FACULTY OF ENGINEERING AND ARCHITECTURE

DEPARTMENT OF FLOW, HEAT AND COMBUSTION MECHANICS

LES/CMC SIMULATION OF THE CORIA ROUEN SPRAY FLAME USING THE LAGRANGIAN POINT PARTICLE APPROACH

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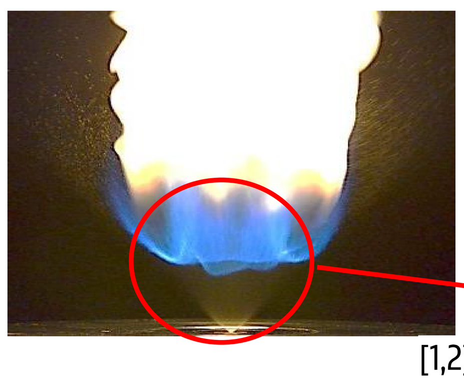
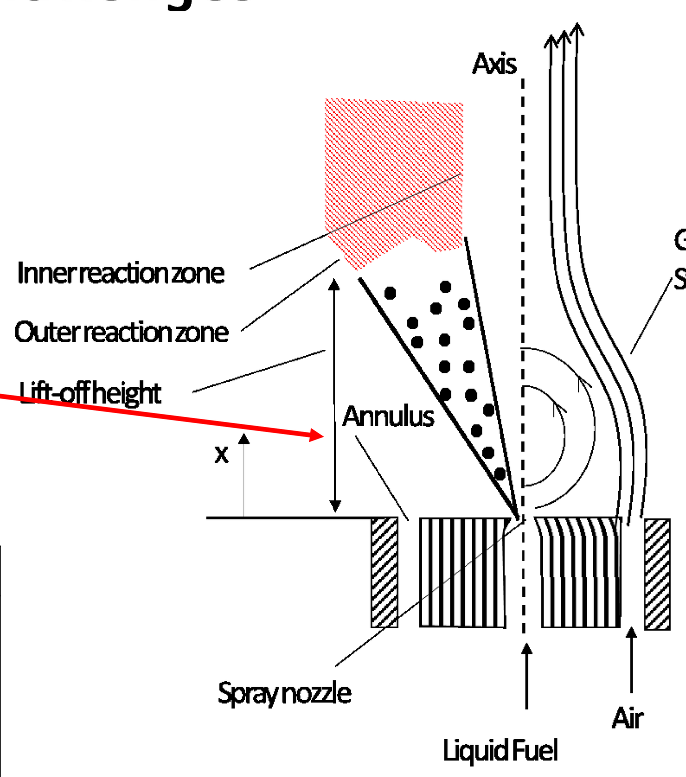
1. Spray Lifted jet flame: challenges


[1,2]



Description of the experimental facility	
Inlet air conditions	6 g/s (T=298 K)
Inlet Fuel conditions	0.28 g/s (T=298 K)
Injector orifice diameter	0.0002 m
Nozzle type	Simplex Fuel injector
Spray angle	80°
Coflow jet type	Non-swirling
Inner coflow diameter	0.01m
Outer Coflow diameter	0.02 m
Reynolds Number	13000
Spray droplets size	[0.5-65 μm]

Challenges
- Spray modeling
- Evaporation → mixture fraction source term
- Micro-mixing → Scalar Dissipation Rate

2. Conditional Moment Closure (CMC) for two phase flow [3,4]

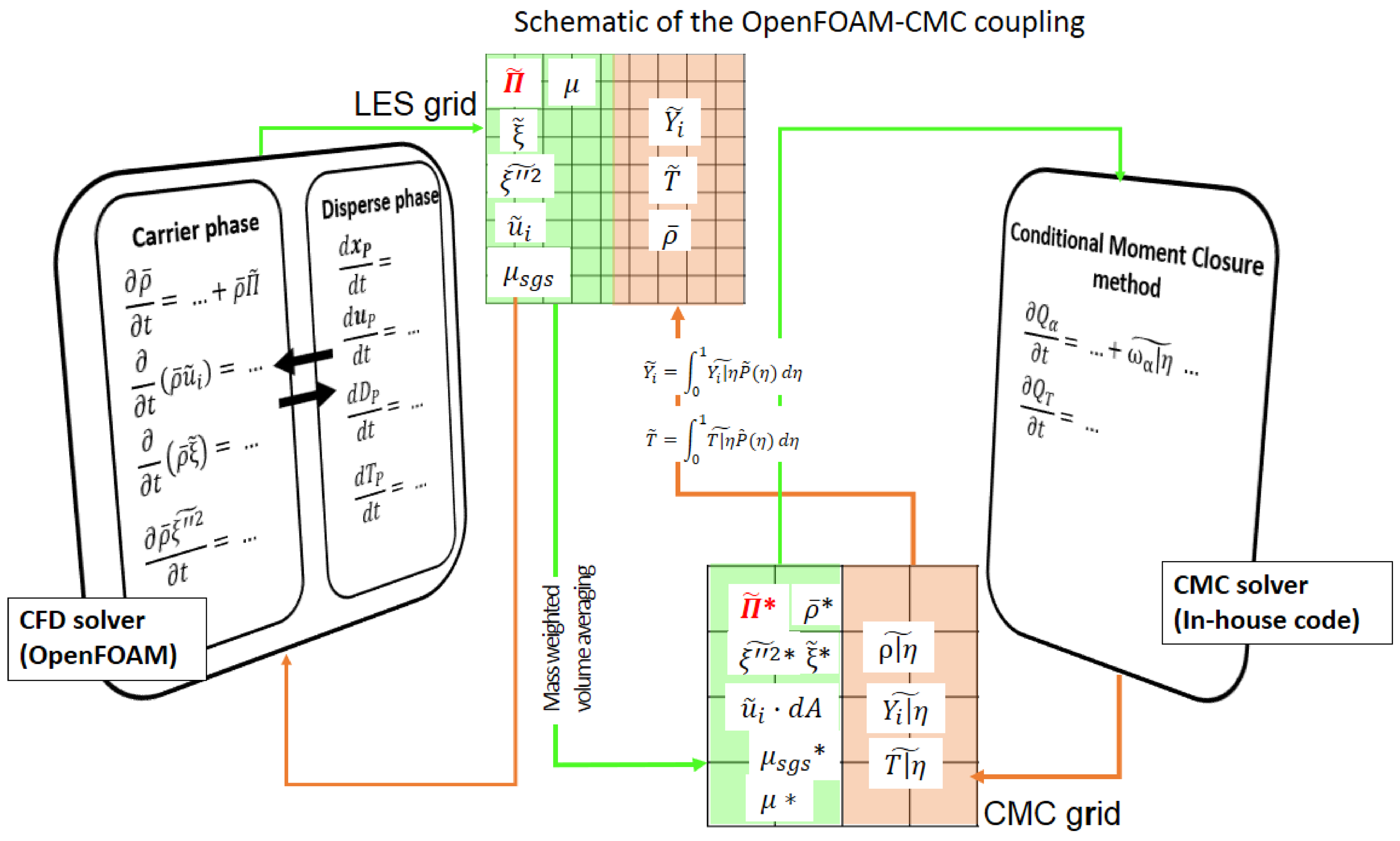
- Mixture fraction based approach
- Fluctuations of mixture fraction <-> Fluctuations of scalars ($Y\alpha$)
- η -> sample space of mixture fraction (ξ)
- Transport equations are solved for conditionally filtered reacting scalars: $Q_\alpha = \widetilde{Y_\alpha|\eta}$

$$\frac{\partial Q_\alpha}{\partial t} = \widetilde{N|\eta}\frac{\partial^2 Q_\alpha}{\partial \eta^2} + \widetilde{w_\alpha|\eta} - \widetilde{u_i|\eta}\frac{\partial Q_\alpha}{\partial x_i} + \frac{\partial}{\partial x_i}\left(D_t\frac{\partial Q_\alpha}{\partial x_i}\right) + S(\widetilde{\Pi|\eta})$$

Diffusion in mixture fraction space
Chemical source term
Subgrid scale conditional flux
Convection term
Conditional spray source term (not include)

3. Numerical Strategy

Schematic of the OpenFOAM-CMC coupling



Conclusions

In this WiPP a numerical study of the Coria Rouen spray flame using LES-CMC has been presented. Results reveal a good characterization of the discrete phase with some discrepancies in the flow field prediction both in the near nozzle region and far downstream. The simplified chemical mechanism adopted and/or the resolution of the grid size at the level both of the CMC and LES have been identified as possible causes of these discrepancies.

4. Computational details

LES

Mesh (cylindrical 0.24×0.26 m): 670000 cells

Parcels' number: 2 M/s

CMC

Mesh (cylindrical): 2880 cells

Mixture fraction space grid: 51 nodes

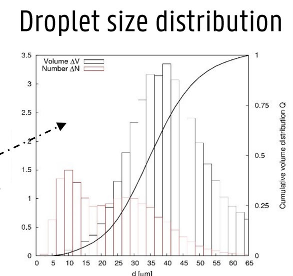
Chemical mechanism: single step

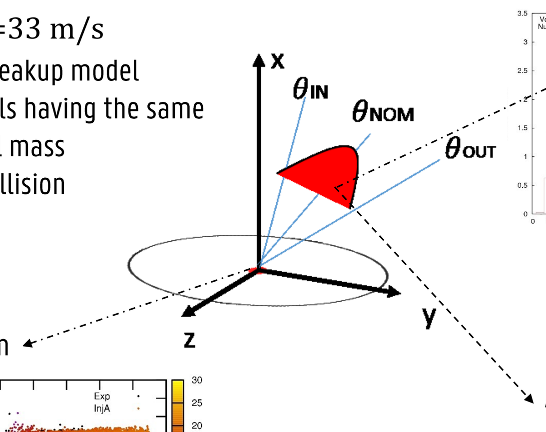
C_7H_{16}+$11O_2$ $\rightarrow 7CO_2 + 8H_2O$

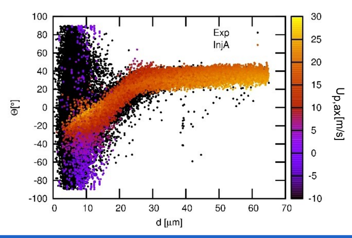
$$q_c = A\exp\left(-\frac{E_a}{R_c T}\right)[C_7H_{16}]^{0.25}[O_2]^{1.5}$$

5. Injection model

- U_{inj}=33 m/s
- No breakup model
- Parcels having the same initial mass
- No collision



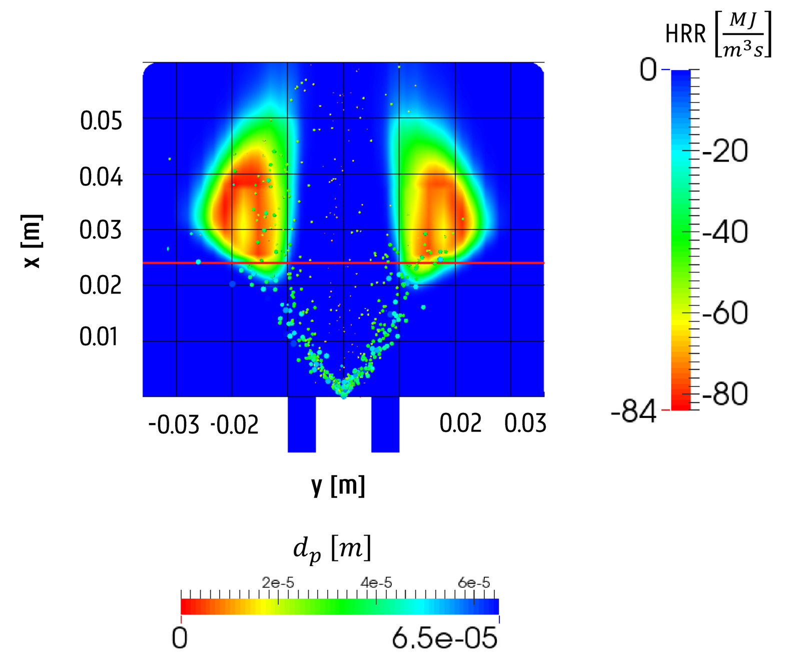




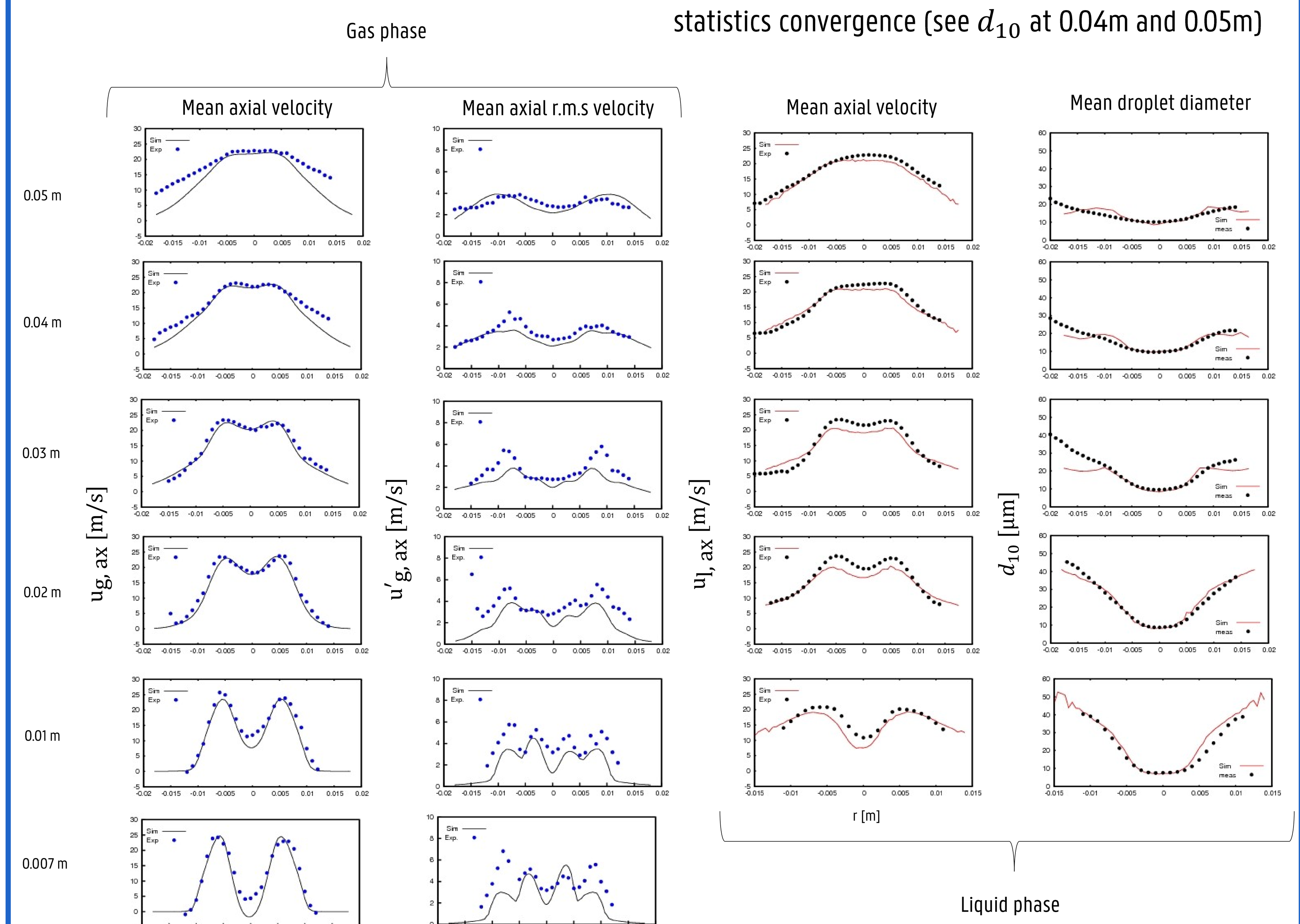
$$f(x|\mu,\sigma^2) = \frac{1}{\sqrt{2\pi\sigma^2}}e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

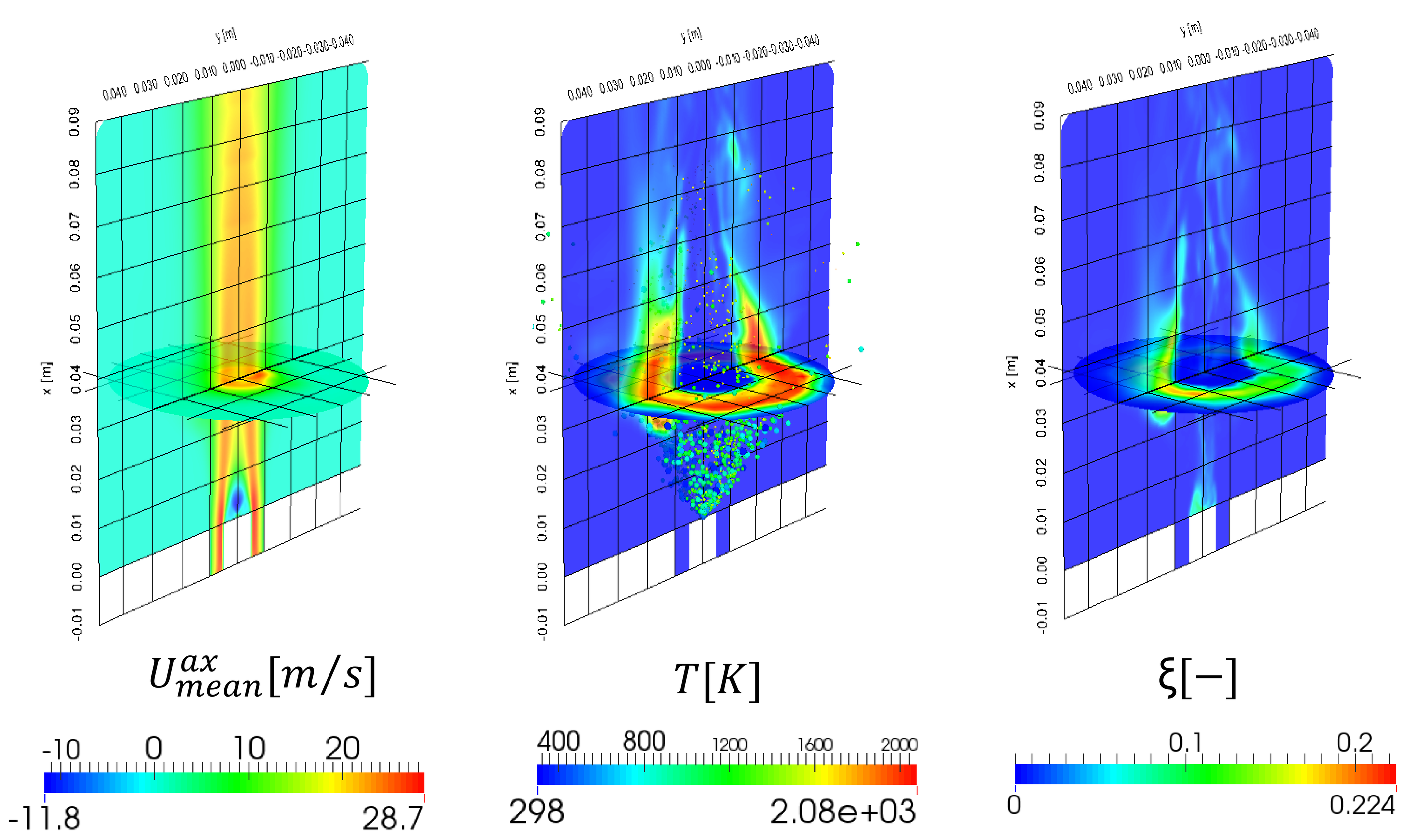
$\mu = 40°$
σ^2=8

6. Results



- Good prediction of Lift-off height L_h^{exp}=0.024±0.003 m
- Inaccurate flow field in the near nozzle-region (approximation burner geometry to annular cylinder + turbulent inflow generator)
- At far nozzle field (x > 0.04 m) the flame jet appears narrower than in the experiments
- The two off center peaks observed experimentally for the mean axial velocity r.m.s along the radial coordinate are not predicted (poor LES resolution)
- Comparison with OH-plif images not possible (1 step mechanism)
- Simulation time (~0.5s) not enough to get liquid phase statistics convergence (see d_{10} at 0.04m and 0.05m)





Future Work

- Inclusion spray source term
- Detailed chemical mechanism
- Mesh Refinement both in LES and CMC

References

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[2] A. Verdier, J. Marrero Santiago, A. Vandel, S. Saengkaew, G. Cabot, G. Grehan, B. Renou, Proceedings of the Combustion Institute,2016.
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[4] P. Schroll, E. Mastorakos, Simulations of spark ignition of a swirling n-heptane spray flame with conditional moment closure, 48TH AIAA, 2010, Orlando, Florida.

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