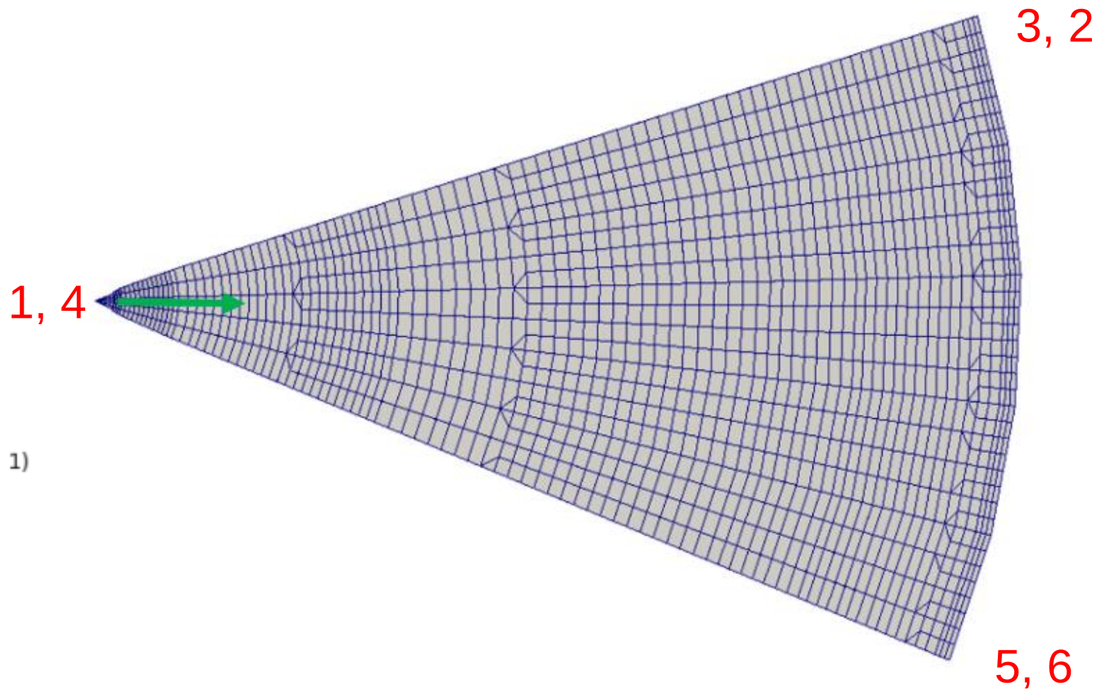
ENGINE MESH

- 40° Simplified sector mesh
  - Create with blockMesh

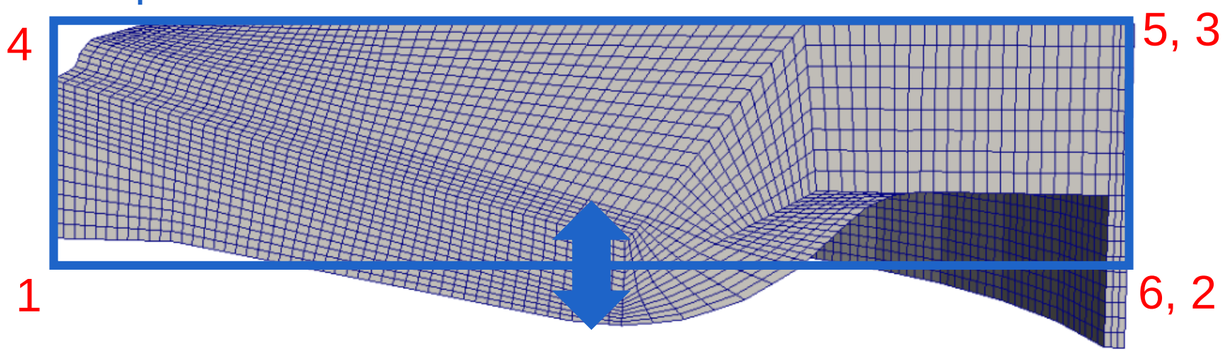
```
convertToMeters 0.001;

vertices
(
    (0 0 -67.263)
    (225.526 -82.085 -67.263)
    (225.526 -82.085 0)
    (0 0 0)
    (225.526 82.085 0)
    (225.526 82.085 -67.263)
);
```

1
2
3
4
5
6

```
blocks
(
    hex (0 1 5 0 3 2 4 3) (75 20 10) simpleGrading (1 1 1)
);

edges
(
    arc 2 4 (240 0 0)
    arc 1 5 (240 0 -28.024)
);

boundary
(
    piston
    {
        type wall;
        faces
        (
            (0 1 5 0)
        );
    }
    liner
    {
        type wall;
        faces
        (
            (1 5 4 2)
        );
    }
    cylinderHead
    {
        type wall;
        faces
        (
            (3 2 4 3)
        );
    }
```



Simplified



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RUNNING ON HPC

- qsub –I –pass=reservation=PRETREF –l nodes=1:ppn=10

- module load OpenFOAM/6-intel-2018a
- source $FOAM_BASH
- source $WM_PROJECT_DIR/bin/tools/RunFunctions

- tar –xzf DieselEngine.tgz
- cd DieselEngine
- blockMesh
- checkMesh

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ENGINE SIMULATION SETUP

- Chemistry through chemkin

```
ELEMENTS
 H   O    C   N   AR
END
SPECIE
C7H16 O2 N2 CO2 H2O
END
REACTIONS
 C7H16 + 1102           => 7CO2 + 8H2O       5.00E+8  0.0   15780.0! 1
        FORD    / C7H16 0.25 /
        FORD    / O2 1.5 /
END
```

  - constant/thermophysicalProperties
  - **change - investigate**

- Define engine geometry
  - constant/engineGeometry

```
bore            bore [ 0 1 0 0 0 0 0 ] 0.24;

stroke          stroke [ 0 1 0 0 0 0 0 ] 0.29;

conRodLength    conRodLength [ 0 1 0 0 0 0 0 ] 0.525;

clearance       clearance [0 1 0 0 0 0 0] 0.028024;

rpm             rpm [ 0 0 -1 0 0 0 0 ] 1000;
```

- Spray injection + modeling
  - constant/sprayCloudProperties
  - **change - investigate**

- Turbulence modeling
  - constant/turbulenceProperties

```
simulationType  RAS;

RAS
{
    RASModel        kEpsilon;
```

- Combustion model
  - constant/combustionProperties
  - **change - investigate**

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ENGINE INITIALIZATION

- Species fields
  - $CO_2/H_2O/O_2/N_2$/fuel

```
dimensions      [0 0 0 0 0 0 0];

internalField   uniform 0.233;

boundaryField
{
    cylinderHead
    {
        type            zeroGradient;
    }
    piston
    {
        type            zeroGradient;
    }
    liner
    {
        type            zeroGradient;
    }
    symmetry
    {
        type            symmetryPlane;
    }
    front
    {
        type            cyclic;
    }
    back
    {
        type            cyclic;
    }
}
```

- Pressure, temperature, U

```
dimensions      [1 -1 -2 0 0 0 0];

internalField   uniform 7.857e+06;

boundaryField
{
    cylinderHead
    {
        type            zeroGradient;
    }
    piston
    {
        type            zeroGradient;
    }
    liner
    {
        type            zeroGradient;
    }
```

```
dimensions      [0 1 -1 0 0 0 0];

internalField   uniform (0 0 0);

boundaryField
{
    piston
    {
        type            movingWallVelocity;
        value           uniform (0 0 0);
    }
    liner
    {
        type            noSlip;
    }
    cylinderHead
    {
        type            noSlip;
    }
```

```
dimensions      [0 0 0 1 0 0 0];

internalField   uniform 975;

boundaryField
{
    cylinderHead
    {
        type            fixedValue;
        value           uniform 600;
    }
    piston
    {
        type            fixedValue;
        value           uniform 600;
    }
    liner
    {
        type            fixedValue;
        value           uniform 600;
    }
```

- Turbulence
  - k/epsilon

```
dimensions      [0 2 -2 0 0 0 0];

internalField   uniform 8.76042;

boundaryField
{
    cylinderHead
    {
        type            kqRWallFunction;
        value   uniform 8.76042;
    }
    piston
    {
        type            kqRWallFunction;
        value   uniform 8.76042;
    }
    liner
    {
        type            kqRWallFunction;
        value   uniform 8.76042;
    }
```

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RUNNING ON HPC

- qsub –I –pass=reservation=PRETREF –l nodes=1:ppn=10

- module load OpenFOAM/6-intel-2018a
- source $FOAM_BASH source $WM_PROJECT_DIR/bin/tools/RunFunctions

- (blockMesh)
- decomposePar
- mpirun –np 10 engineFoam –parallel (> log &)
- reconstructPar

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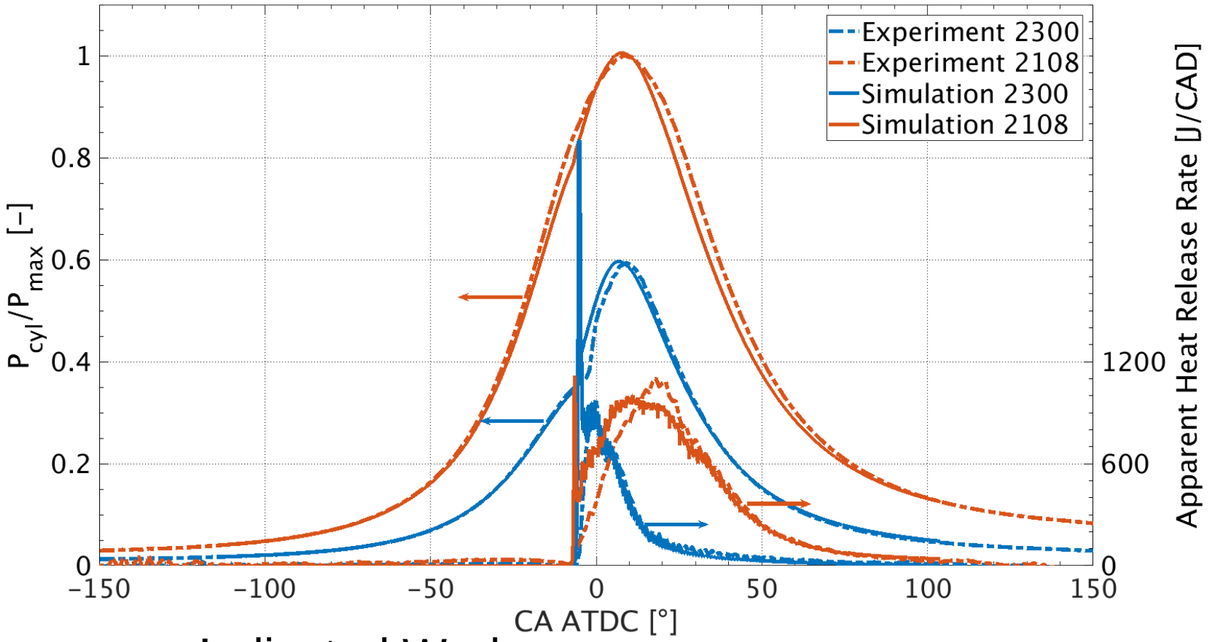
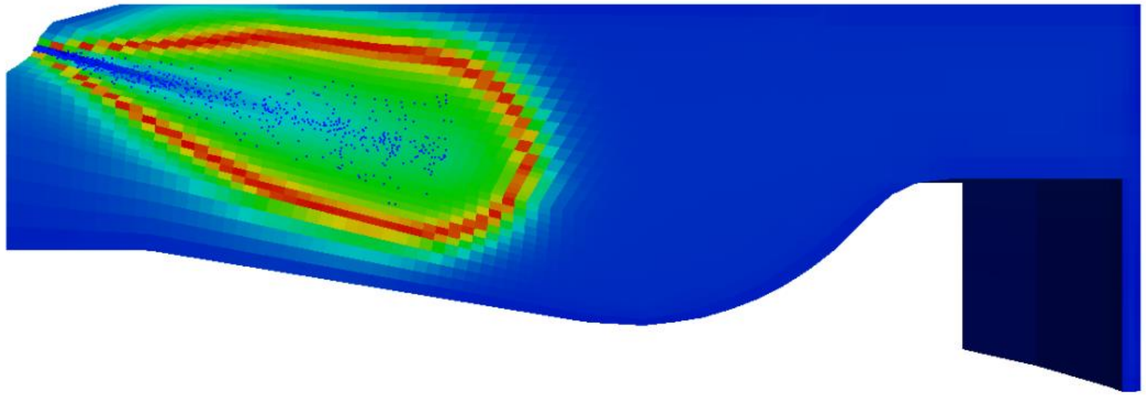
RESULTS

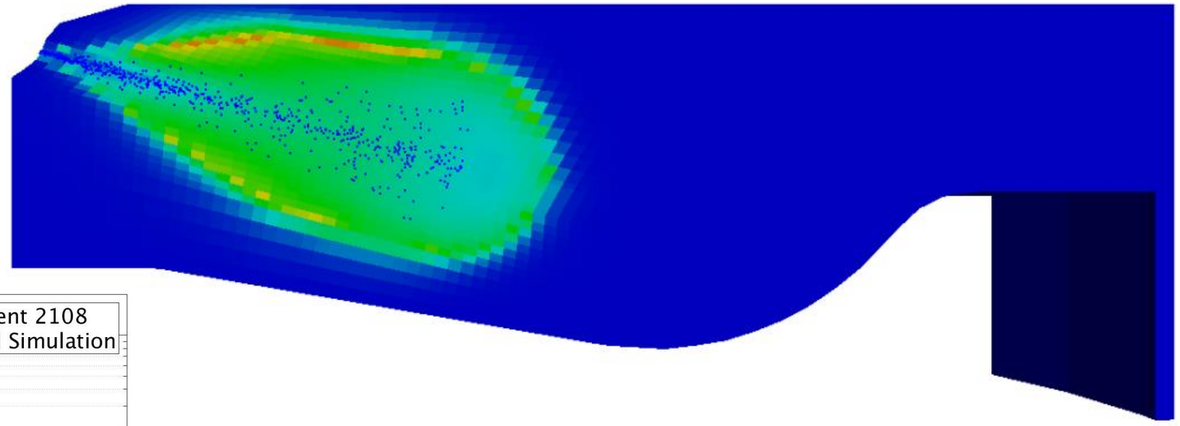
Pressure and HRR trace



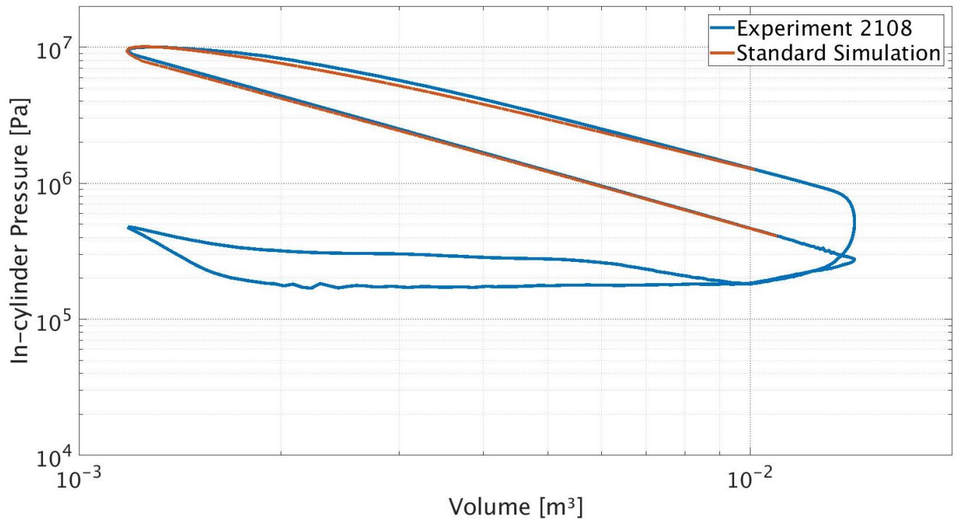
Temperature field



NOx emissions



Indicated Work



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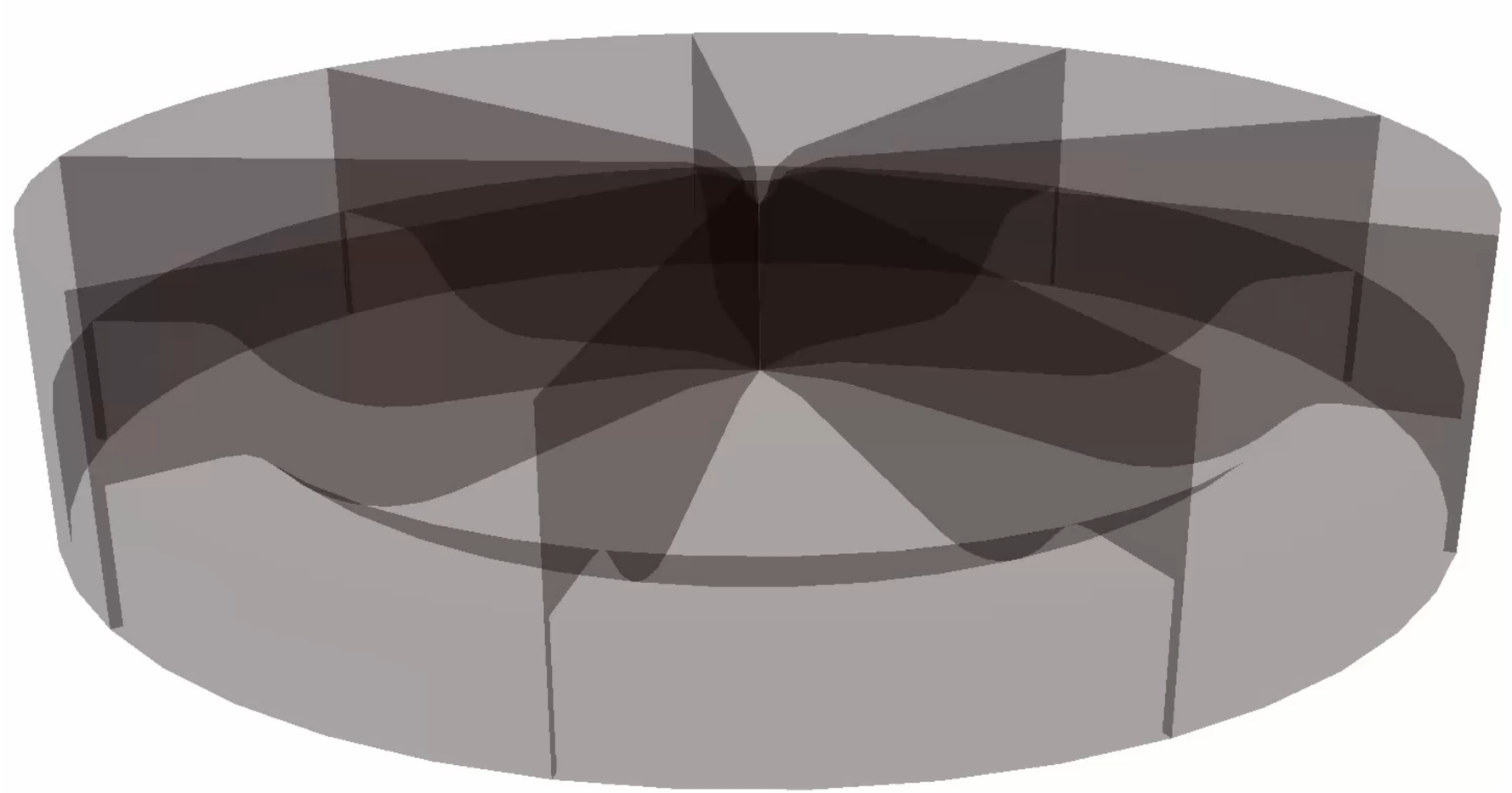
RESULTS



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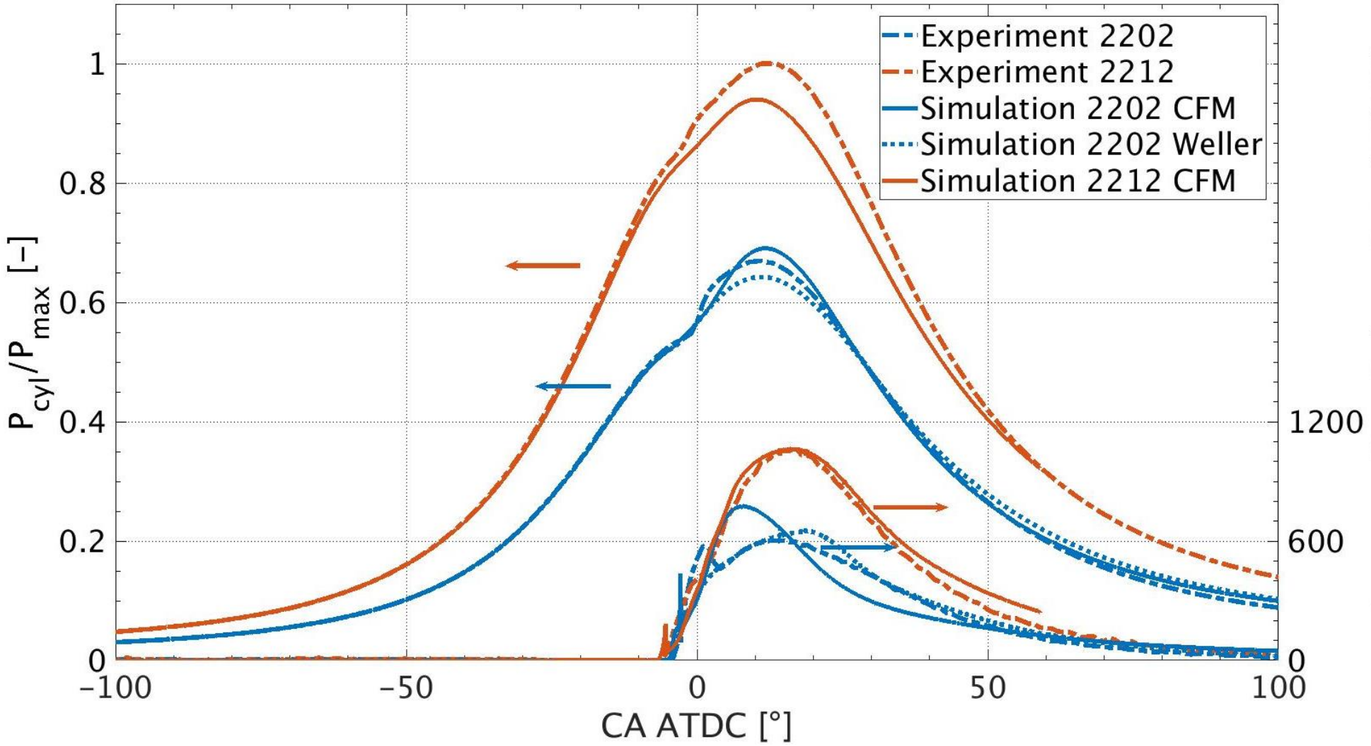
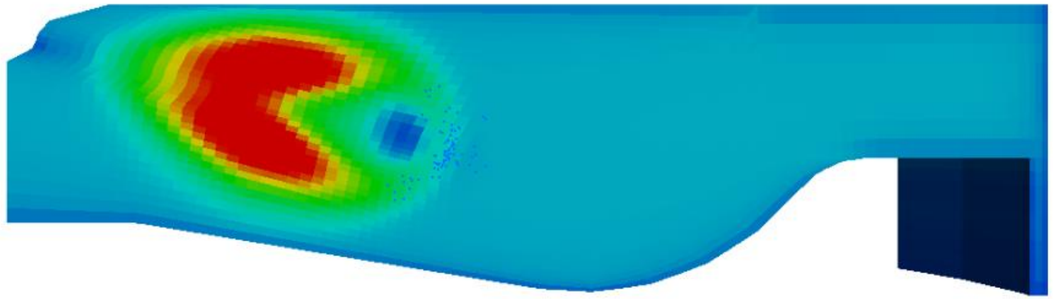
DUAL FUEL RESULTS

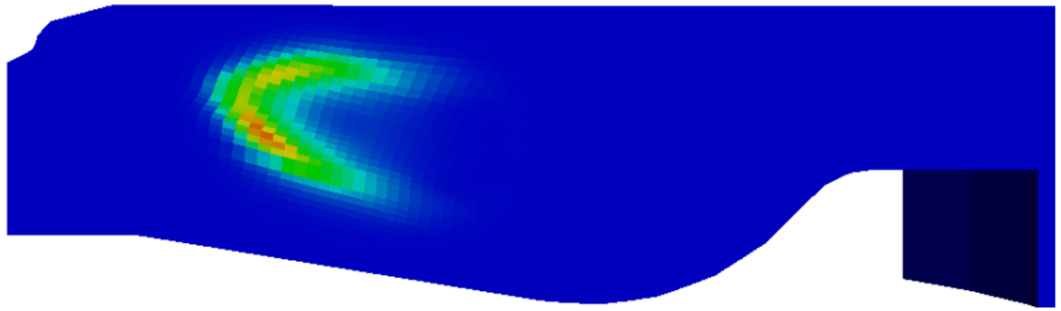
Pressure and HRR trace



Temperature field



NOx emissions



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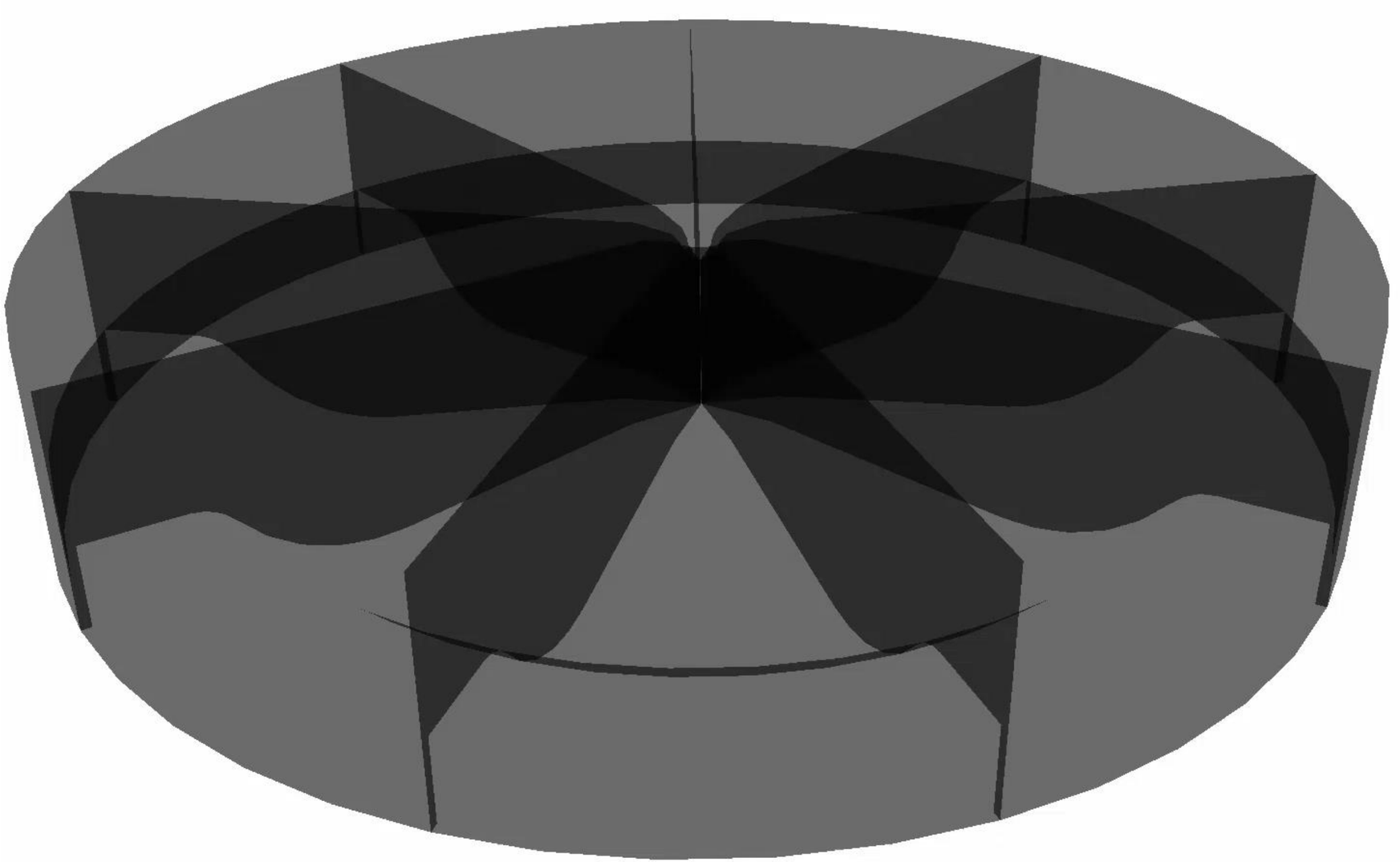
DUAL FUEL RESULTS



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