Latest Development in OpenFOAM and Industrial Applications

German OpenFoam User meetiNg (GOFUN)

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Public

esi-group.com

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Features

Robustness

Accuracy

Performance

Usability

Stability

Scalability

Deterministic

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Content

- Development
  - Mesh
    - New hybrid layer input — Usability
    - high Aspect Ratio — Accuracy
  - Numerics
    - Improved Arbitrary Mesh Interface (AMI) — Robustness, Accuracy
  - Post-processing
    - New dynamic mode decomposition (DMD) function object — Features
    - sampledSurface: distanceSurface — Usability, Accuracy
- Industrial Applications
  - Visual-Environment for OpenFOAM
    - Reacting and non-reacting Flow
    - Hood Fluttering

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Development

Mesh

New Hybrid Layer Input
High Aspect Ratio

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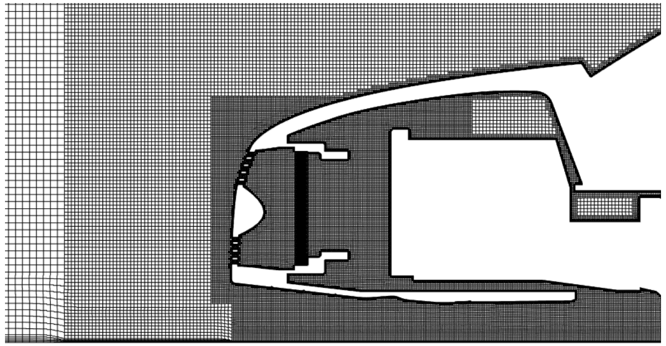
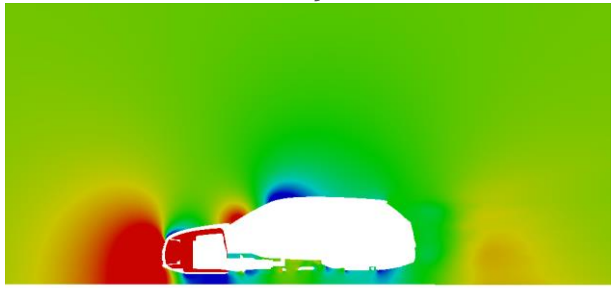
Development: Mesh

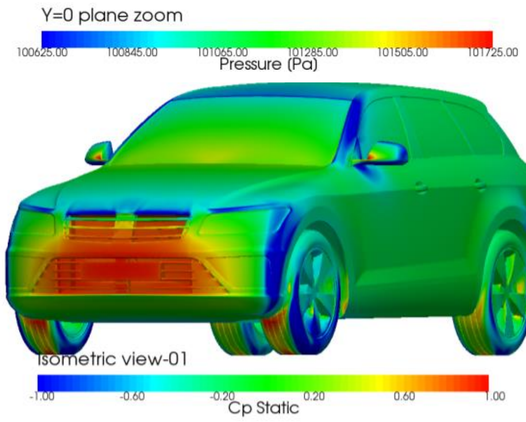
Current mesh for Aerodynamics (low-Re Mesh)

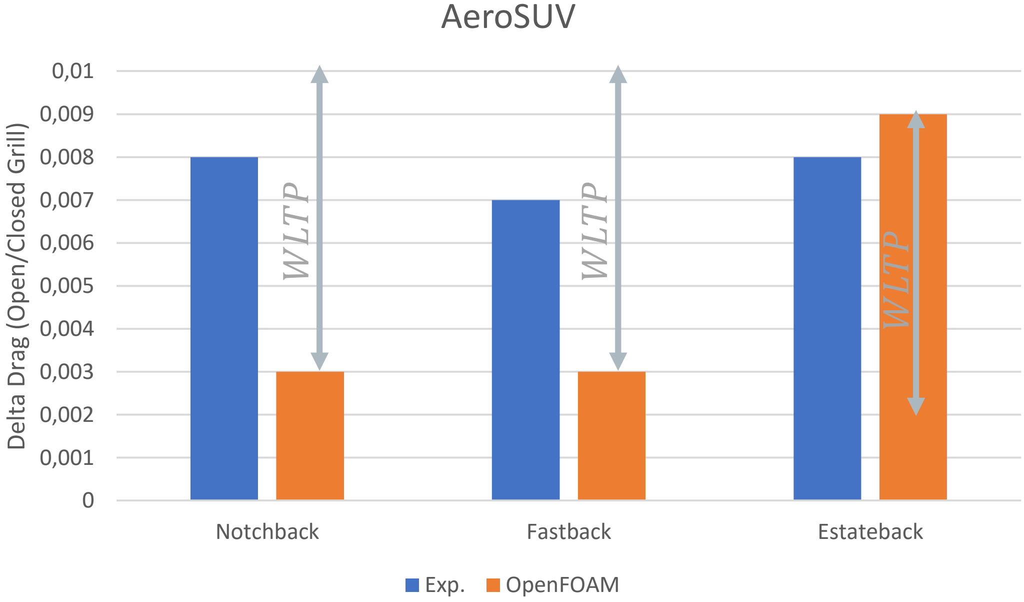
- Open/Closed Grill
  - WLTP (Annexe 7): accuracy $\Delta(C_d A_f) \pm 0.015m^2$



drivAer Model (y+~30, 3 layers, 96% layer coverage)







https://blog.esi-group.com/driving-change-vehicle-emission-policies

http://ecara.org/

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Development: Mesh
Towards high-Re Mesh

- Flow separation requires high-Re Mesh
  - **Target**
    - y+1
    - 20 layers
    - 100% layer coverage
    - complex CAD
  - **Constraint**
    - Mesh size
    - Mesh time + automated

OpenFOAM® v2012

Handling high aspect ratio cells + Hybrid input specification of layer generation + Layer generation (layer by layer) + Generalized mesh motion solver for snapping and shrinking + Partial or no snapping before layer addition + Topology changes after castellation = Universal full layer coverage

https://www.openfoam.com/contact/

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Development: Mesh

New hybrid layer input

- This release adds a new option to specify the near-wall layer using an absolute thickness, e.g. to obtain a desired y+ at the first wall layer, and a relative thickness for the final layer closest to the bulk to minimize mesh distortion.

model	firstLayer	finalLayer	overall	expansion
firstAndOverall	✓		✓	
firstAndExpansion	✓			✓
finalAndOverall		✓	✓	
finalAndExpansion		✓		✓
overallAndExpansion			✓	✓
firstAndRelativeFinal	✓	✓		

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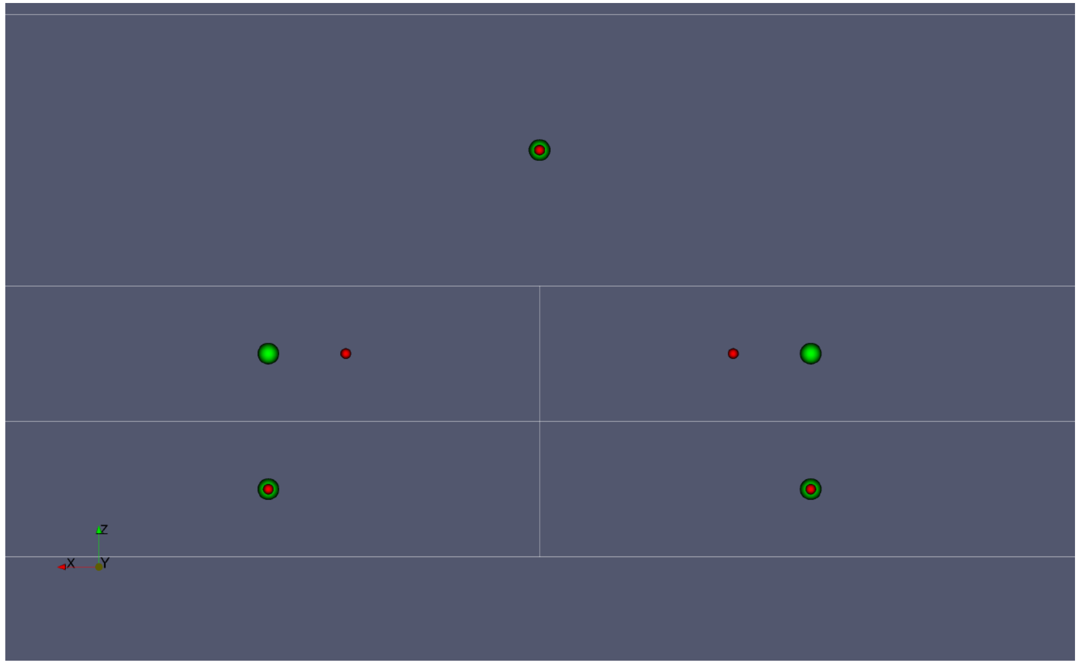
Development: Mesh

Layer Coverage (high Aspect Ratio)

- The system/fvSchemes dictionary now has an optional geometry section which overrides the method to calculate the geometric properties:
  - **Basic**
    - This is the default scheme and provides the exact behaviour as previous versions. It calculates the mass centroid for faces and cells.
  - **Stabilised**
    - Face centres are calculated using only positive triangle contributions and is supposedly more stable on concave/distorted faces. This is the default in openfoam.org.
  - **highAspectRatio**
    - This scheme blends between basic and an edge-length weighted, face-area weighted average. This avoids truncation errors on high aspect ratio cells, at the cost of being lower order. The blending is linear across the range minAspect, maxAspect (see example above).
  - **averageNeighbour**
    - Similar to highAspectRatio but followed by a pass to align cell centres on top of one another to minimise non-orthogonality.

```
geometry
{
    // Use specialised method for high-aspect ratio cells
    type        highAspectRatio;
    minAspect   10;     // when to start blending lower-order method
    maxAspect   100;    // when to use lower-order method only
}
```



the **original centroids** are shown in green and the **average neighbour** ones in red

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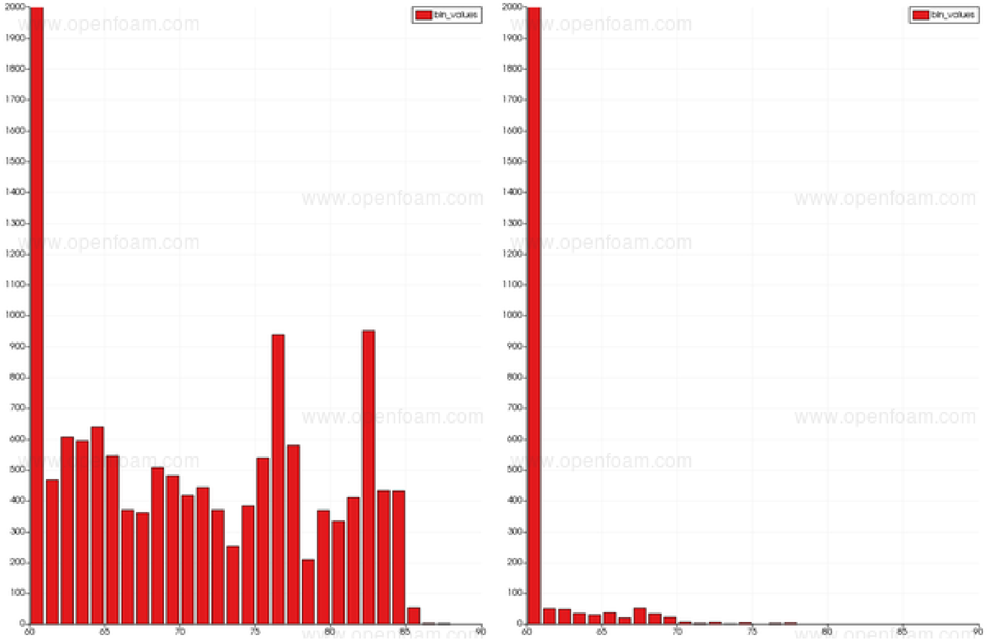
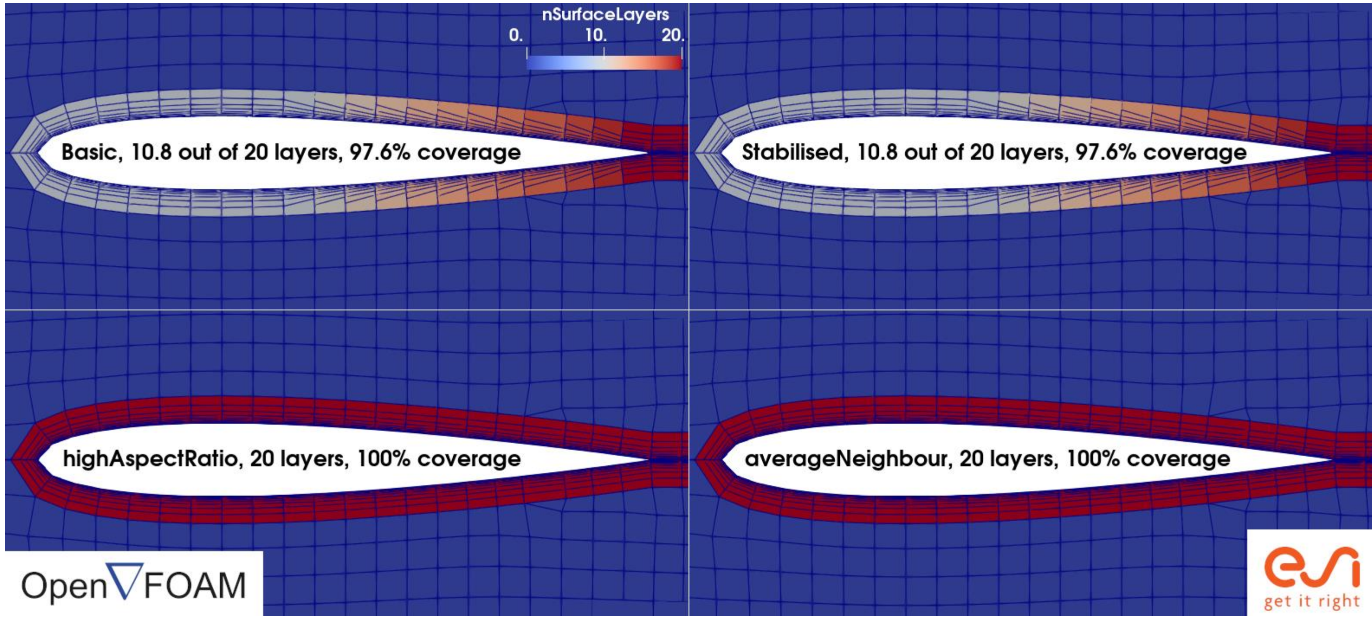
Development: Mesh

Layer Coverage (high Aspect Ratio)

Basic **averageNeighbhour**





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Development

Numerics

Improved Arbitrary Mesh Interface (AMI)

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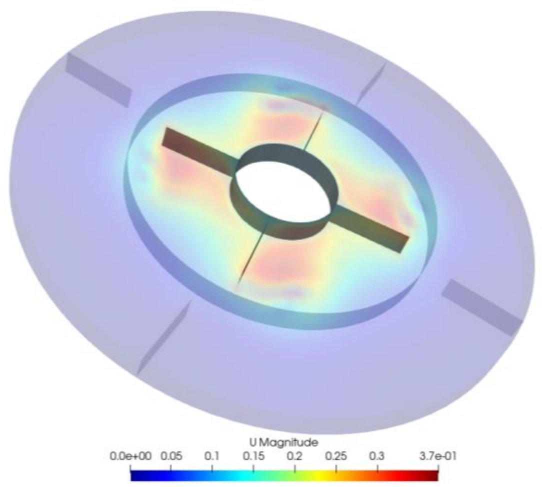
Development: Numerics

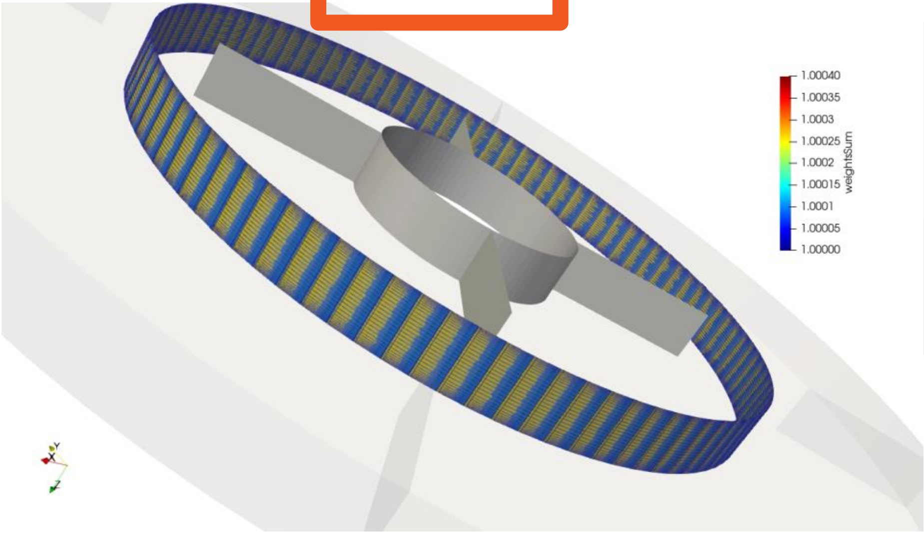
Improved Arbitrary Mesh Interface (AMI)

- topological change capabilities to the cyclicAMI and cyclicACMI patches
  - enabling topology change where a 1-to-1 connectivity is established across the AMI leads to a much smoother pressure trace.
- `Constant/dynamicMeshDict`

```
dynamicFvMesh    dynamicMotionSolverFvMeshAMI;
```



Old AMI



New AMI

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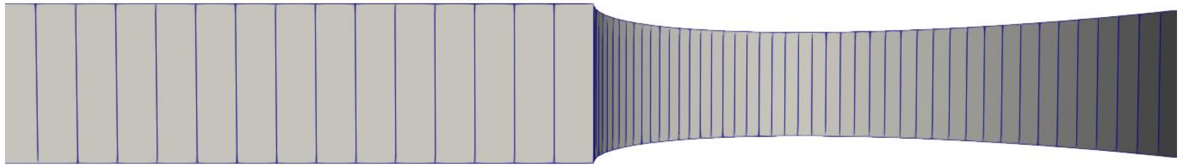
Development: Numerics

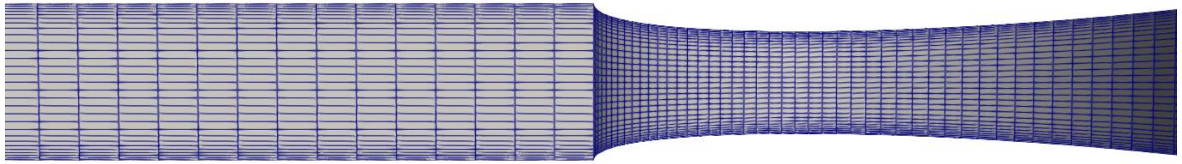
Improved Arbitrary Mesh Interface (AMI)

- topological change capabilities to the cyclicAMI and cyclicACMI patches
  - enabling topology change where a 1-to-1 connectivity is established across the AMI leads to a much smoother pressure trace.
- `Constant/dynamicMeshDict`

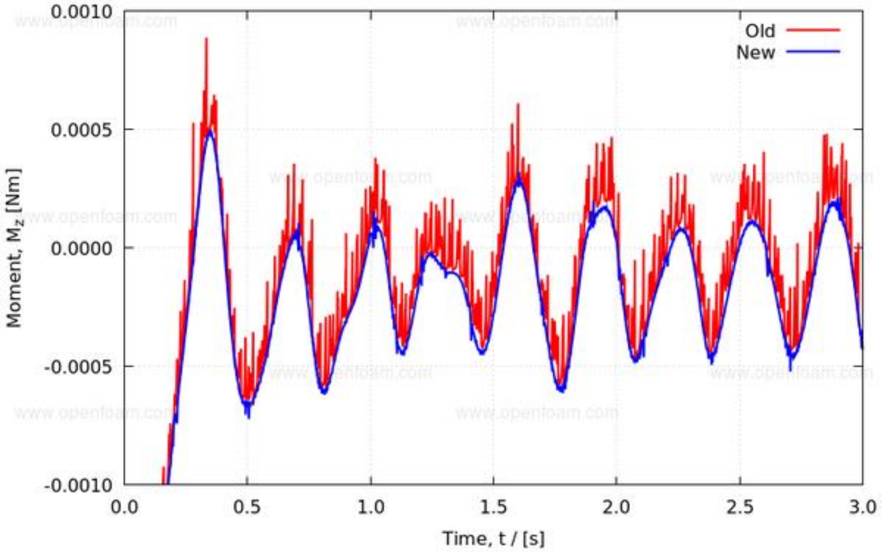
```
dynamicFvMesh    dynamicMotionSolverFvMeshAMI;
```



$FOAM_TUTORIALS/incompressible/pimpleFoam/laminar/mixerVesselAMI2D/mixerVesselAMI2D



$FOAM_TUTORIALS/incompressible/pimpleFoam/laminar/mixerVesselAMI2D/mixerVesselAMI2D-topologyChange



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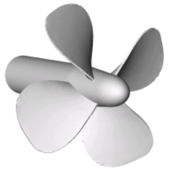
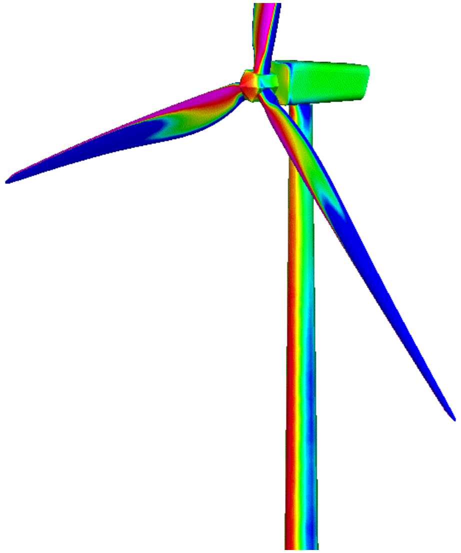
Development: Numerics
Improved Arbitrary Mesh Interface (AMI)



	Method 1 (Old AMI)	Method 2 (New AMI)
Name	`dynamicMotionSolverFvMesh`	`dynamicMotionSolverFvMeshAMI`
Advantages	Efficient	Mass conservative
Disadvantages	Not conservative	Slower
Applications	Propeller, windturbine, rotating wheel	Turbomachinery, aeroacoustics (fan, etc)



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Development

Post-Processing

New Dynamic Mode Decomposition (DMD) function object
sampledSurface: cuttingPlane
sampledSurface: distanceSurface

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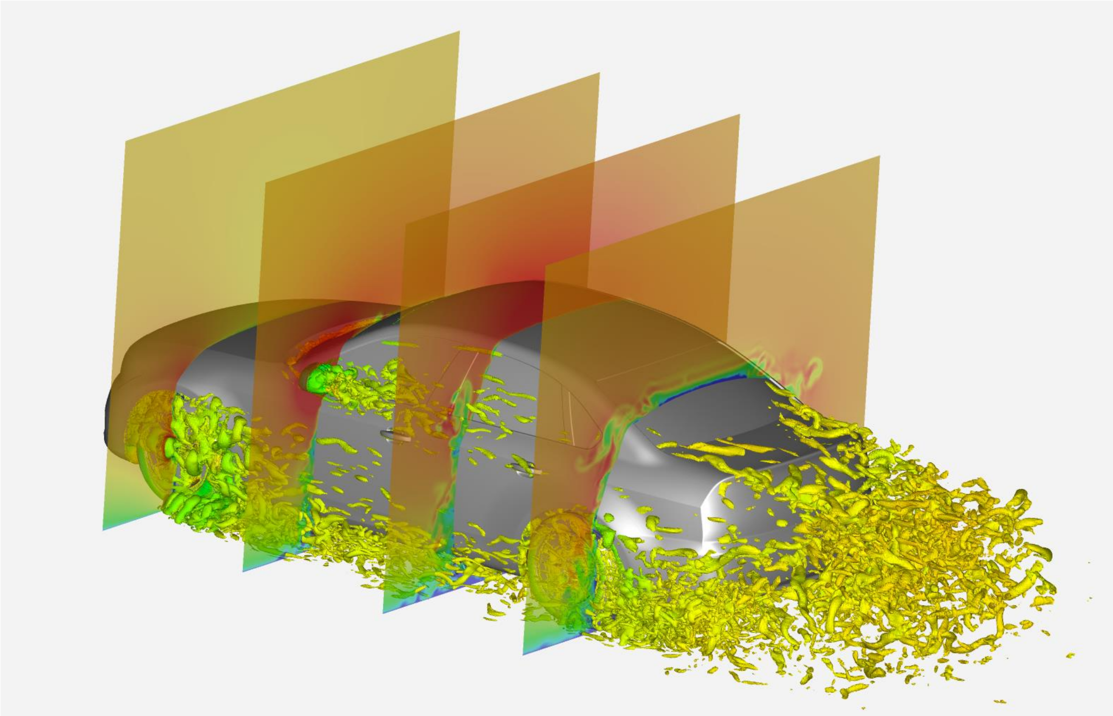
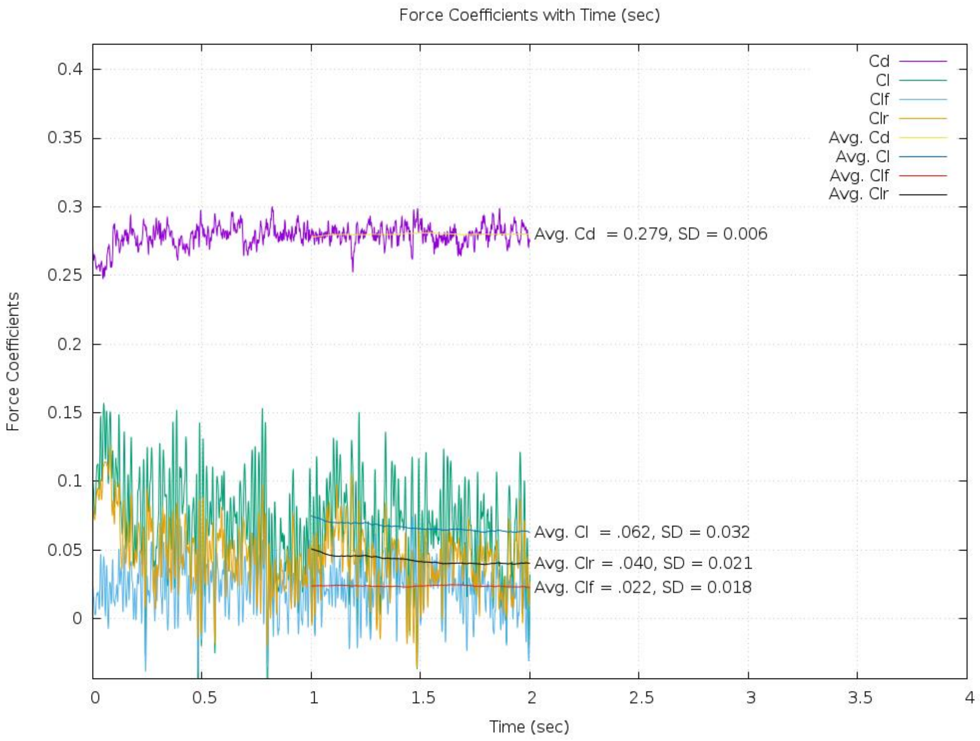
Dynamic mode decomposition (DMD) function object

Motivation





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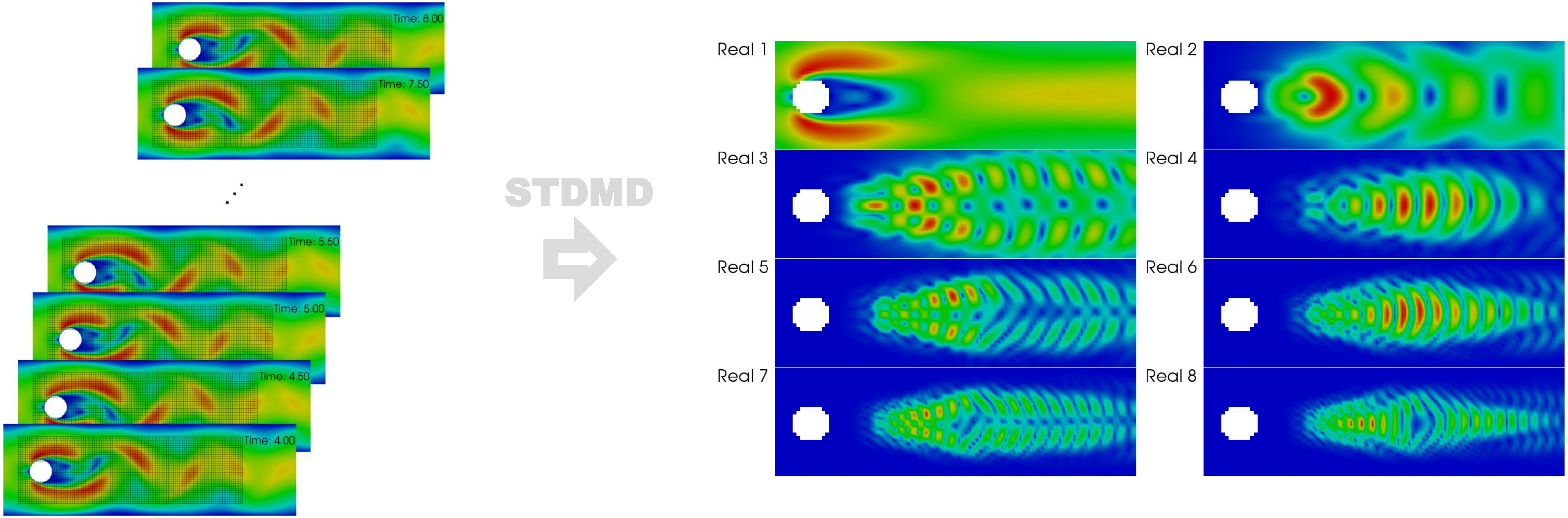
Dynamic mode decomposition (DMD) function object

Disclaimer: beta release – stay tuned for the upcoming versions

- The DMD method is introduced here as a **function object** called **Streaming Total Dynamic Mode Decomposition (STDMD)** based on an algorithm developed by Kiewat (2019), Hemati et al. (2017), and Hemati et al. (2014)



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Model Order Reduction

	High Fidelity Simulation	ESI Reduction Methodology	Standard Reduction Methodologies
Reduced Model Setup		PGD-based	POD-based
DOE sampling	-	Any	Strictly defined
Number of cases in DOE	-	~ #parameters	$\sim 2^{\#parameters}$ / ~ #parameters^2
Reduced Model Ready			
Set-up time	Days/Weeks	Seconds	Seconds
Solution time	Hours/days	Seconds	Seconds
Computing costs	Very High	Very low	Very low
Typical Accuracy	Very High	High	Low
Possibility to Enrich	-	Yes	Costly
Integration with experimental data	No	Yes	No
Isolation components (puzzlePGD)	-	Yes	No

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Sampling field values on surfaces

In OpenFOAM we have two options to create a sampled surface from an input surface:

```
surfaceSampling
{
    type            surfaces;
    libs            (sampling);
    …
    surfaces
    {
        // Create the sampled surface
        // from the input surface
    }
}
```

```
surfaceSample_distance
{
  angledPlane_distance
  {
      type        distanceSurface;
      distance    0;
      signed      true;
      regularise  true;
      surfaceType triSurfaceMesh;
      surfaceName angledPlane.obj;
  }
}
```

OR

```
triSurfaceSampling
{
  angledPlane_distance
  {
      type          sampledTriSurfaceMesh;
      surface       angledPlane.obj;
      source        cells;
      interpolation true;
  }
}
```

The quality of the surface sampled data depends on the input surface resolution

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Sampling field values on surfaces

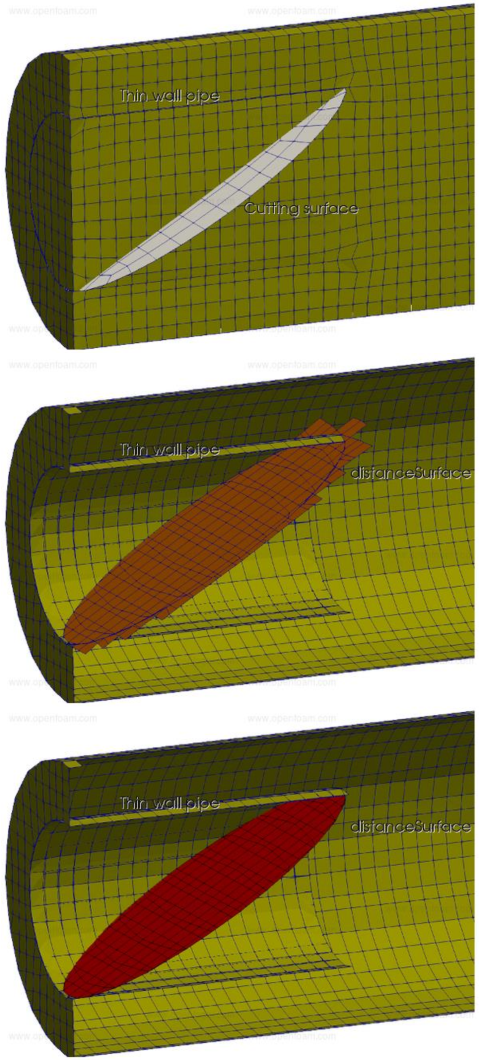
In OpenFOAM we have two options to create a sampled surface from an input surface:

```
surfaceSampling
{
    type            surfaces;
    libs            (sampling);
    …

    surfaces
    {
        // Create the sampled surface
        // from the input surface
    }
}
```

Improved in v2012

```
surfaceSample_distance
{
  angledPlane_distance
  {
      type        distanceSurface;
      distance    0;
      signed      true;
      regularise  true;
      surfaceType triSurfaceMesh;
      surfaceName angledPlane.obj;
  }
}
```



Cutting surface

Sampled surface before v20 12

Sampled surface **from v20 12**

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Industrial Applications

Visual-Environment

Reacting and non-reacting Flow
Hood Fluttering

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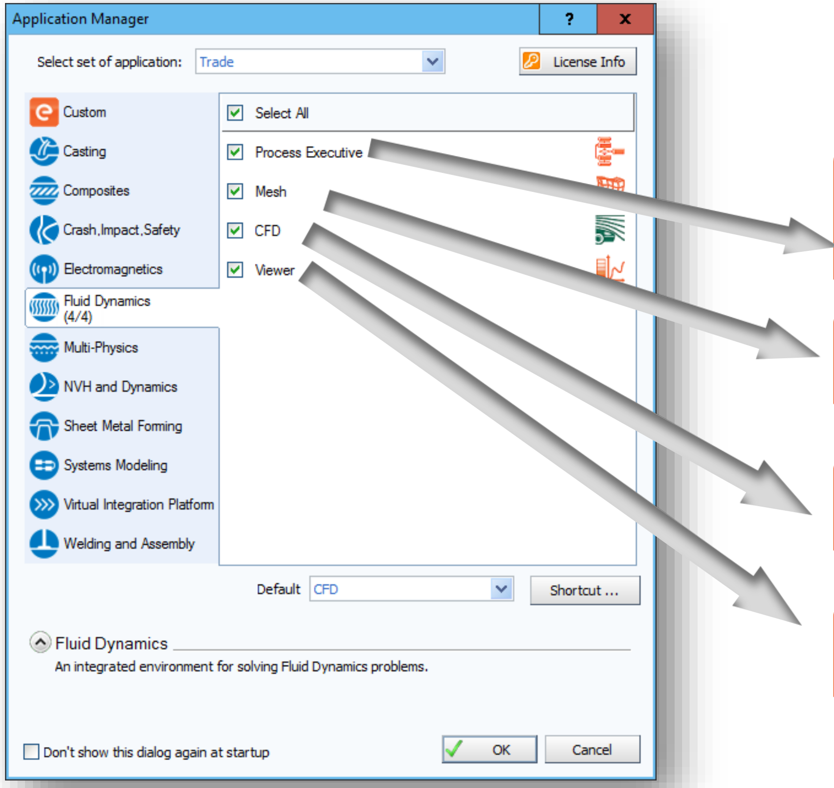
Visual-Environment



Process Executive – Predefined Automated Processes

Mesh – Pre-Processor for CAD preparation

CFD – Front End User Interface to set-up OpenFOAM Mesh and Case

Viewer – Post-Processor for OpenFOAM Results

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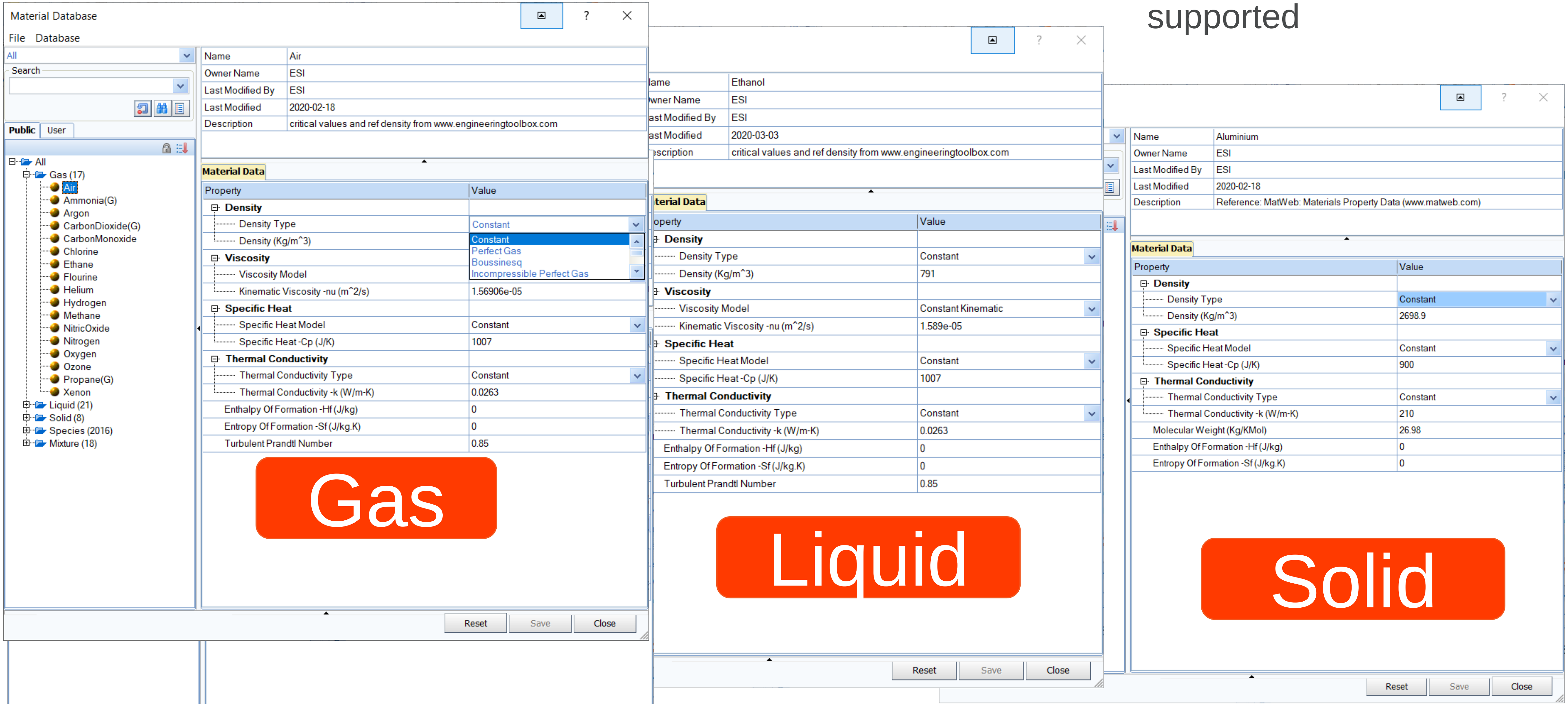
Visual-Environment: Reacting Flow

Material Data Base

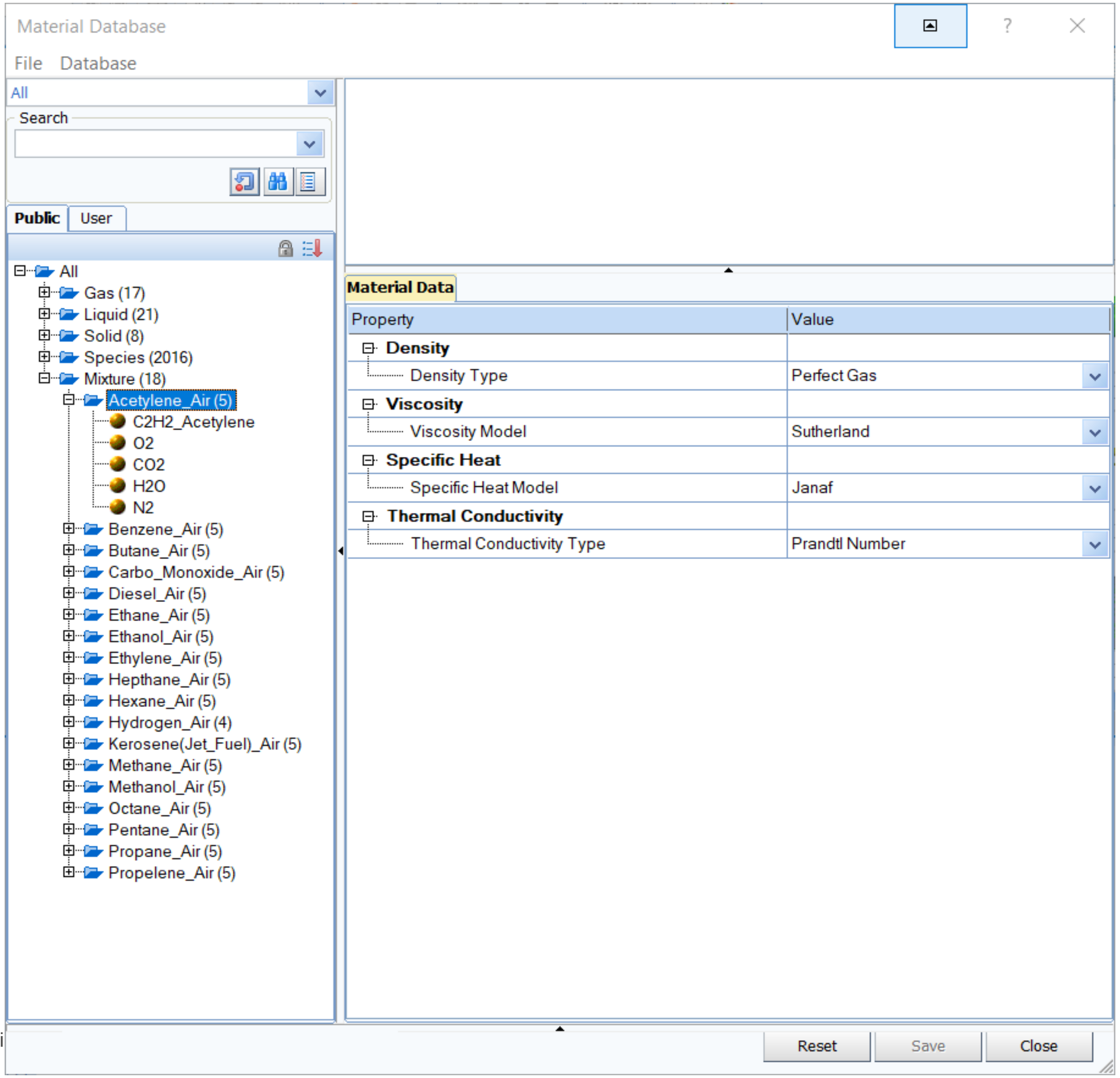
Extensive material database for Gas, Liquid, Solid is being supported



Visual-Environment: Reacting Flow

Material Database

- **Material Database**
  - Species and Mixture are also supported with material database
  - Extensive list of species are brought under material database.
  - Mixture category is introduced, which can be created by picking up multiple species and copying to newly created mixture.



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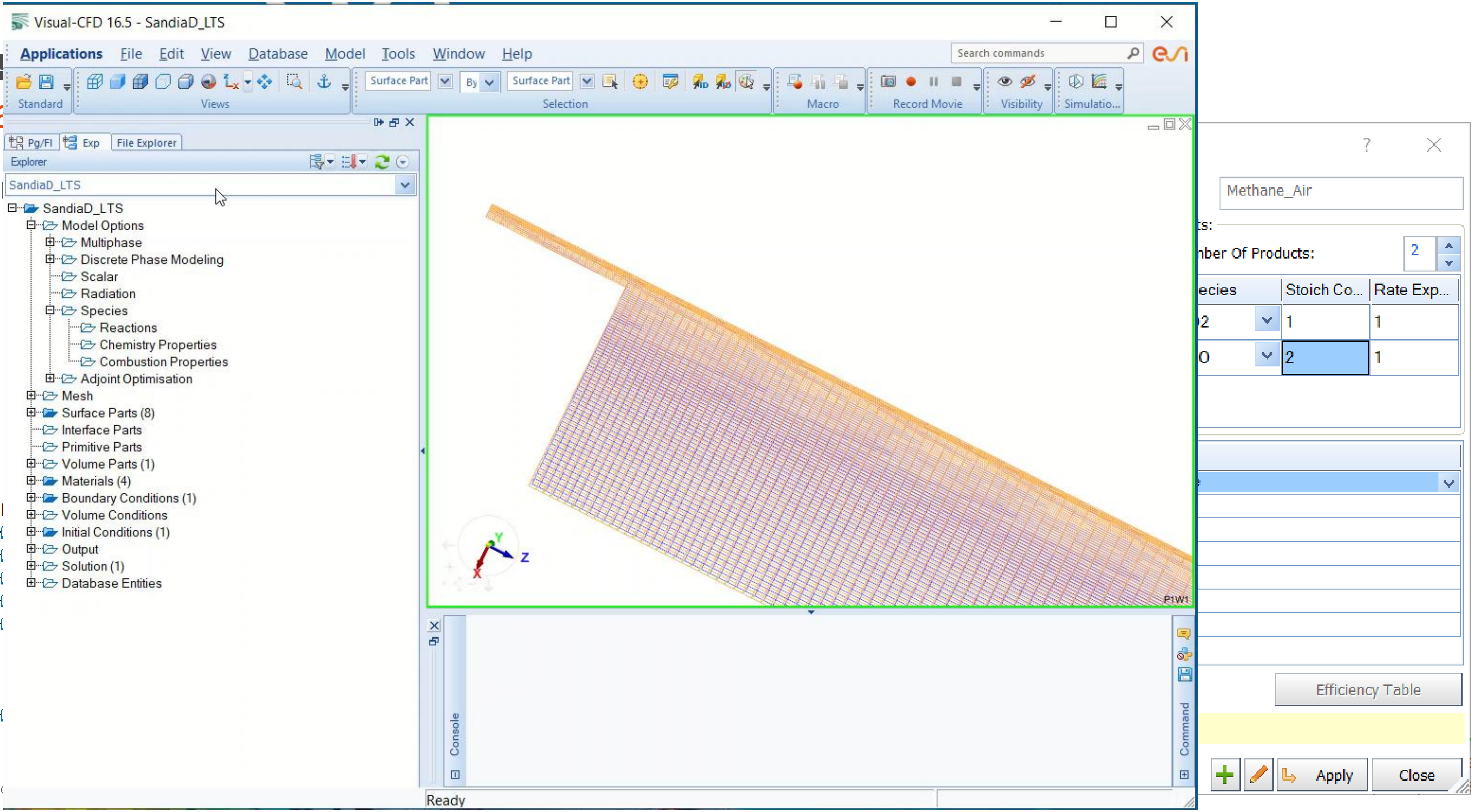

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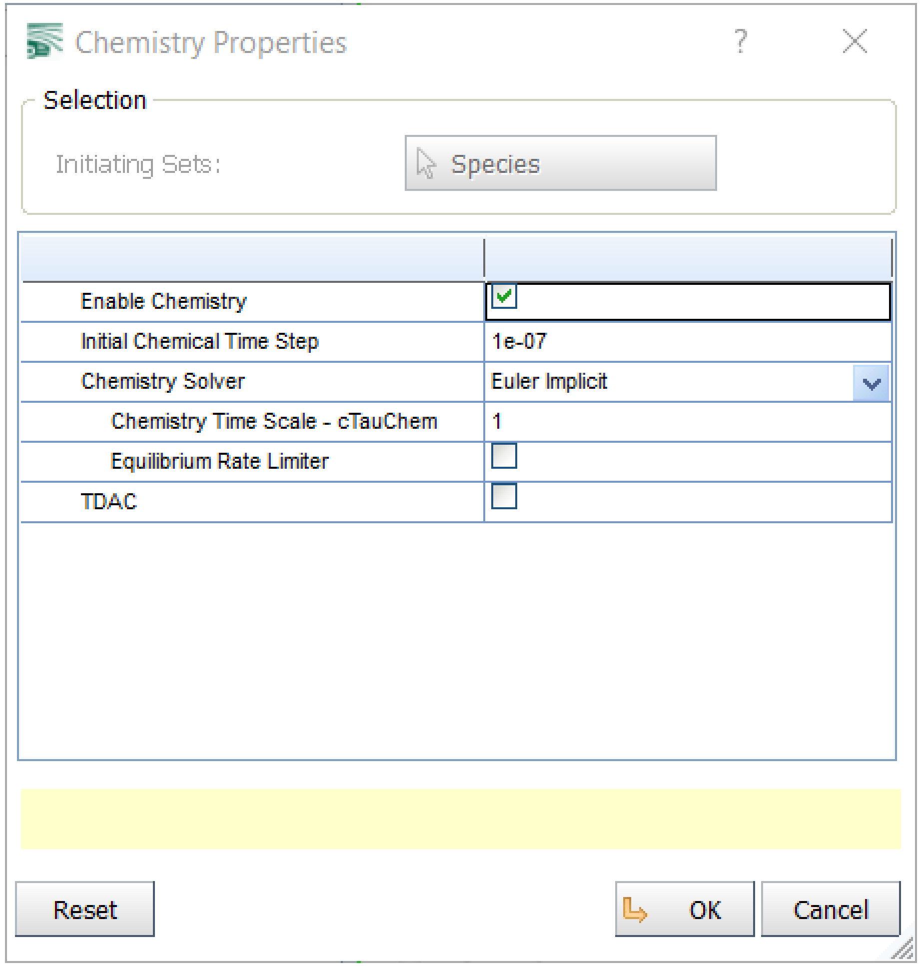
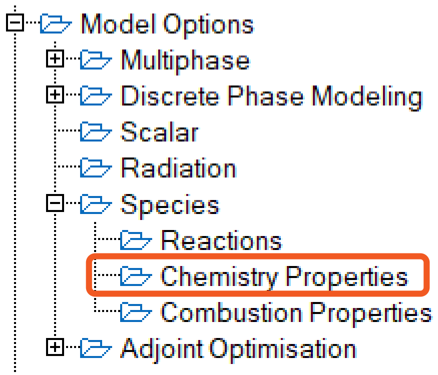
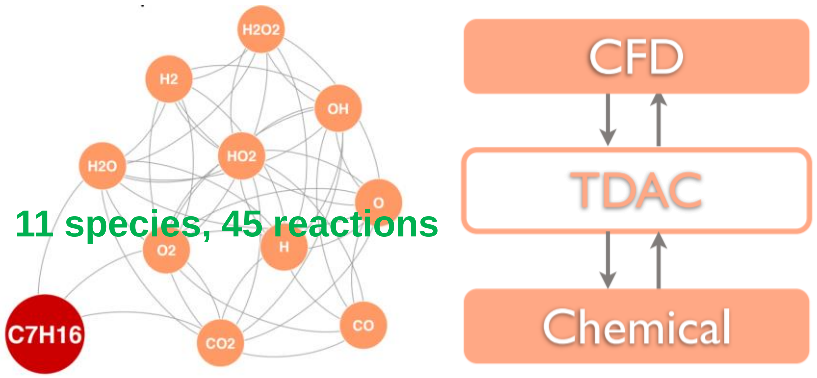
Visual-Environment: Reacting Flow

Chemistry Properties

- Once Chemistry is enabled, user will have option to pick up various ODE or Euler implicit chemistry solver.
- User can apply tabulation of dynamic adaptive chemistry (TDAC) method. TDAC have shown great potential of alleviating the huge computational cost while improving the chemistry fidelity for combustion problems





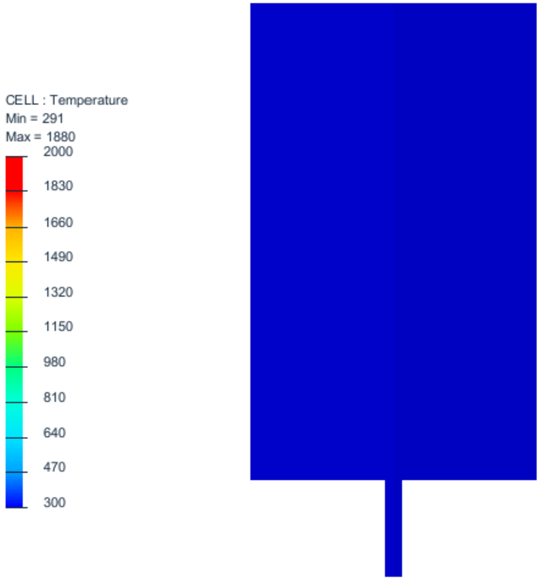


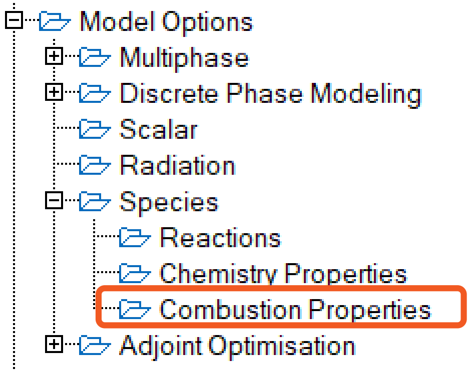
TDAC: An approach to include detailed mechanisms

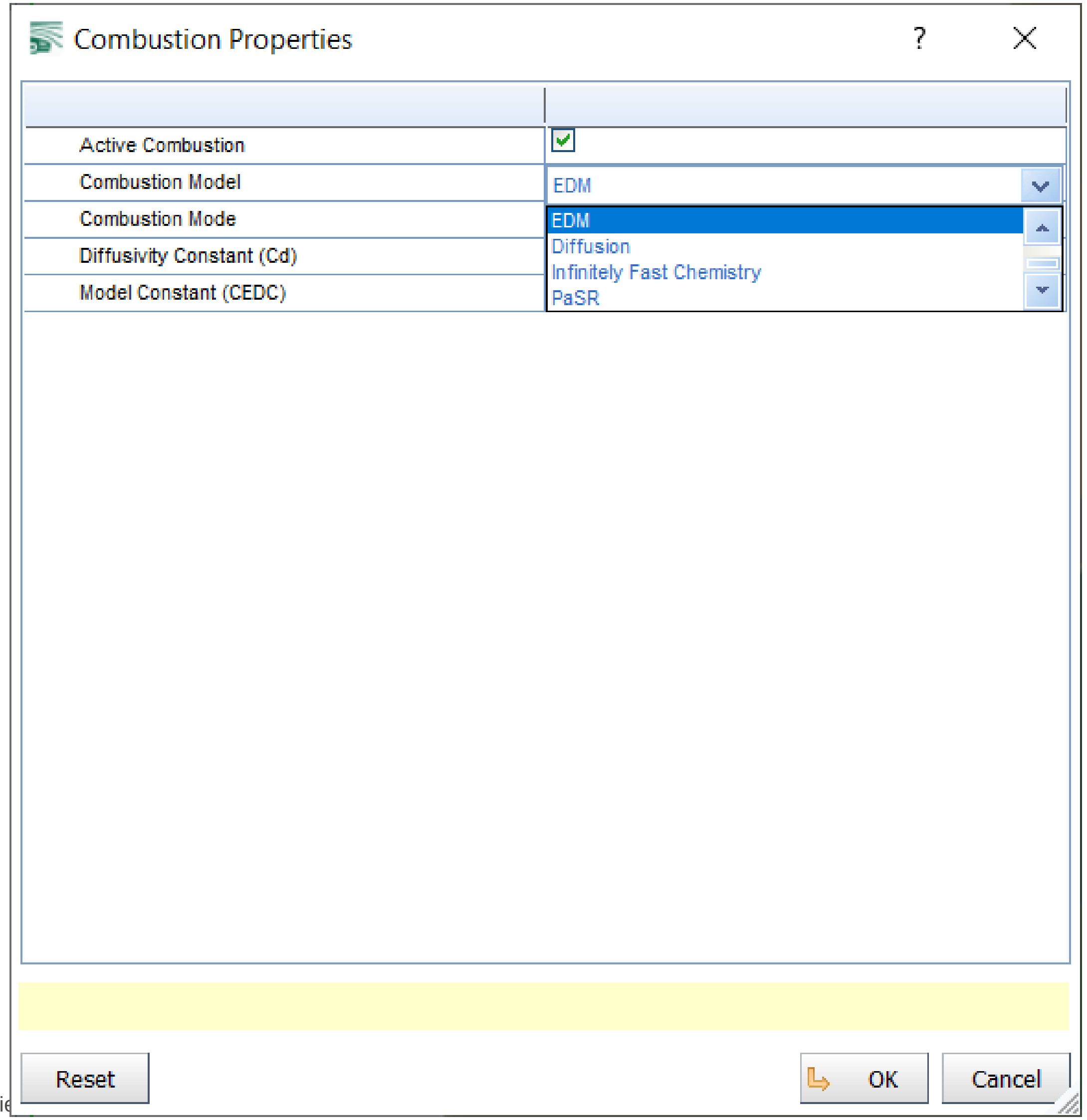
Visual-Environment: Reacting Flow

Combustion Properties

- Different combustion models have been supported, which can be picked based on type/nature of combustion and fuel & oxidizer conditions.







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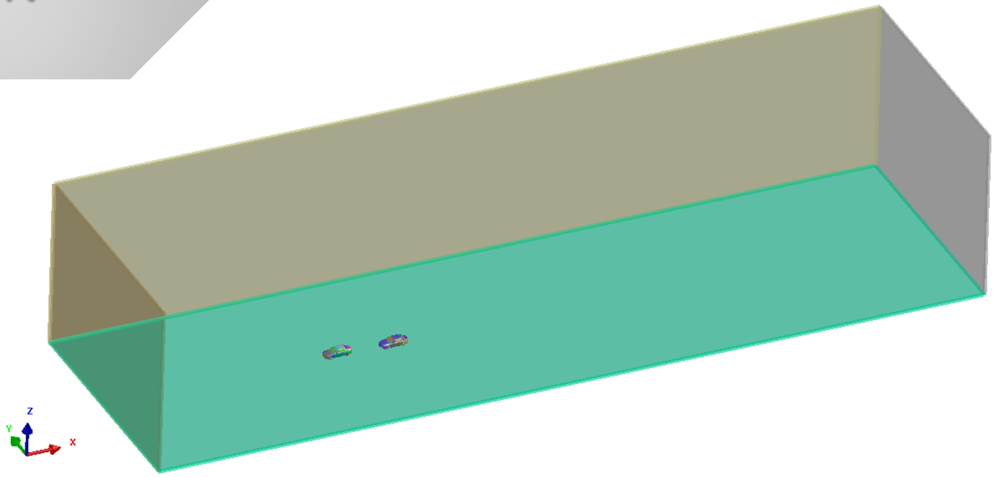
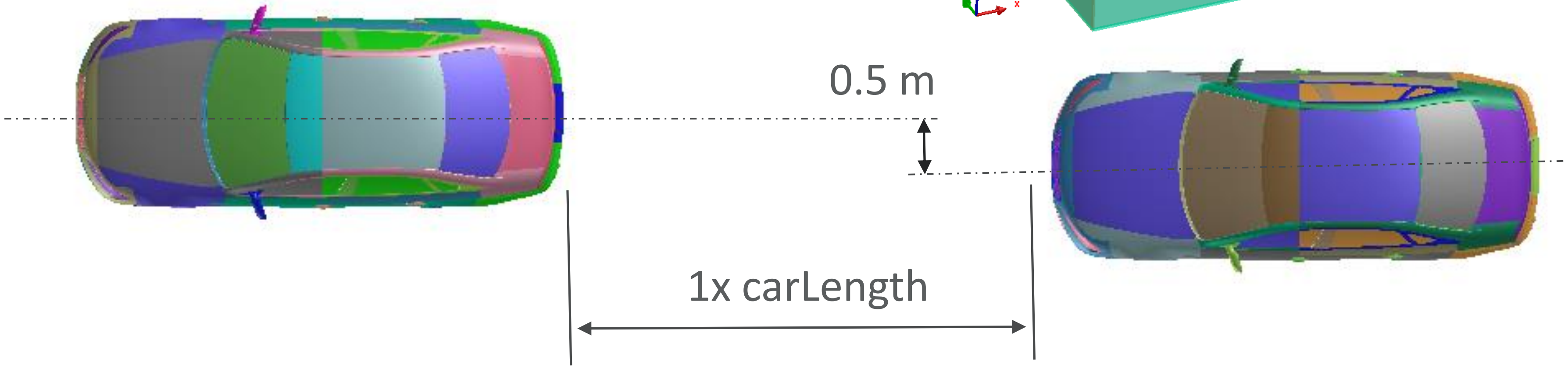
Visual-Environment: Hood Fluttering

Extracting the aerodynamic excitation

AERODYNAMIC EXCITATION → VIBRATION

Vehicles in overtaking maneuver (static case):
- Lateral offset of 0.5m
- Separation of 1 car length
- Velocity of 250 km/h





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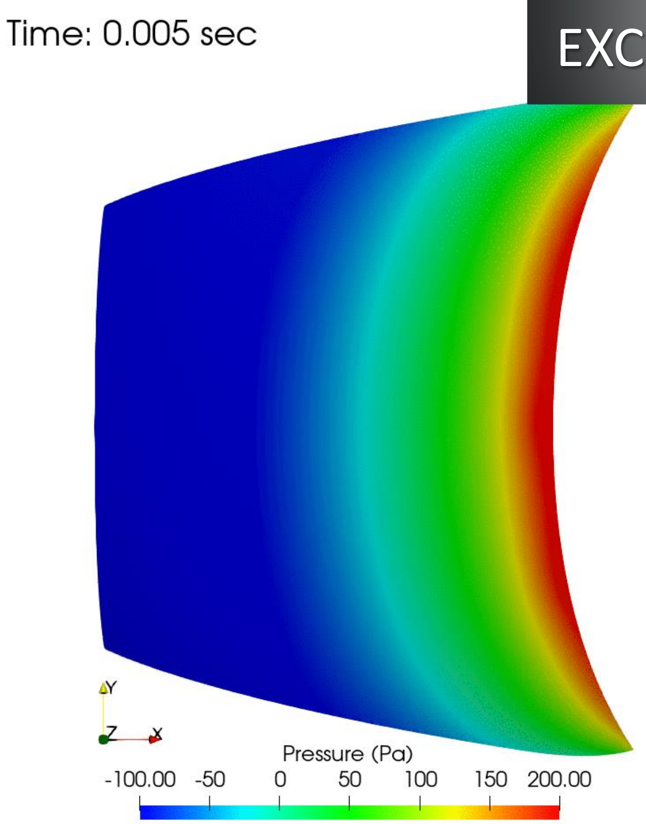
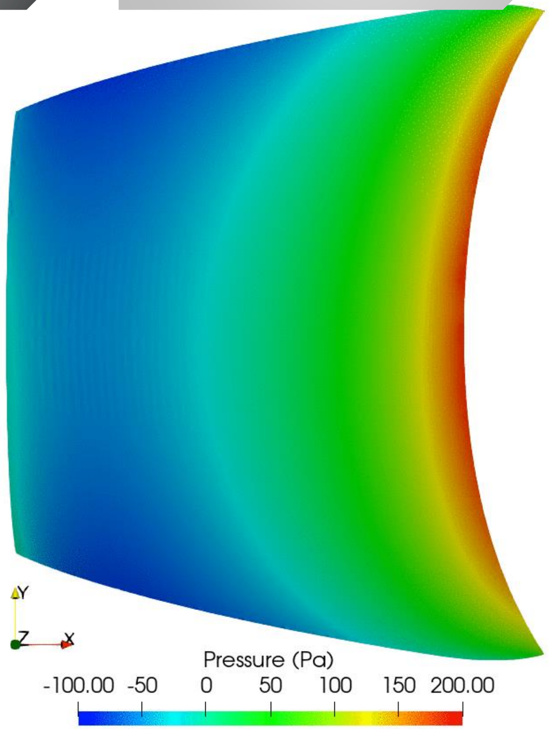
Visual-Environment: Hood Fluttering

Extracting the aerodynamic excitation

AERODYNAMIC EXCITATION → VIBRATION



Front vehicle



Rear vehicle

Vehicles in overtaking maneuver (static case):

- Same vehicle geometry as demonstrator.
- Different geometries (truck+vehicle, truck+motorbike, SUV+B-car) could be used

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Visual-Environment: Hood Fluttering

Sensitivity to velocity and signal

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Road Map

- Single field CHT **Performance**
- AMI Improvement **Performance**
- surfaceFilm Model in finite area **Performance** **Accuracy** **Robustness**
- Dynamic Mode Decomposition Improvement (reduced order modelling) **Performance**
- Enhancements in numerics (Coupled solver, etc)
- Improvements in layer coverage with snappyHexMesh
- Improvement in redistibutePar **Performance**
- **Community Contribution**

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ESI is proud to lead the exaFOAM Consortium

H2020 EuroHPC JU project commencing 2021

- €5.4m project 2021-2023 awarded on July 2020

- OpenFOAM towards exascale computing
- Scope includes
    - Hardware utilization, including GPUs
    - Evolutionary and Revolutionary algorithms
    - Democratisation via HPC Grand Challenges

- Let us know if you'd like to be involved as a
    - Stakeholder
    - Observer
    - Supporter

*… an initiative by the **HPC Technical Committee chaired by Ivan Spisso***

OpenFOAM **The Consortium**

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3. E4 Computer Engineering spa (Italy)
4. PoliTecnico di Milano (Italy)
5. University of Zagreb (Croatia)
6. Technische Universitaet Darmstadt (Germany)
7. Wikki (Germany)
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Upcoming Events

- Workshop: COVID-19, March 30th
  - Return to work imperative - Minimizing the risk of airborne transmission
  - https://www.esi-group.com/company/events/2021/covid-19-workshop
- SIA Simulation Numérique digital, 7th April
- SAE World Congress Experience, 13th April 2021
- OpenFOAM 21 06 Release Webinar, July
- **9th OpenFOAM Conference, 19th -21st October**
- NAFEMS World Congress, 25-29th October
- FKFS Conference, T.B.D

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Any Questions?

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