Motivation and Overall Goal

**Motivation**
- Gaining further insight into the droplet impact process on thin liquid wall film with application to fuel combustion and exhaust gas aftertreatment.
- Understanding how to minimize the formation of secondary fuel droplets that prompts release of lubricating oil inside the combustion chamber which can trigger pre-ignition.
- Acquiring knowledge to maximize the formation of secondary urea/water droplets in the exhaust system to advantageously reduce the wall film in the exhaust pipe.

**Overall goal**

Phase-field Method

- The interface has a small but finite thickness [1,3]
- Based on models of fluid free energy [1,3]
- Continuum thermodynamic diffuse interface model
  - Local phase-field $\chi$ ($-1 \leq \chi \leq 1$)
  - Order parameters (volume averaged)
  - Capillary width $\xi$ [m]
  - Mobility $\lambda$ [J/m²]
- Cahn-Hilliard Navier-Stokes equations (alternatively Allen-Cahn)
  - Chemical potential $\Phi$ [J/m³]
  - Interfacial tension $\sigma$ [N/m]
  - Mixing energy density $\lambda$ [J/m³]

**Fig. 1:** Representation of the simulation setup for examining the drop-wall film interaction with miscible fluids (left) and the diffuse drop interface in the phase field method (middle & right).

- Implemented in OpenFOAM (new top level solver phaseFieldFoam, PFF)
- Dynamic adaptive techniques of high performance computing
- Interface relaxation model for high dynamics:
  - Equilibrium Planar: Standard formulation where diffuse mixing energy is considered to be equal to the interfacial energy, assuming a planar interface at equilibrium.
  - Relaxation: Novel formulation where the interfacial energy is non-constant, see [3], and the interface has its own local relaxation dynamics.

Preliminary Results

**Research Questions:**
1. To what extent (quantitatively) can the crown diameter and opening angle in the case of a drop impact on wall films of identical fluids be brought into agreement with experimental results?
2. Which methodological extensions are necessary?

**Test Case Description**

<table>
<thead>
<tr>
<th>Fluid</th>
<th>Silicone Oil</th>
<th>Computational Settings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kinematic viscosity</td>
<td>5-1050 s⁻¹</td>
<td>Interface Model</td>
</tr>
<tr>
<td>Interfacial tension</td>
<td>17.7 m²/N</td>
<td>Domain Configuration</td>
</tr>
<tr>
<td>Density</td>
<td>900 kg/m³</td>
<td>Assymetrical</td>
</tr>
<tr>
<td>Droplet diameter</td>
<td>1.5 mm</td>
<td>Adaption Mesh Refinement</td>
</tr>
<tr>
<td>Drop impact velocity</td>
<td>3 m/s</td>
<td>Cahn number</td>
</tr>
<tr>
<td>Film thickness</td>
<td>0.5 mm</td>
<td>0-035</td>
</tr>
</tbody>
</table>

**Fig. 2:** Profile of the order parameter for a flat interface in equilibrium.

**Fig. 3:** Comparison of the standard equilibrium mixing energy model (left) and the novel relaxation mixing energy model (right) with the experimental study (middle).

Highlights & Outlook

- Interface relaxation model is essential for correct prediction of the dynamics of the corona as visualized by the experimental studies
- Very low artificial / parasitic currents [2]
- Extension of the solver for M phases and N components as well as for miscible and immiscible systems
- Further validation of the method based on experimental studies

References