Overset mesh for Internal Combustion Engine Simulation in STAR-CCM+

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Outline

- Two-stroke engine regular Overset interface
  - Geometry
  - Regions
  - Interface setup
  - Mesh
  - Physics
  - Overset features
  - Post-processing

- Two-stroke engine with Overset ZeroGap approach
  - Regions
  - Interface setup
  - Mesh and Physics
  - Post-processing

- Pro/Con Overset vs Overset ZeroGap for two-stroke engines

- Four-stroke engine with Overset ZeroGap approach
  - Geometry
  - Regions
  - Interface setup
  - Mesh
  - Physics
  - Overset features
  - Post-Processing
Two-stroke engine regular Overset interface
Piston, connecting rod and crank web were taken from GrabCAD*. The crankcase was built in STAR-CCM+ 3D CAD.

*https://grabcad.com/library/two-stroke-slider-crank-mechanism
Regions

7 regions: piston, connecting rod, crank web, crankcase, inlet, outlet, channel
Interface setup

4 boundary interfaces:
- channel – crankcase
- inlet – piston
- outlet – piston
- channel – piston

6 regular Overset interfaces:
- piston – crankcase
- connecting rod – crankcase
- crank web – crankcase
- piston – crank web
- connecting rod – crank web
- connecting rod – piston

Overset topology - Direction: for applications where the Overset boundary does not completely enclose the overset region
Mesh

- 2.9m poly cells
- 5 prism layers

Exact opening and closing time for the inlet and outlet flow
Mesh

Mesh motion

Solution Time $2 \times 10^{-5}$ (s)
Physics

- Implicit unsteady
- Ideal gas
- Segregated flow solver
- Realizable k-epsilon two-layer

Boundaries
- Stagnation inlet = 0Pa (unrealistic)
- Pressure outlet = 0Pa (unrealistic)

Motion
- Crankweb: rotation 10,000rpm
- Piston: translation
- Connecting rod: superposing rotation

Overset interfaces
- Close proximity enabled
- Interpolation: linear
Overset features

- **Close Proximity**
  - cell is deactivated only when the cell centroid is outside the boundary

- **Linear interpolation**

- **Dynamic Overset Behaviour: Active, Acceptor**

- **Overset topology: Direction**
Post-processing

Note: This is a generic geometry. We do not apply realistic boundary conditions.
Two-stroke engine with Overset ZeroGap approach
Regions

4 regions: piston, connecting rod, crank web, crankcase

Crankcase (background region)
Interface setup

1 Overset ZeroGap interface:
   - piston – crankcase

5 regular Overset interfaces:
   - connecting rod – crankcase
   - crank web – crankcase
   - piston – crank web
   - connecting rod – crank web
   - connecting rod – piston
Mesh and Physics

- 3.3m poly cells
- 5 prism layers

ZeroGap walls can have an influence on the opening and closing time for the inlet and outlet flow.
Mesh and Physics

Solution Time $2e^{-05}$ (s)

Physics are identical to the previous case
Post-processing

Note: This is a generic geometry. We do not apply realistic boundary conditions.
Pro/Con Overset vs Overset ZeroGap

‼️ Pro Overset ZeroGap:
- Less interfaces
- Piston-crankcase penetration allowed

⁉️ Con Overset ZeroGap:
- Incorrect opening and closing time of the inlet and outlet
- More cells required

✅ Pro regular Overset interface:
- Correct opening and closing time of the inlet and outlet
- Less cells required

⚠️ Con regular Overset interface:
- More interfaces
- Piston-crankcase penetration not possible
Four-stroke engine with Overset ZeroGap approach
Geometry

Generic 4-stroke geometry*

Outlet
Exhaust valve
Intake valve
Inlet
Piston

*Courtesy of Simon Fischer, CD-adapco
Regions

4 regions: piston, engine, exhaust valve, intake valve

- Engine fluid (background region)
- Exhaust valve
- Intake valve
- Piston

red marks Overset boundary
**Interface setup**

- **4 regular Overset interfaces:**
  - engine fluid - piston
  - piston – intake valve
  - piston – exhaust valve
  - intake valve – exhaust valve

- **2 Overset ZeroGap interfaces:**
  - engine fluid – intake valve
  - engine fluid – exhaust valve

Piston topology is used.
Mesh

- 3.6m cells
- 5 prism layers in ZeroGap area (otherwise 3 prism layers)

A gap will be created, if there are less than 2-4 cells between two wall boundaries
Mesh

Mesh motion

Crank Angle: 302

ZeroGap wall
Physics

- Implicit unsteady
- Ideal gas
- Segregated flow solver
- Realizable k-epsilon two-layer

Boundaries

- Stagnation inlet (unrealistic)
- Pressure outlet (unrealistic)

Motion

- Engine RPM 3600
- Piston, intake/exhaust valve: User Defined Vertex Motion

Overset interfaces

- Close proximity enabled
- Alternate hole cutting enabled
- Interpolation: distance weighted
Overset features

- **Close Proximity**
  - cell is deactivated only when the cell centroid is outside the boundary

- **Alternate Hole Cutting**
  - determines whether the global or the layered hole-cutting approach is used

- **Overset topology: Piston**
  - for applications where a piston moves within a cylinder. The cells underneath the piston are deactivated
Post-processing

Note: This is a generic geometry. We do not apply realistic boundary conditions.
Thank you!

Questions?