ECN 3.0

Topic 4: Engine Flow and Combustion

Guidelines

ECN3.0 Workshop begins the new Topic 4.0, Engine Flows & Combustion (EFC) .

Purpose of EFC* includes:

- Simulation benchmarking of reciprocating internal combustion engine, ICE, in-cylinder flows (RANS, LES, & DNS).
- Source identification & control of cyclic variability, CV.

Scope of EFC:

- Identifying available experimental data
- Identify and learn from existing measurement/simulation collaborations.
- Initiate meaningful dialogue and collaboration between modelers and experimentalists.
- Identify metrics and approaches to quantify CV and the efficacy of the simulations.

* The breadth of the topic and the individual needs/directions of the voluntary collaborators render it impractical to *begin* with a single, round-robin engine and experiment as for Spray Topics A, B, and G. It is intended that this current EFC effort may justify and define an engine platform to transition of Spray G from a quiescent vessel to a gasoline ICE. Although this initial effort focuses on SI ICE platforms, there is no reason to exclude Diesel engine needs from future work.

Theme of ECN3.0: What exists & what to do for ECN 3.x work.

- Identify major & sub topics based on interest to date.

  Topics restricted to Spark Ignited ICE.

  Topic activity restricted to volunteered contributions.

- Create "wire frame " structure as guide for the ECN3.X technical efforts.

- Identify Topics most likely to create interest and volunteerism for non/pre competitive collaboration.

Objectives of the ECN3.0 / EFC Presentations :

A. Identify currently available SI ICE measured data sets and attributes.

B. Identify current simulation efforts and simulation needs.

Use currently available experimental and simulation efforts to identify:

C. State of the art.

D. Physical processes necessary to simulate CV.

E. Quantitative assessment of simulation efficacy.

F. Define the ECN3.x/EFC path forward based on these findings.

G. Motivate volunteer contributions.

EFC Major Topics

4.1 Measurements for Simulation benchmarking

4.2 Simulation-to-simulation benchmarking (LES, RANS)

4.3 Benchmarking: comparisons, analysis, and validation

4.4 CCV origins and abatement

Objectives of the 4.1

Presenter: Brian Peterson TUDarm.

Goals:

Summarize

- Available measured data
- Scope of data
- EFC 3.x subtopics to address data format and needs.

4.1. Measurements for Simulation benchmarking

- **4.1.1. Measurement and instrumentation standards**
  - **4.1.1.1. Required engine and system geometry**
  - **4.1.1.2. In-cylinder & extra-cylinder instrumentation needs.**
    - **4.1.1.2.1. EnsAve, crank-resolved volume-ave**
    - **4.1.1.2.2. Gas temperature measurements**
    - **4.1.1.2.3. Wall temperatures**
  - **4.1.1.3. Sensors: location, type, BC**
- **4.1.2. Engine operation, test-to-test repeatability criteria.**
  - **4.1.2.1. Metrics and criteria**
  - **4.1.2.2. Run-time control**
  - **4.1.2.3. Post-run analysis & charting**
- **4.1.3. Motored flow characterization.**
- **4.1.4. Motored spray characterization**
- **4.1.5. Combustion characterization**
  - **4.1.5.1. Global analysis**
  - **4.1.5.2. Product gas Identification, 2-D/ 3-D**
  - **4.1.5.3. Resolved homogeneous-Flame Front**
- **4.1.6. Error Analysis**
  - **4.1.6.1. Compression ratio, TDC, valve events, & pegging**
  - **4.1.6.2. Pressure measurements**
  - **4.1.6.3. Temperature measurements**
  - **4.1.6.4. PIV: u & dx dynamic range, u &du/dx accuracy**
  - **4.1.6.5. Spray measurements**

Objectives of the 4.2

Presenter: Cecile Pera

Goals:

Define needs, metrics, and methods for benchmarking simulations against each other to assess efficacy of numeric methods and models.

4.2. Simulation-to-simulation benchmarking (LES, RANS)

4.2.1. Engine simulation methodology
- **4.2.1.1. Complete test-bench coupled with 1D simulation**
- **4.2.1.2. Type of boundary conditions**
- **4.2.1.3. Consecutive vs. Perturbed engine cycles**

4.2.2. Meshing strategy and resolution
- **4.2.2.1. Immersed boundary, auto mesh movement**
- **4.2.2.2. Spatial resolution**
- **4.2.2.3. Resolved-flow measures for sub-grid efficacy**

4.2.3. Modeling issues
- **4.2.3.1. Numerical method (spatial and temporal)**
- **4.2.3.2. Which models capture relevant physics & chemistry?**
- **4.2.3.3. Robust CPU doable computations**

Objectives of the 4.3

Presenter: Dave Reuss UM

Goals:

Define metrics and criterion used to assess equivalency of measured & simulated flow and combustion.

4.3. Benchmarking: comparisons, analysis, and validation

- **4.3.1. Global engine operating conditions**
  - **4.3.1.1. Motored vs. fired.**
  - **4.3.1.2. In-cyl Global/0-D quantities**
  - **4.3.1.3. Extra-cylinder 1-D quantities**
- **4.3.2. Simulated-to-Measured Flow characterization**
  - **4.3.2.1. Intra-cycle vs. inter-cycle comparison**
  - **4.3.2.2. Statistics:**
    - **4.3.2.2.1. phase-averaged mean and standard deviation**
    - **4.3.2.2.2. CCV vs. turbulence vs. noise**
    - **4.3.2.2.3. POD: phase dependent, phase invariant.**
    - **4.3.2.2.4. Conditional sampling on flow events**
  - **4.3.2.3. Required Number of sampled cycles.**
  - **4.3.2.4. Crank angle sampling frequency**
  - **4.3.2.5. Qualitative comparison of velocity fields, 2-D vs. 3-D**
  - **4.3.2.6. Sub-grid model efficacy from resolved-scale measures.**
  - **4.3.2.7. Simulation noise vs. measurement noise.**
  - **4.3.2.8. Quantitative comparison of velocity component profiles.**
- **4.3.3. Simulated to measured Combustion modeling validation**
  - **4.3.3.1. Ignition**
  - **4.3.3.2. Early flame propagation**
  - **4.3.3.3. Global combustion behavior**
  - **4.3.3.4. CCVs**

Objectives of the 4.4

Presenter: Cecile Pera

Goals:
Define metrics and methods to identify physical sources of CCV that need to be modeled.

4.4. CCV Origins and abatement

- **4.4.1. Exploring CCV origin**
  - **4.4.1.1. Flow motion influence**
    - **4.4.1.1.1. Geometry of intake manifold and ducts**
    - **4.4.1.1.2. Flow around valve or exiting valve curtain**
    - **4.4.1.1.3. In-cylinder flow motion**
    - **4.4.1.1.4. Flow motion near spark plug at spark timing**
    - **4.4.1.1.5. Influence of the previous engine cycle**
    - **4.4.1.1.6. Influence of the engine scavenging process**
  - **4.4.1.2. Cylinder charging variation**
  - **4.4.1.3. Local mixture heterogeneity**
  - **4.4.1.4. Role of the spark-ignition period**
  - **4.4.1.5. Combustion process in CCVs**
    - **4.4.1.5.1. Early flame kernel propagation?**
    - **4.4.1.5.2. Occurrence of partial combustion & quenching**
    - **4.4.1.5.3. Heat transfer influence**
- **4.4.2. Factors that increase CCVs**
  - **4.4.2.1. Engine geometry**
  - **4.4.2.2. Engine operating points**
  - **4.4.2.3. Mixture preparation**
  - **4.4.2.4. Flow motion pattern**