ME – PhD Thesis Colloquium

Evaluation of Air Blast Swirl Injector: Flow-Field Hybrid RANS-LES Studies and Coupling with RANS Spray Characterisation Colligating Global Combustor Characteristics-A Novel Exploration

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ABSTRACT

Protocol of designing future engines meeting requirements of lower emissions, noise, use of multi fuel, green hydrogen, renewable fuels may lead to increase in research in combustion system. Injector, the active component in the combustion plays a pivotal role in meeting requirements in terms of combustion efficiency, flame stability, ignition and combustor exit profile and the signature of the sprays holds the key here. Existing calculations for injector performances include empirical calculations, uncertainty in boundary conditions and lacking a proper framework to predict spray performances from first principle. Through modelling, understanding, and characterizing of air blast swirl injector from flow field and spray non-uniformity in injector level is tried to linked to combustor pattern factor which is connected to the peak temperature at combustor exit. This framework would be an important design tool to evaluate air blast injector at design stage at short time with low cost.

The RANS based calculations were initially performed for flow field. Analysis involved in selecting geometry (2D to 3D), type of grids (tetrahedron to hexahedron) and their resolution requirements (course to fine), types of downstream boundary conditions (outlet to wall) and turbulence models (Reynolds Stress Model (RSM) to Realizable k-epsilon (rke)). RSM model captures closely the averaged turbulence kinetic energy whereas averaged mean velocity profile is better captured through Realizable k-epsilon turbulence while comparing with experimental PIV results. This is, however, still inclusion of the inherent isotropic assumption while trying to resolve Reynold Stress components. Therefore, in LES approaches (kind of applying higher order methods in risks areas of design) we have utilized hybrid RANS-LES simulations where zone-based models have been used. The analysis is carried out with limiting CFL number up to 2, time step of 1 micro second. While comparing the experimental time averaged PIV data with numerical predicted time averaged results, a close match was observed thus hybrid RANS-LES approached depicted improved over RANS results.

In spray characterisation, unsteady Lagrangian tracking of droplet particles using Discrete Phase Model of ANSYS Fluent with the steady state Eulerian air flow field already developed in RSM simulation have been used where the droplets are injected with time step of 0.025 milli second with Rosin-Rammler distribution having mean droplet diameter which is arrived through single phase, multiphase VOF (Volume of Fluid), Liner stability analysis to remove empiricism. The injection time step of 0.025 milli second is the inverse of the FFT of the time co-efficient of lower energy 7th POD mode and the crucial droplet injection velocity derived from that lower energy. Instantaneous r-θ variation of droplet size D32 and droplet number density at location X/D=1.68 (emerged as sweet spot on the field) captured as peak fuel pocket (maximum values of number density distribution) finally responsible for higher pattern factor in the combustion chamber and a correlation is also devised. The position of localized value of fuel pocket is related to the local vorticity field. It was concluded that the spray non-uniformity may be quantified in terms of circumferential distribution of droplet number density and its associated droplet mean velocity.

ABOUT THE SPEAKER

Rampada Rana is a scientist working at Gas Turbine Research Establishment at DRDO. He is pursuing PhD at the Mechanical Engineering Department at the IISc under the esteemed Prof. Saptarshi Basu, and under Dr. N. Muthuveerappan, with research focus on numerical studies of flow field, atomization, and spray. He holds BE in Mechanical Engineering from NIT, Durgapur. He had worked in electronic cooling, thermodynamic cycles of gas turbines, LCF life test evaluation; also having interest in cooling, FSI, rotodynamic, experiment and SCM.