Implementation of Lagrangian Surface Tracking for High Performance Computing

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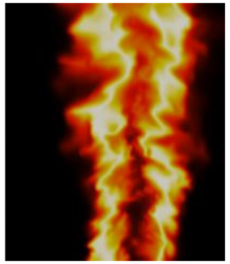
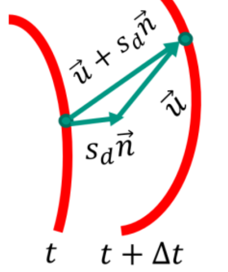
Motivation

Laminar flame



Turbulent flame

In laminar flames, correlations exist to describe the **flame speed** as a function of the flow field (*flame stretch*). For turbulent flames, there are no general correlations. The goal of this work is to investigate this correlation by tracking flame surfaces with **Lagrangian particles** that follow material points, so called **flame particles**.



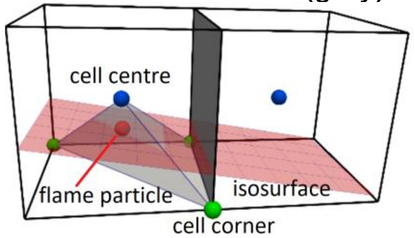
They move with the fluid velocity $\vec{u}$ and the displacement speed s_d. Their trajectories reveal interactions of diffusive and chemical effects.

Implementation

Surface tracking is implemented in **OpenFOAM**. The code shows computation of displacement speed **Sd** for a temperature isosurface, **interpolated** velocity U at the particle position and **movement** of particles [1,2].

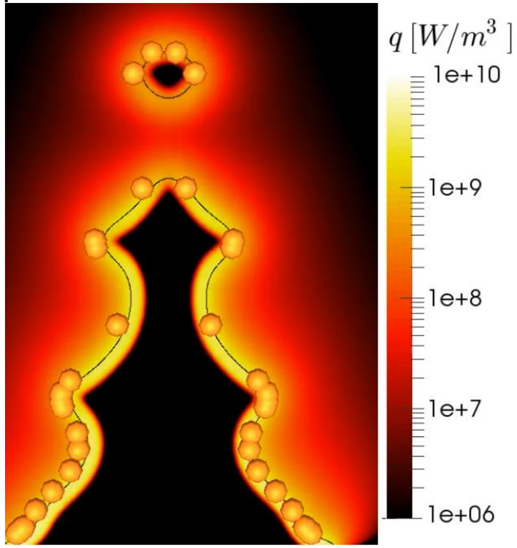
```
bool trackingParticle::move(){
Sd = -fvc::DDt(T)/
     mag(fvc::grad(T));
W = U + sd*N;
W_p =
 Wi.interpolate(position());
track(W_p*DeltaT, 1.);   }
```

Tracking/interpolation is done in **barycentric coordinates**. Each cell is split into tetrahedra. The figure shows cell centers (blue), flame particle (red), isosurface and **tetrahedron** in cell (gray).

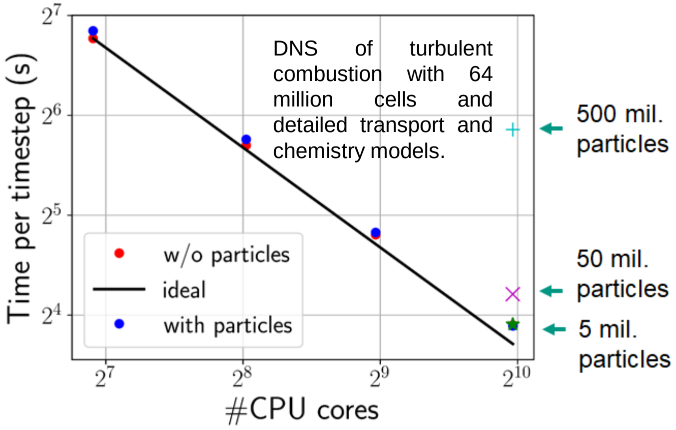


Example

The figure below shows **flame particles** (spheres) seeded onto the flame surface of an **oscillating Bunsen flame**. This allows to investigate the mutual interaction of convection-diffusion-reaction processes occurring within the flame, which determine the overall burning behavior in terms of flame stabilization, burning efficiency and pollutant emission.



Performance



The tracking code [1,2] **scales linearly** with and without particle tracking and the implemented **parallel tracking algorithm** does not create overhead. Usually, tens of thousands of particles are tracked. Even with millions of particles, overhead stays below 5% in typical cases.

References

[1] T. Zirwes, F. Zhang, Y. Wang, P. Habisreuther, J.A. Denev, Z. Chen, H. Bockhorn, and D. Trimis, *"In-situ Flame Particle Tracking Based on Barycentric Coordinates for Studying Local Flame Dynamics in Pulsating Bunsen Flames,"* in Proceedings of the Combustion Institute, vol. 38, Elsevier, 2020 (https://doi.org/10.1016/j.proci.2007.033)

[2] T. Zirwes, F. Zhang, J.A. Denev, P. Habisreuther, H. Bockhorn, and D. Trimis, "*Implementation of Lagrangian Surface Tracking for High Performance Computing*," in High Performance Computing in Science and Engineering '20 (W. Nagel, D. Kröner, and M. Resch, eds.), Springer, 2020

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