ADVANCED SIMULATION TECHNOLOGIES

HYDSIM-FIRE-Coupling, FIRE v2013.1

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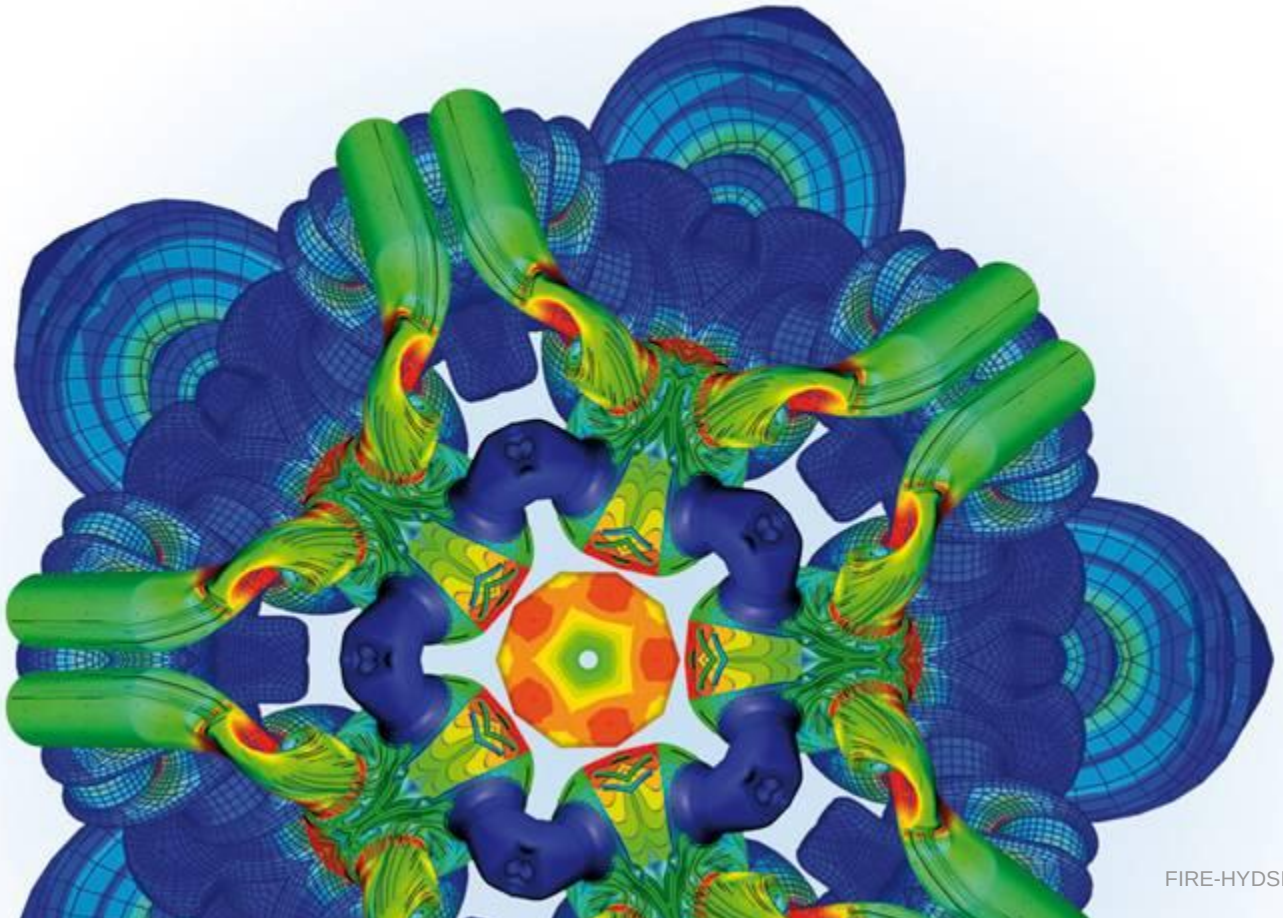


FIRE-HYDSIM Coupling Formulas

FIRE-HYDSIM-Coupling-formulas support both longitudinal and lateral (radial) needle movement.

Lateral needle movement is not yet supported by HYDSIM v2011!

The formulas support FIRE full models (360° round nozzle axis), half models (180° with symmetry plane) and segment (cake) models. With half-models, needle movement is applied only along the principal lateral direction (parallel to the symmetry plane). With segment-models, only the longitudinal needle motion is taken into account.

Enhancement with v2010.2 versions: if a selection `smooth_displacements` exists, the displacements are smoothed in this region. This might be needed for large needle lifts in the region above the upper end of the seat-cone (see next slide). The selection must not contain surface nodes, but it must contain corresponding nodes in the symmetry plane (if present).

Enhancement with v2011: An option has been added to obtain the (longitudinal) needle lift from file instead of HYDSIM. In this case no co-simulation with HYDSIM is performed.

FIRE-HYDSIM Coupling Formulas

Enhancement with v2013: The file-option for needle movement has been extended so as to allow longitudinal motion, longitudinal motion with motion in principal lateral direction and longitudinal motion with lateral motion in both directions.

Enhancements with v2013.1:

If the surface selection `needle_shaft` is present, the integral pressure force acting onto this surface is added to the (lateral) needle force sent to HYDSIM.
Both lateral and co-lateral needle movement may be specified by file instead of HYDSIM as well.

A new mesh-movement-type has been introduced. Instead of moving the mesh nodes in the nozzle gap explicitly according to the conical needle seat and tip surfaces, the nodes within a selection `interpolation` are moved purely by interpolation between the other nodes. This allows more general nozzle shapes. In any case, the mesh and the interpolation-selection has to be prepared accordingly. The interpolation-selection should be similar to the buffer-selections in FAME-Engine meshes and should be a node-selection to avoid problems with the movement under MPI. The selection must not contain any nodes at walls (needle or nozzle surface). The option **mesh movement** in the global-formula needs to be set to **interpolation**, to get this new movement type. The needle-shaft-selection (see above) must be present with this movement type. The old, explicit movement is selected with **explicit**.
In any case, the mesh should be generated at nearly closed needle position (at lift 1µm or even 0.1µm for typical Diesel injection nozzles in car engines).

Nozzle geometry / FIRE domain
Required selections

Required Face Selections

needle_seat: conical seat surface

needle_tip1…n: arbitrary number of conical needle-tip-segments

needle_tip: union of all needle_tip* selections

inlet: inlet of FIRE domain

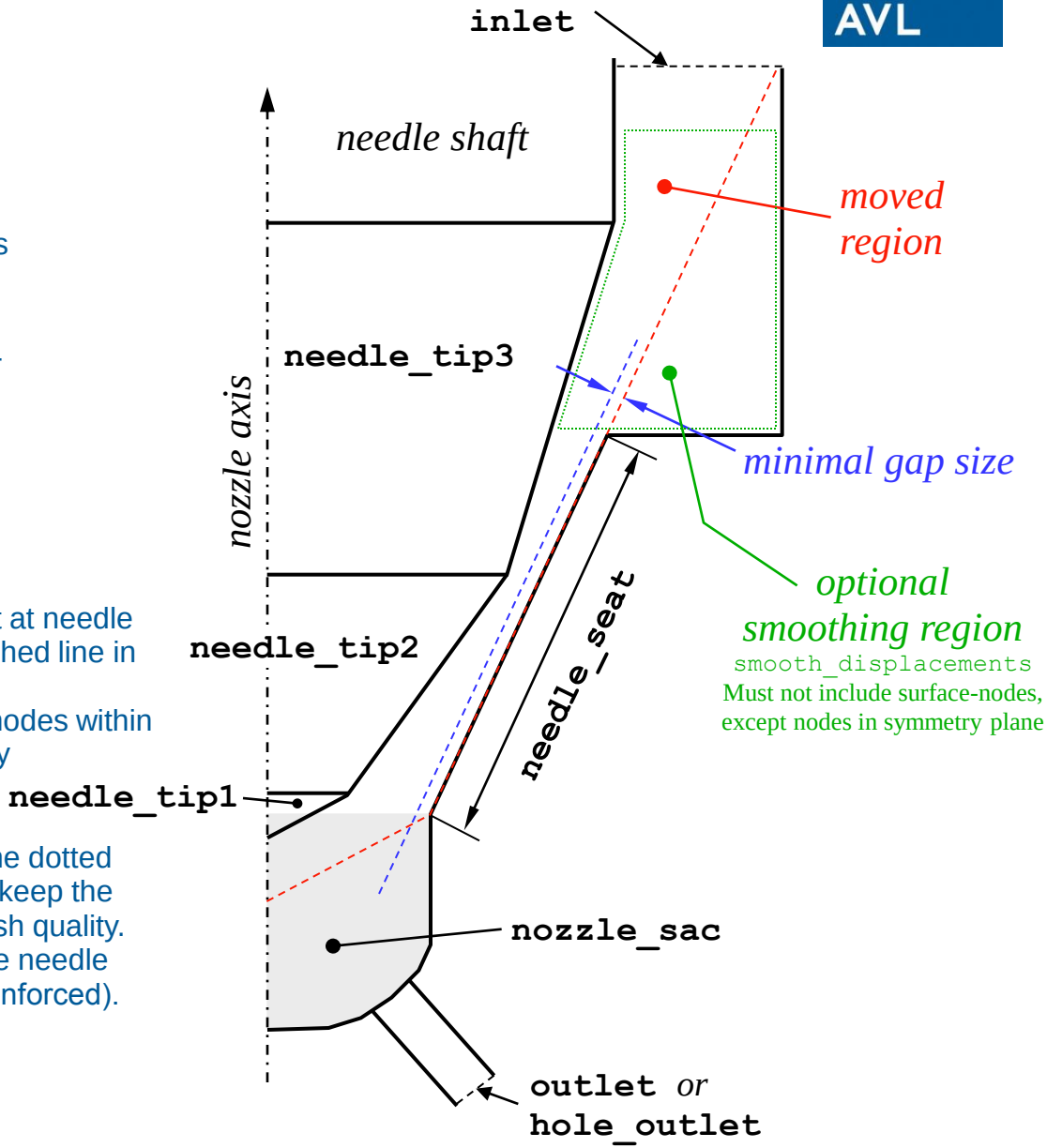
hole_outlet or **outlet** (if former missing): outlet of FIRE domain or hole-exit-surface into chamber

Required Cell Selections

nozzle_sac: sac volume (used to average pressure for HYDSIM). Should be volume at VCO for VCO-cases.

Moved mesh region (red): full needle movement at needle surface decreases to zero movement at red dashed line in case of **explicit** movement.
If **interpolation** movement, the positions of all nodes within the selection **interpolation** are computed by interpolation from neighboring nodes.

Parts of (moved) needle surface that protrude the dotted blue line (cone in 3D) are shifted back, so as to keep the user-specified minimal gap size, needed for mesh quality. Mesh cells with center actually located within the needle solid can optionally be „blocked“ (zero velocity enforced).

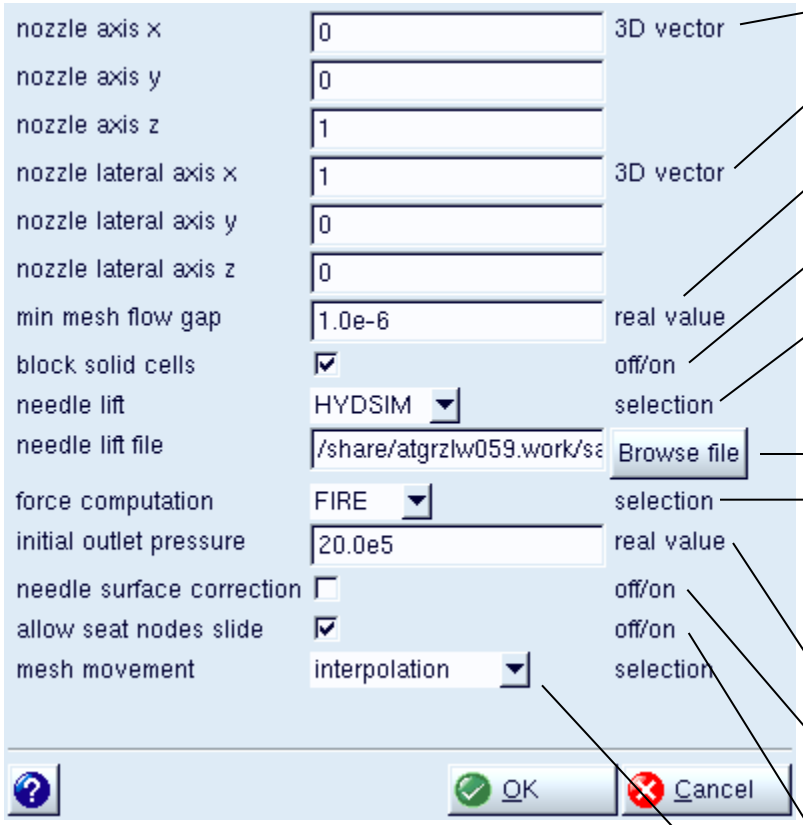


Required formulas with HYDSIM-coupling

Note that the global formula (see below) must be loaded in the SolverGUI as first of these formulas! The formulas are part of the FIRE installation with version v2010.1 and later. The can be loaded on **Import example** in the Formula Editor.

1. Global formula (must be loaded first): `fire_hydsim_coupling_global.h`
   This formula contains **Formula parameters** to be defined by the user (see next slide). The formulas below do not contain any further parameters.
   (Note that this formula automatically loads the formula file *`fire_hydsim_coupling.h`*, which is also contained in the installation.This formula contains the major formula functions for the FIRE-HYDSIM-coupling.)
2. Mesh-deformation-formula: `fire_hydsim_coupling_mesh.h`
3. Result-2D-formula (apply to selection needle_tip): `fire_hydsim_coupling_2D_result.h`
   This formula triggers the computation of the FIRE results that are sent to HYDSIM (needle force, mass flow etc.)
4. Initialization of pressure: `fire_hydsim_coupling_init_pressure.h`
   Above the needle seat edge, pressure is set to the HYDSIM-value received at the inlet. Below the edge, it is set to the outlet-pressure, as defined in the global formula.
5. Initialization of temperature: `fire_hydsim_coupling_init_temperature.h`
6. Inlet-pressure: `fire_hydsim_coupling_inlet_pressure.h`
7. Inlet-temperature: `fire_hydsim_coupling_inlet_temperature.h`

Formula parameters in global formula for HYDSIM-Coupling



Nozzle axis direction, pointing against tip. Note that the nozzle axis must pass through the origin of the FIRE model!

Nozzle lateral direction: must conform to HYDSIM principal lateral displacement direction, if lateral displacement is considered.

Minimal gap size [m] to keep mesh quality in the flow gap

Activation of cell-blocking: due to the minimal gap size, cells may actually be located within the needle-solid. These cells are blocked if this option is active.

Source of needle lift. Must be set to **HYDSIM** for coupling, to **file** for axial lift from file (columns time [s] and lift [mm]), to **fileLat** for additional lateral displacement in 3rd column [mm] and to **fileLat2** for additional co-lateral displacement in 4th column [mm].

Needle lift file, **irrelevant** in case of HYDSIM-Coupling

Mode for computing needle force in FIRE:

- **HYDSIM**: force computed by HYDSIM always.
- **FIRE**: force computed by FIRE.
- **HYBRID**: force computed by FIRE, if no cells are blocked at the time. If cells are blocked, the force is computed by HYDSIM.

Initial outlet pressure [Pa]: used for pressure-initilization (by formula of previous slide) below the needle seat edge. Irrelevant if lift from file.

If active, mesh nodes in `needle_tip` are repositioned so as to match the respective conical surfaces exactly. Might move nodes in selection `symmetry` as well.

If active, mesh nodes in `needle_seat` are moved according to the current needle displacement along the conical surface. This option must NOT be used for VCO nozzles! It might improve mesh quality in SAC-nozzle cases.

Option **interpolation** specifies new mesh node movement (pure interpolation of positions of nodes in selection `interpolation`). Option **explicit** specifies old, explicit movement of nodes.

Required formulas for needle-lift explicitly specified in file (without HYDSIM-Coupling)

In case of needle lift from file, only the following formulas are needed:

1. Global formula (must be loaded first):
   `fire_hydsim_coupling_global.h`
   Formula parameters definition see previous slide: **needle lift** must be set to **file**, **fileLat** or **fileLat2**

2. Mesh-deformation-formula: `fire_hydsim_coupling_mesh.h`

The remaining formulas are not needed. All initial conditions and boundary conditions must be specified in the FIRE Solver GUI.