Mixing and Velocity session

(A summary by the session coordinators:
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Experimental Results

This part of the session focused on the experimental results:

- mixture fraction measurements performed by Sandia, through Rayleigh scattering technique (see SAE 2011-01-0686)
- velocity fields measurements (inside and surround the spray) performed by IFPEN using high speed PIV.

Mono-parametric variations of the boundary conditions have been performed:

- injection pressure variations: 150, 100 and 50MPa (only for mixture fraction for these latter condition)
- ambient temperature variations: 900 and 1100K
- ambient density variations: 22.8 and 15.2kg/m3

Rather than on the results in themselves, the presentation was focused on 2 points:

- how to assess the accuracy of the boundary conditions?
- how to compare PIV and Rayleigh scattering results, because they were obtained in 2 different facilities?

The main outputs of this presentation are:

- With high speed PIV, it is possible to obtain on a single injection event both the velocity fields inside and surrounding the spray.
- Both the PIV and Rayleigh scattering results show radial profiles that are Gaussian profile.
- Once the spray penetration is known, a 1D model based on the momentum conservation (proposed by Siebers, Musculus and Pickett) adequately predicts the mixing and velocity distributions of the spray, including the radial profiles. Therefore, this model can be used for assessing the accuracy of the boundary conditions, and to assess the consistency of the data obtained in 2 different facilities and for 2 different physical values (mixture fraction and velocity fields).
- Based on the results from this 1D model, it seems that the mixture fraction data obtained at Sandia, and the velocity data obtained at IFPEN, can be used as a single dataset for modelers, describing the mixing processes occurring in the spray.

Recommendations/future work:

- Difficulties have been encountered to measure the velocity fields near the nozzle tip (no data are available under 30mm). The reason for this must be analyzed, and some solution proposed.
- Data concerning the air entrainment need to be analyzed.

Modeling contributions

This part of the session compared models and experiments of mixture fraction distributions and velocity fields for the non-reacting Spray-A spray.

The following seven groups contributed modeled results:

- Argonne National Laboratory: S. Som, D.E. Longman
- Chalmers University of Technology: A. Kösters, A. Karlsson
- Universitat Politècnica de València CMT: R.Novella, A. Pandal, J.M.Pastor, J.F. Winklinger
- Georgia Institute of Technology: C. L. Genzale, G. Magnotti

• Politecnico di Milano: G. D'Errico, T. Lucchini, R. Torelli
• University of Wisconsin, Engine Research Center: C. Rutland, C-W. Tsang
• The University of New South Wales: E. Hawkes, Y. Pei, S. Kook

Most groups of this session, contributed to the previous Spray and Development session. All groups used RANS turbulence models. Most of the spray models were based on the Lagrangian discrete phase approach, though one group (CMT) contributed an Eulerian approach.
Despite the fact that some standard/baselines guidelines were given, all groups preferred to use their choice of spray sub-models and only few groups submitted results with the suggested set-up guidelines. However, at the end of the discussion, conclusions sounded to be independent on the spray sub-model choice.

Comparisons between measured and computed data were performed at centerline and at two radial positions (25 mm, 45 mm). Effects of fuel injection pressure, ambient density and temperature were evaluated.

Modeling results and comparison with measured data
The comparisons at the baseline condition were good for the majority of the models, confirming also the consistency between the mixture fraction and PIV velocities data, as mentioned in the comments of the experimental part of the session. Some discrepancies between measured and computed velocity results appeared at the 25 mm sample, but at this location the PIV data had a very high standard deviation.

Modeling results differed in the near nozzle region, where no measured data was available. Both mixture fraction and velocity profiles suggest different interpretations of the occurring physical phenomena by the available modeling contributions.

Two groups (PoliMI, UNSW) provided mixture fraction variance results too and in both cases measured and computed values were in good qualitative and quantitative agreement.

With respect with the variations of the operating conditions the following conclusions were drawn:

- models were able to reproduce the effect of variations of the fuel injection pressure;
- models were sensible to ambient density. Results differed a little, but it was not possible to make a definite quantitative assessment on the basis of the available experimental data;
- no experimental data was available for the temperature variations at constant density. All models predicted similar variations of the mixture fraction and the velocity with the ambient temperature;

Finally a series of comparison between results provided by some of the groups with different CFD and similar model set-up were shown. Obtained results were similar but not identical and comments on the comparison were analogous to the ones which were done in the previous analysis.

General conclusions and future suggestions.
The comparison between measured and computed velocity fields and mixture fractions evidenced some good predicting capabilities of the tested modeling approach under the chosen

operating conditions. Some differences among modeling results were evidenced in the near nozzle region and should be matter of future investigation.

All analyses were performed at steady state conditions. The modeling and experimental analysis under transient conditions should be matter of future investigation. Besides, the use of longer injections would be preferable to verify that the behavior of the spray is fully steady-state.

In all the conditions the spray evolution was observed to be mainly momentum driven, which also explains the similarity among the different models and contributions. Because the liquid penetration is quite short for Spray A (~10mm), the necessity to consider in the future injector holes with a larger diameter was suggested in discussion. Larger diameter nozzles would present liquid and vapor together downstream as the maximum liquid penetration scales with nozzle size.