Profile Submission for Engineering Simulation Manager Position

PRESENTED TO: SUN HYDRAULICS INTERVIEW TEAM

PRESENTED BY: EMAD AMIN, PHD, P.E.

Profile Information (Academic)

- Name: Emad Amin.
- Latest position: Thermo-fluid consultant, NASA Kennedy Space Center, FL. (2018-2020).
- Academic qualifications: B.Sc. Mechanical Power Engr., M.Sc. in fuels and Energy, Ph.D. in Combustion Science, University of Leeds, UK (1995).
- Professional License: West Virginia State Board of Engineers, current professional engineer license.
- **Academic positions:**
- Research fellow, South-Bank University, London, UK (1995-1997), CFD simulation of off-shore enclosure fires (Soot-Radiation interaction).
- Research assistant and associate professor, Dep. Of Mech. and Aerospace at West Virginia University, (1997-2005), Large Eddy Simulation of diesel engine in-cylinder flows, NASA-WV Consortium Research grants - Teaching ICE, Power Plant, Fluid Dynamics and Heat Transfer courses.
- More than 15 scholarly and research papers in technical conferences and archived journals.
- Member of AIAA, SAE and ASME Internal Combustion Engine Division.

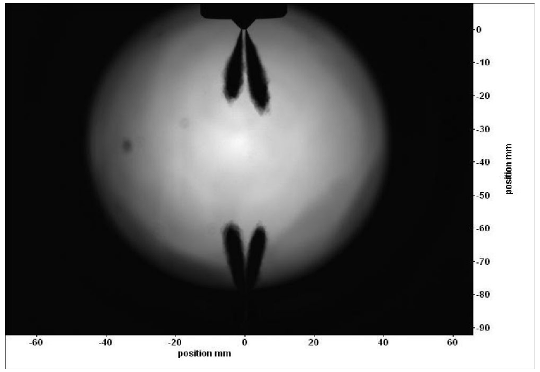
Profile information (industrial)

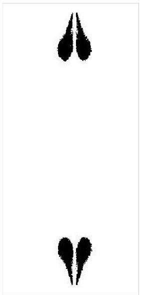
- **Senior Project/Development Engineer**, Thermo-fluid analysis, Navistar-International Co., 2005-2008. (In-cylinder combustion simulations for I6, V8 and HCCI engines using STAR-CD es-ice and Kiva3V, validation of Kiva3V and Ricardo Vectis, attended training courses on STAR-CD and es-ice, and Ansys(Fluent).
- **Senior Combustion Simulation Engineer**, Achates Power Inc. 2008-2011 (In-cylinder combustion simulations for 2-stroke opposed piston engine, development of counter-flow fuel injection, piston crown optimization for NOx and soot reduction and HCCI combustion strategy using Kiva3V and Converge.
- **Technical CFD Advisor**, Cummins Technical Research Center, 2011-2016 (Natural gas SI In-cylinder combustion simulation with Pre-chamber optimization, using Star-CD es-ice, Star-CCM+ for meshing and performing CHT thermal analysis for cylinder head cooling. Attended several training courses on STAR-CD es-ice and Star-CCM+.
- I have more than **15 years** of industrial CFD and Thermo-Fluid Simulation.

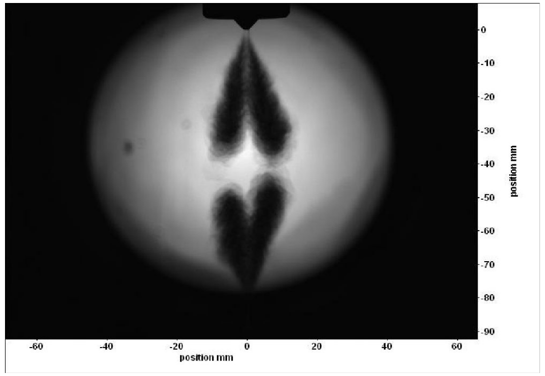
Consulting, Contract Projects and Patents

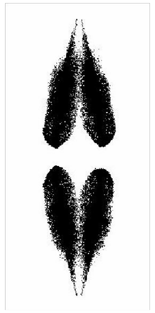
- Developed reduced reaction mechanism for Benzene oxidation for BFGoodrich. (2004)
- Race engine piston crown development (Honda Performance Development)(2016-2017).
- NASA research grant for CFD simulation of pressure drop in flexible connections (2018) and Filter Boxes Thermal Load determination (2019).
- After treatment Urea Mixer to reduce Urea Solidification Issues, Navistar-International Co (2007)
- Colliding Spray side fuel injection system for HCCI early injection applications, Achates Power, Inc. (2010).

Examples of Past Industrial Simulation experience (Colliding Jets Injector Development)

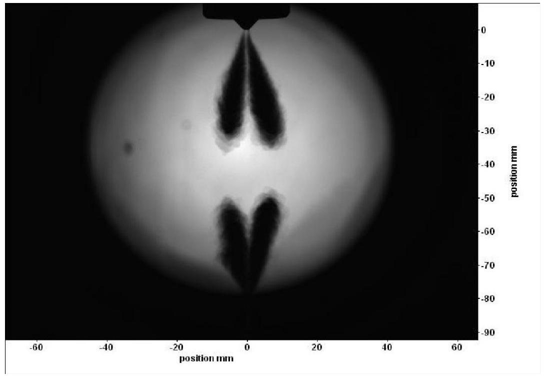


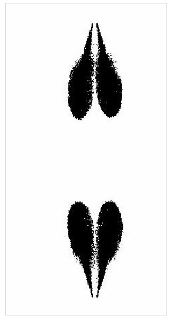


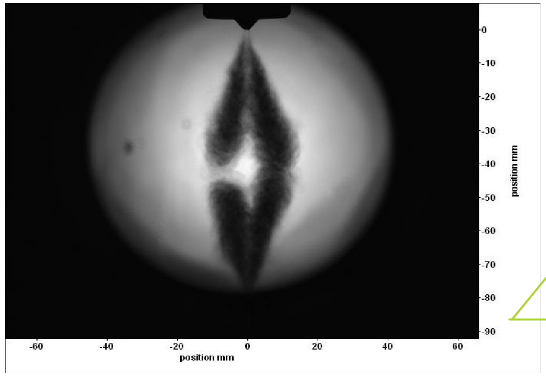


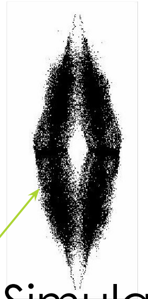


Shadow Graph Images

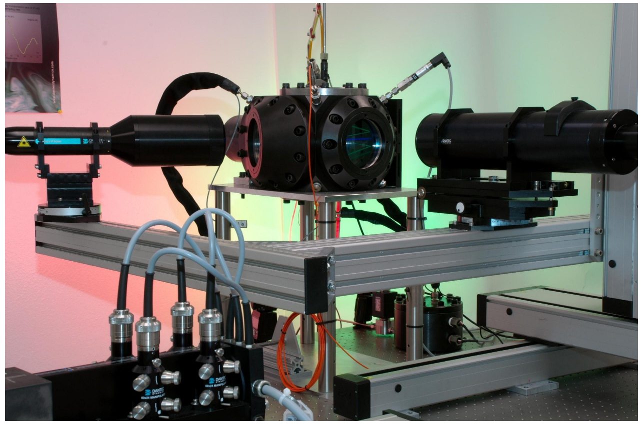






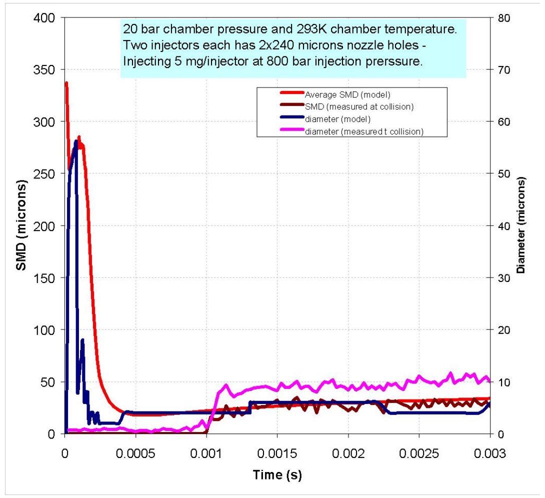


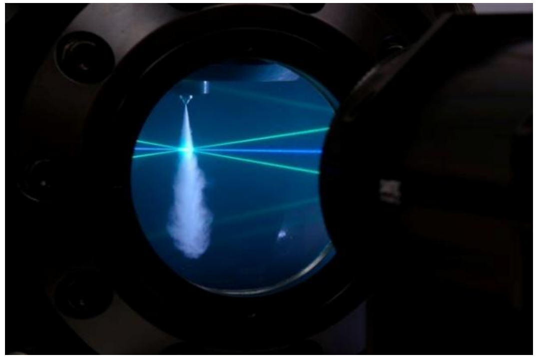
Simulation



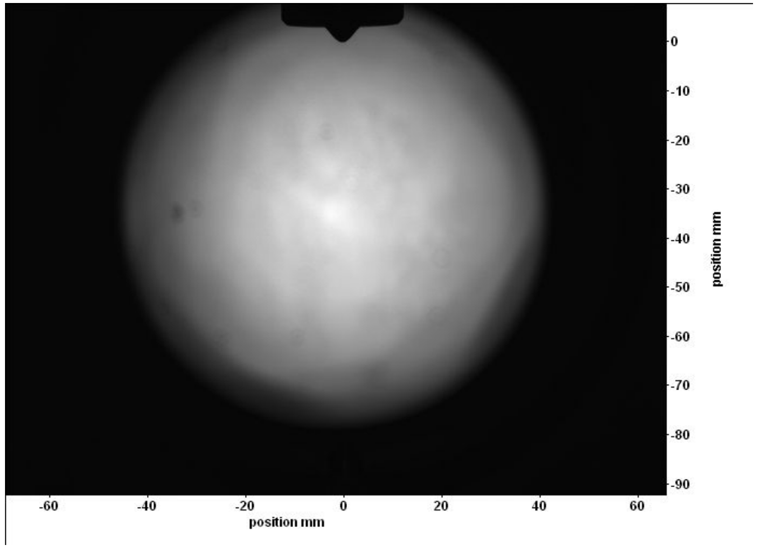
Fuel Bench Set-up

Colliding Sprays (CFD Validation of Fuel Bench Testing)

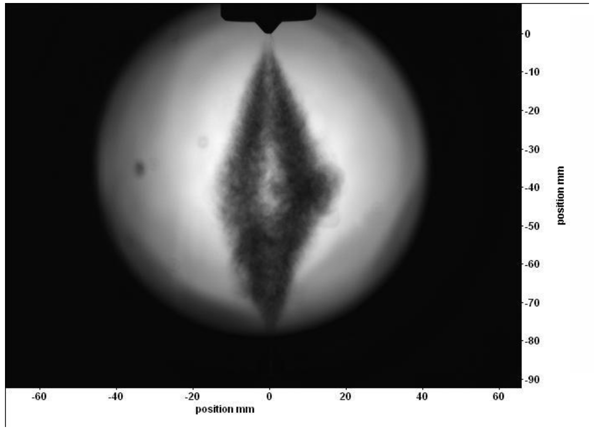


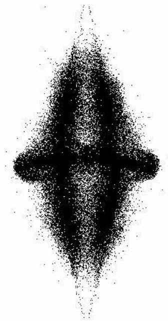


Laser measurement

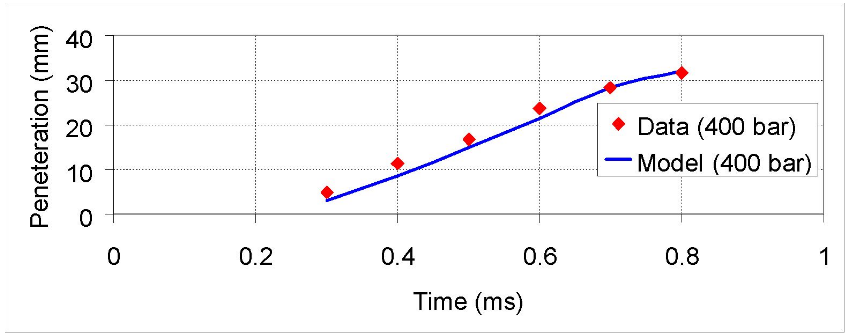


Shadowgraph Visualization



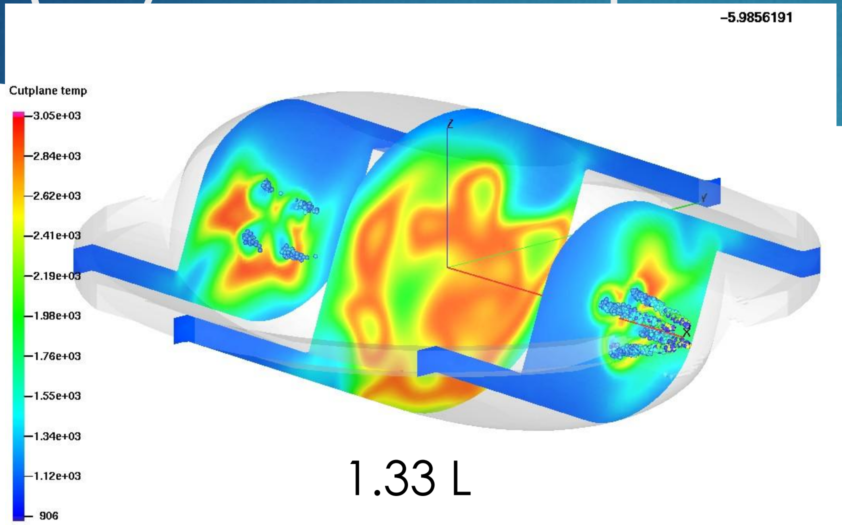


Simulation

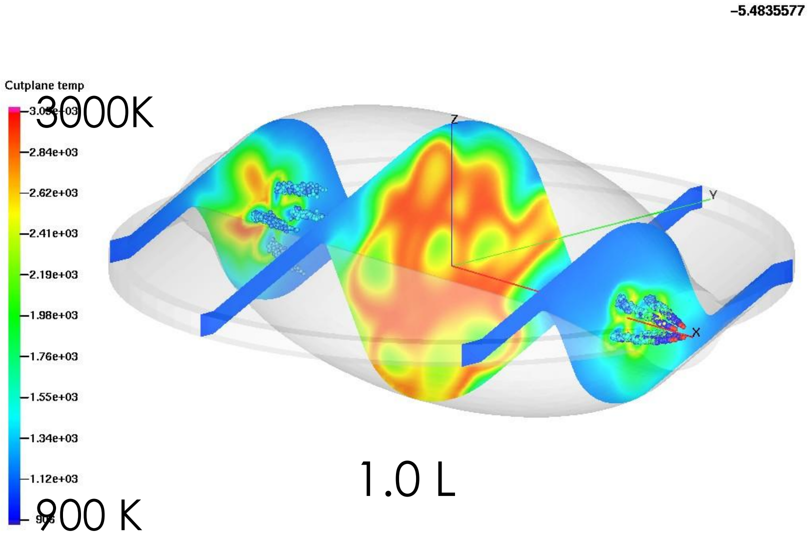


Analysis

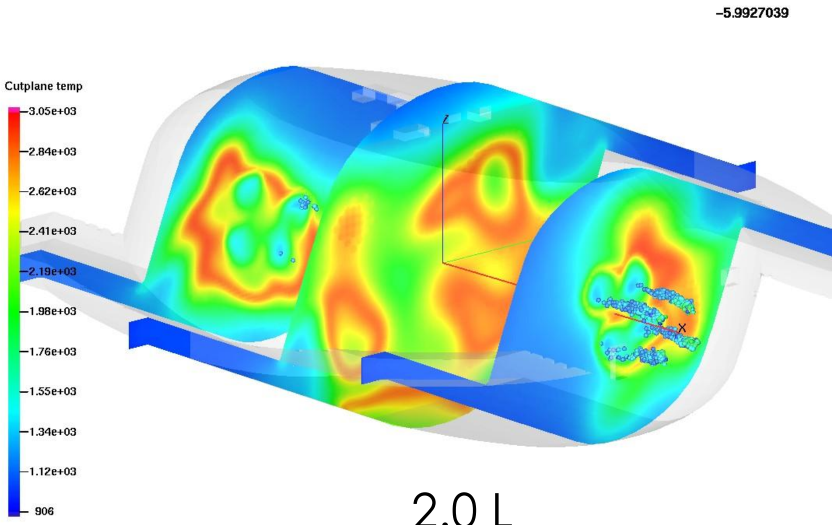
Temperature field near TDC (Cylinder Capacity)



1.33 L



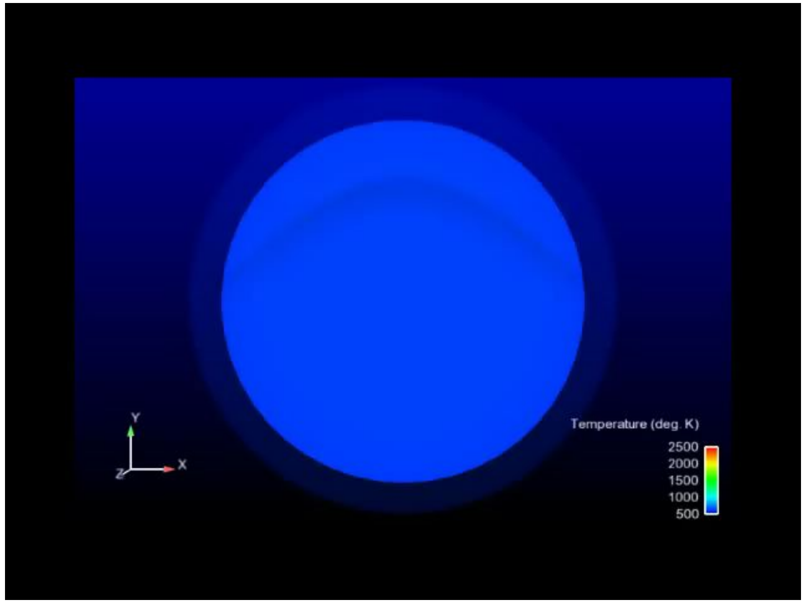
1.0 L



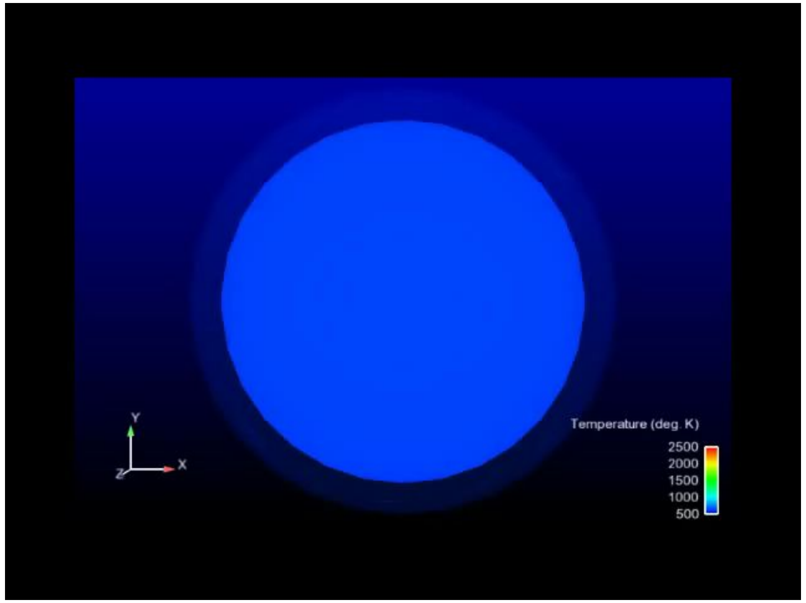
2.0 L

Piston Crown Studies (Combustion Deveopment)

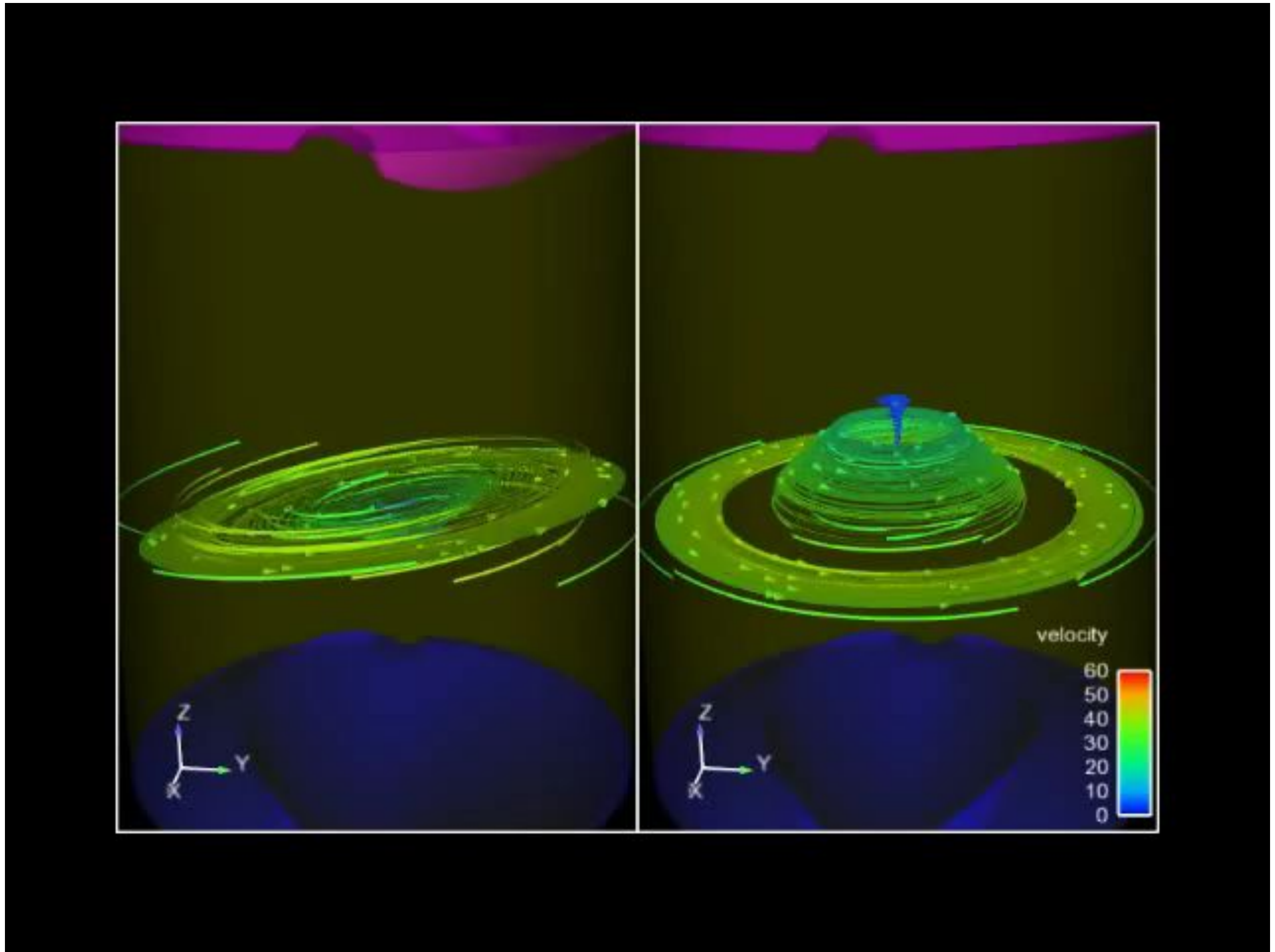
Design A



Design B



Swirl Visualization



Project Example II:
6 Cylinder Diesel Engine Development
Simulation and Analysis of Results

Data Supplied

General

number of cylinders: 6
bore: 116.5 mm
stroke 119.0 mm
connecting rod length: 219.45 mm
geometric compression ratio: 16.79:1
squish height (static piston top to head clearance): 0.787 mm (8.4 cc)
piston bowl volume: 57.13 cc
total dead volume (bowl, squish, valve recess, crevice, nozzle recess etc.): 80.36 cc
average swirl ratio at IVC: 1.6
IVC (crank angle): 572.5 cad after firing tdc
EVO (crank angle) : 124 cad after firing tdc

Injection Nozzle

<u>Nozzle</u> (8x153x490)

- Number of holes: 9, 10 and 11
- Nozzle cone angle: 153 deg
- Hydraulic flow rate (or hole size): 490 cc/30s (exit hole dia after 10% HE: 172 um)
- Radial distance from center of nozzle to nozzle hole exit: 1.68 mm
- Protrusion (axial distance from cylinder head to nozzle hole exit): 1.27 mm

Bowls Investigated

- Three bowl designs are investigated in this analysis:
  1. Shallow bowl.
  2. Wider bowl.
  3. Turbulence bowl.

Initial and Operating Conditions

Simulated operation	Rated power
Bore (mm)	116.5
Stroke (mm)	119
Squish (mm) design/simulation *	0.787 / 2.177
Piston bowl	Shallow, Wider and Turbulence
Geometric compression ratio	16.8
Connecting rod length (mm)	219.45
Swirl ratio (at IVC)	1.6/1.4
rpm	2300
Torque (ft-lbs)	513
Bmep (psi)	166.5
Bhp	225
Fuel mass injected (mg)/cycle/cylinder	0.099
A/F	22.17
EGR %	26.6
P intake ("Hgg)	51.77
T intake(°F)	179.42
P exhaust ("Hgg)	69.62
T exhaust (°F)	1437.8
Sac pressure/injection velocity profile	See ROI slide
Number of injector holes / hole size	(9,10,11) / 0.172 mm
Spray angle (deg.)	153
SOI (deg. ATDC)	0.311
Injection duration (C. A. deg.)	26.48

*: To produce a CR of 16.8 in the model.

Changed and Fixed Parameters

- The calculations assume the same fixed initial SMD for all cases with a spray size distribution as well as fixed spray cone angle, cylinder wall and head temperatures, spray angle, injected mass, SOI , duration, sac pressure profile and, Initial mixture concentrations that correspond to the specified EGR%.

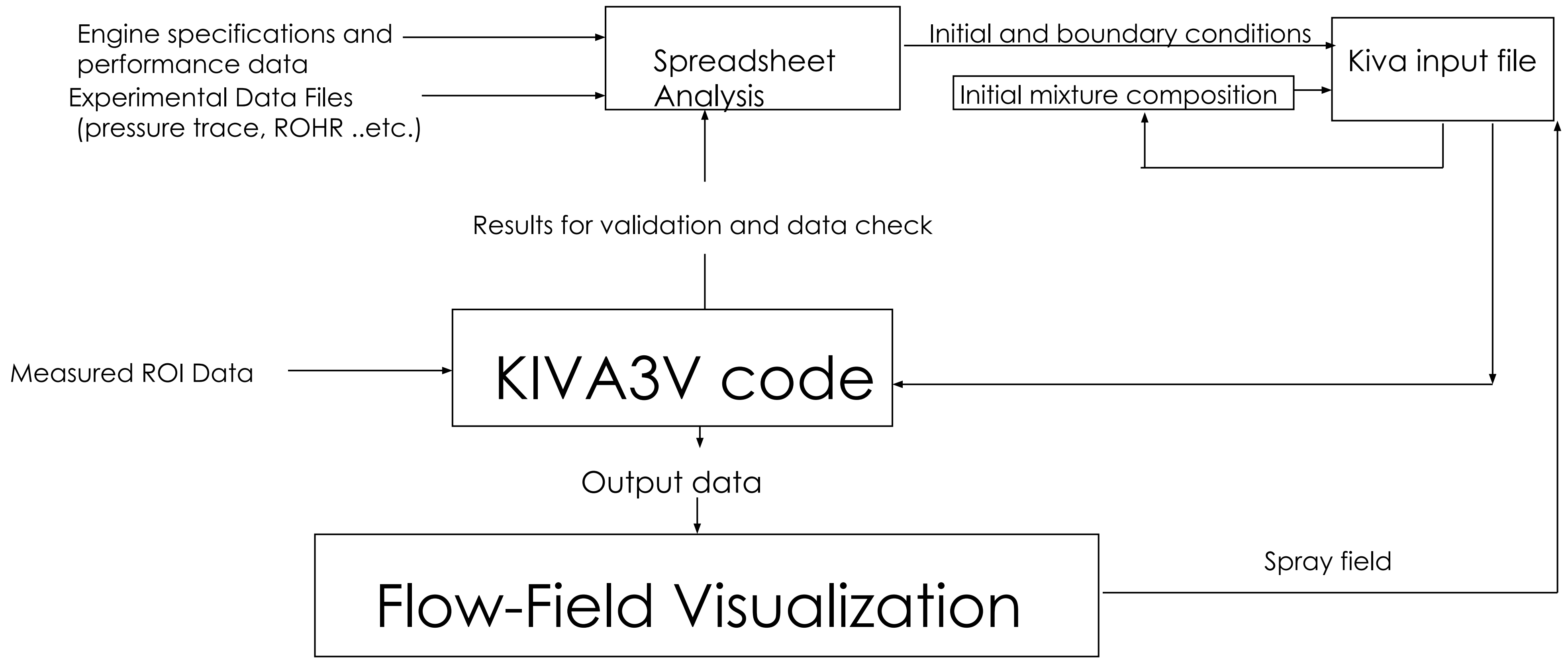
- The only changes between the three cases are the:

(1) Bowl geometry (Shallow, Wider and Turbulence).

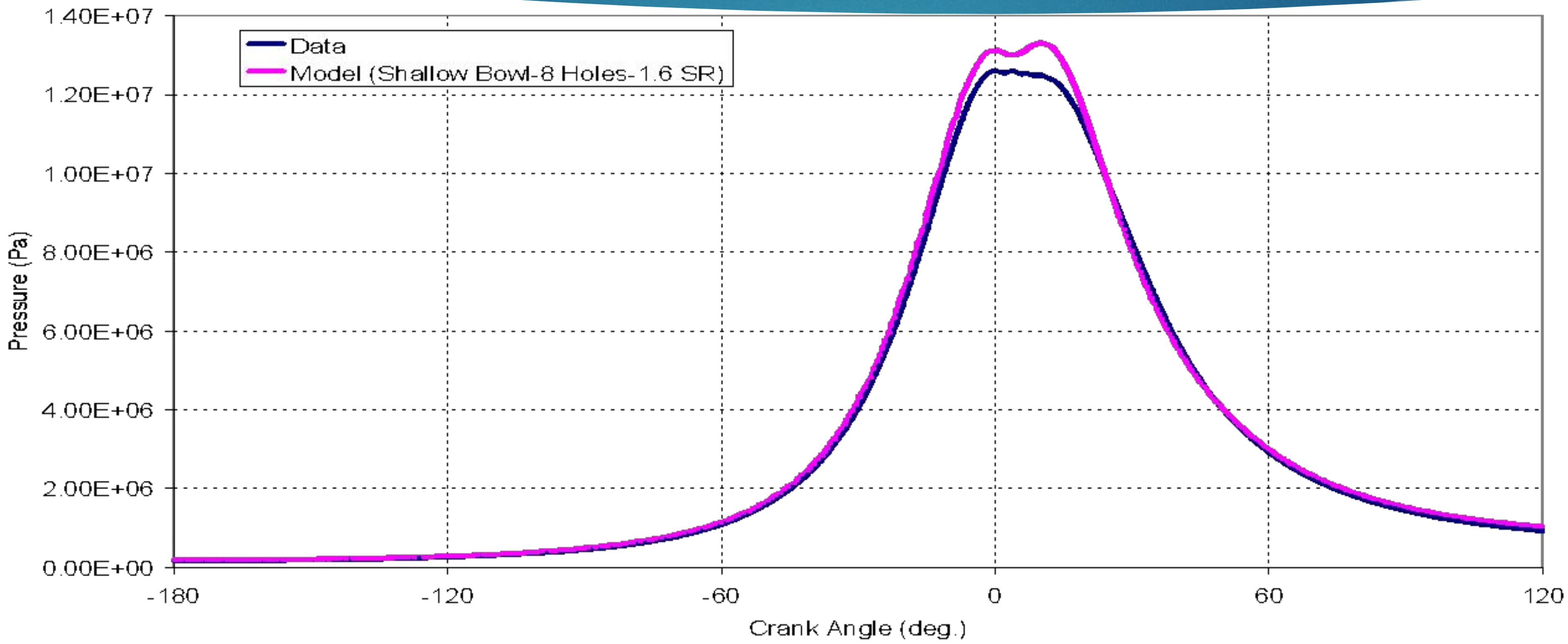
(2) Injector number of holes (9, 10, and, 11)

(3) Specified swirl ratio (0.0, 1.4, 1.6)

Flow Diagram of Simulation Procedure

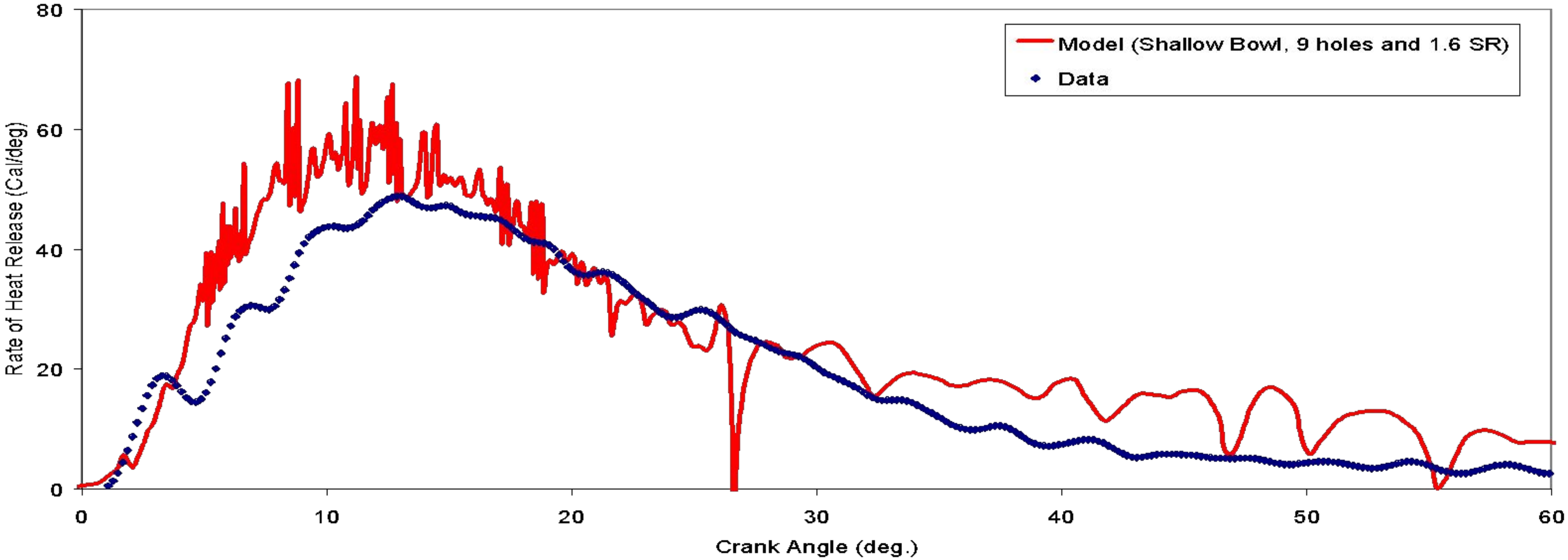


Validation of the Base Case: Pressure Trace

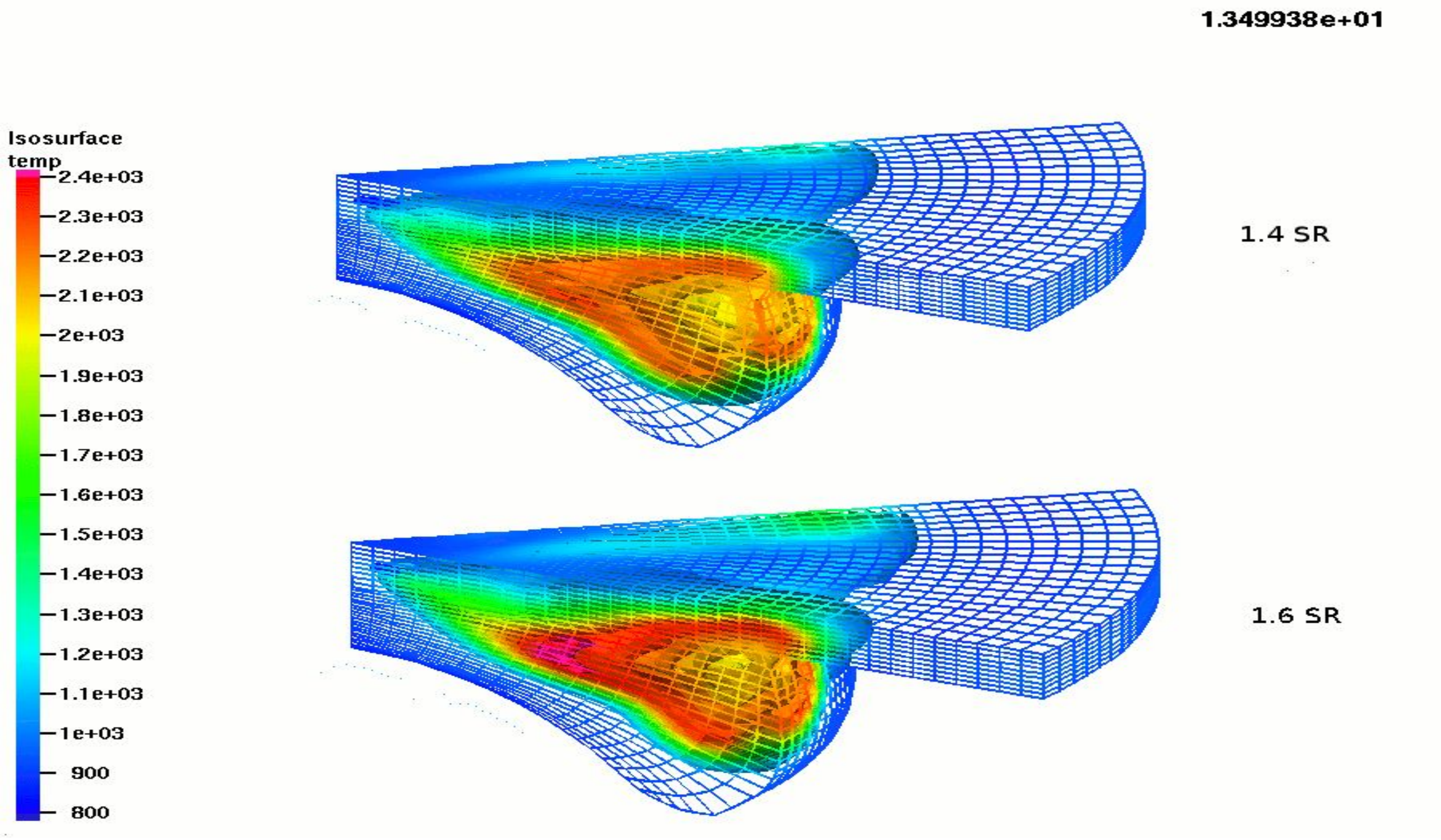


The base case is the shallow bowl with 8 holes at Rated power conditions.

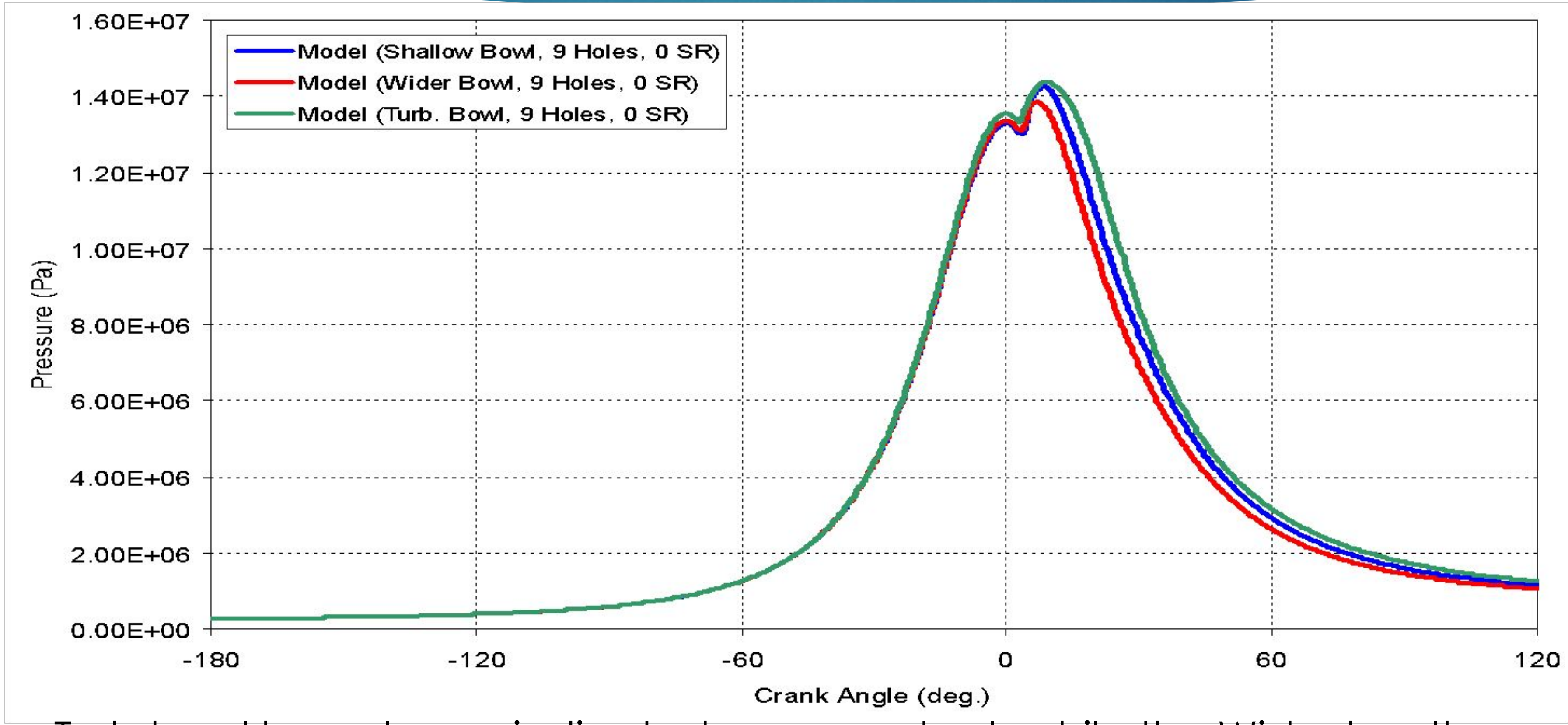
Validation of the Base Case: ROHR



Shallow Bowl, 9 Holes

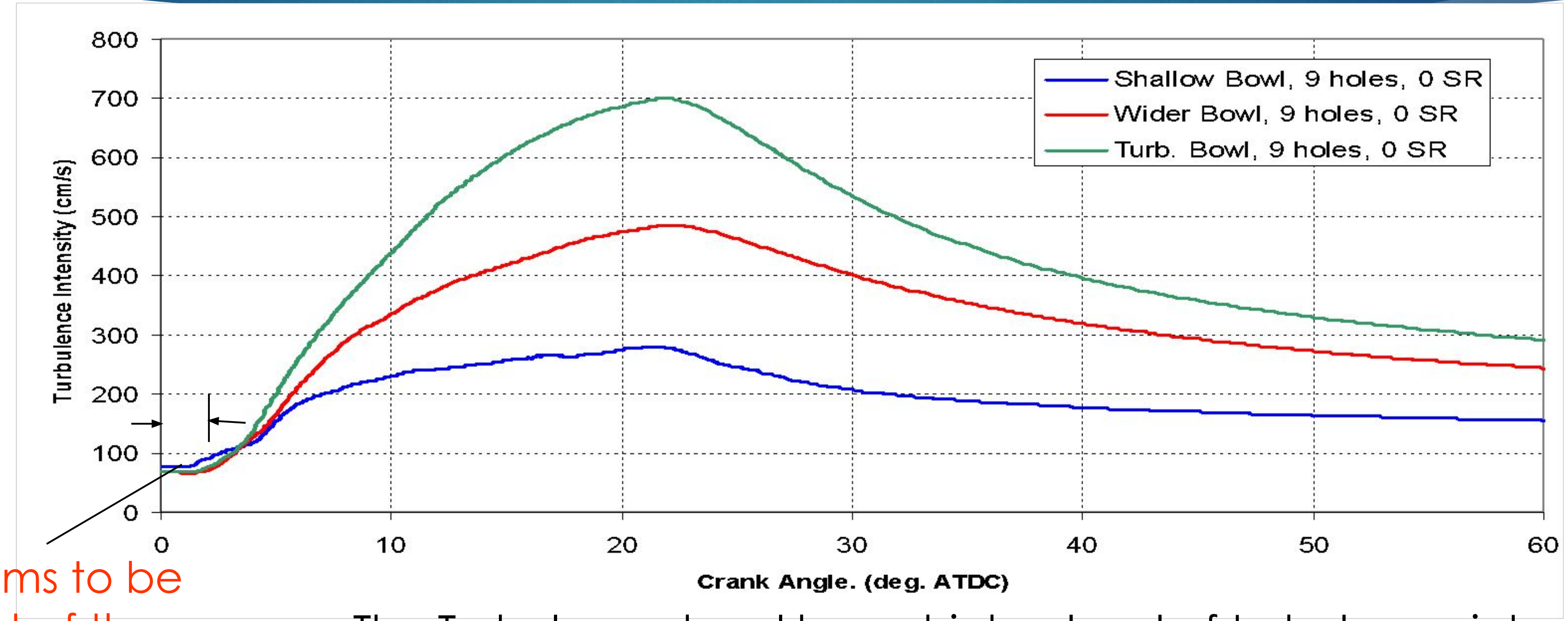


Effect of Bowl Geometry: Pressure



The Turb bowl has a larger indicated power output, while the Wider has the smallest for 9 holes at zero swirl.

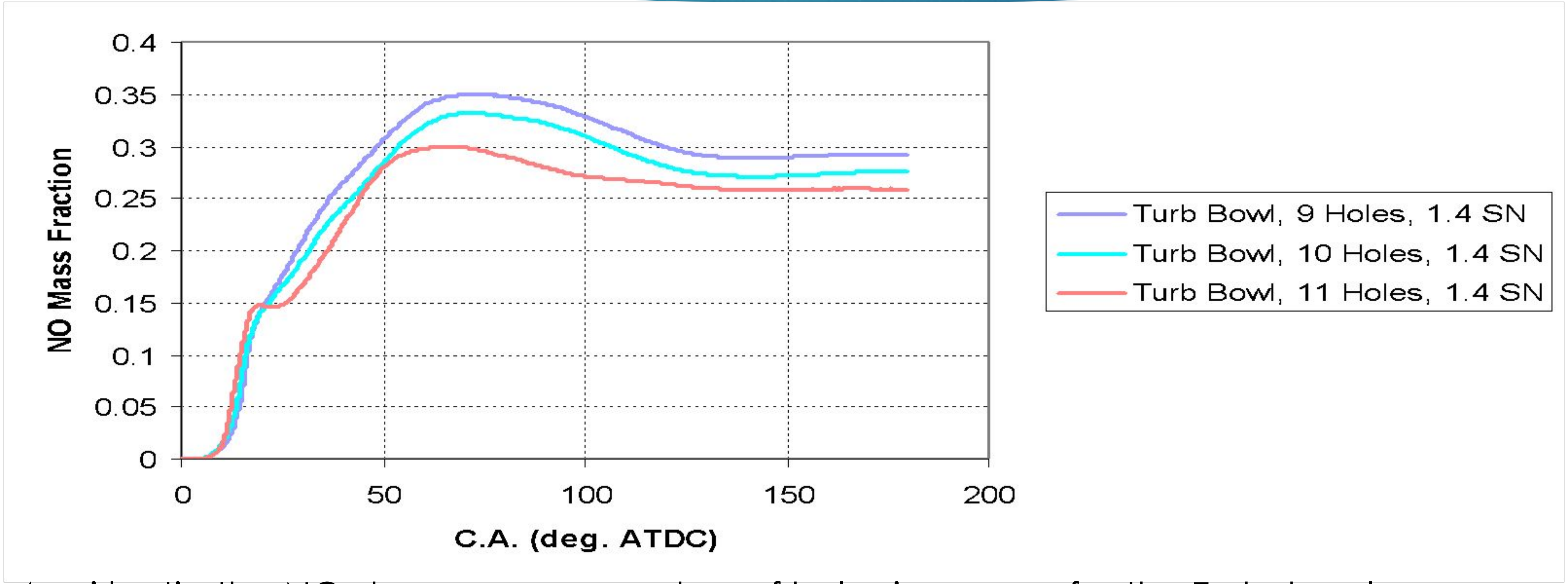
Effect of Bowl Geometry: Turbulence Intensity



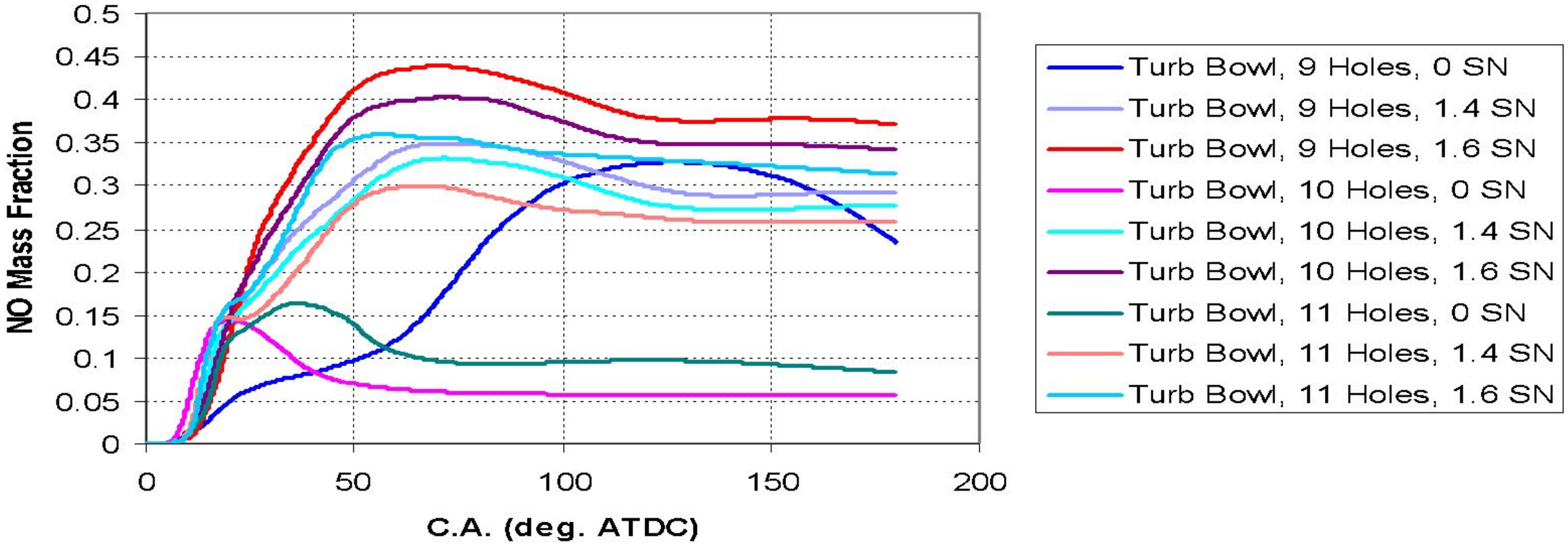
This part seems to be independent of the bowl shape and could be related to the jet-induced turbulence

The Turbulence bowl has a higher level of turbulence intensity compared to the other two bowls. The difference in turbulence intensity is mainly related to the bowl combustion space and is independent of the fuel jet induced turbulence (same number of holes).

Effect of Number of Holes: NO Emission



At 1.4 swirl ratio the NO decreases as number of holes increases for the Turb. bowl.



Increasing swirl for the same number of holes with the Turb. bowl increases NO emission. While, for the same swirl ratio, increasing the number of holes decreases NO emission.

Main Conclusions

- Turb. Bowl produces higher NO emissions at all swirl ratios and number of nozzle holes.
- The trend of EQR depend on the trade-off between mixing and vaporization.
- The Swirl increases turbulence intensity and NO emissions.
- In general, increasing the number of holes decreases NO emissions.
- At high swirl ratios, the NO formation seems to be more sensitive to the swirl number compared to the number of holes.
- To control NO emissions, the swirl ratio should be decreased as the number of holes increases.

Turbulent Gaseous Diffusion Flames

EXAMPLE OF FUNDED RESEARCH WORK

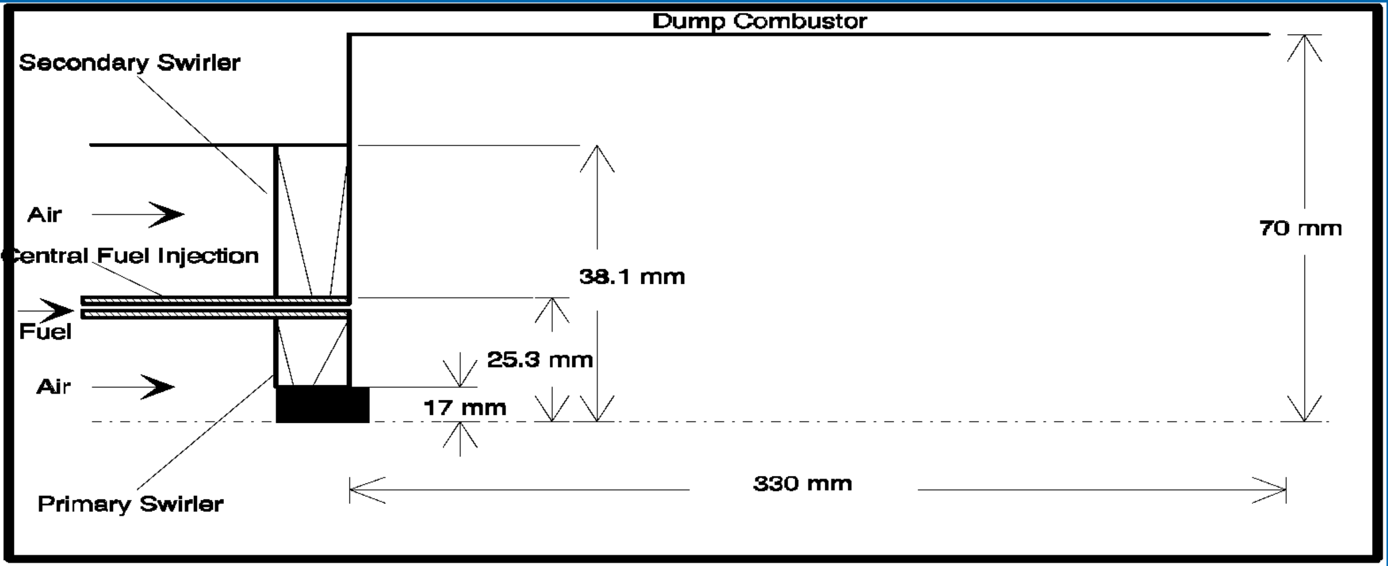
Validation Against Sandia Diffusion Flame Experiments (H2/Argon-Air diffusion flame.1992-1995)

H2/Argon-Air Diffusion Flame

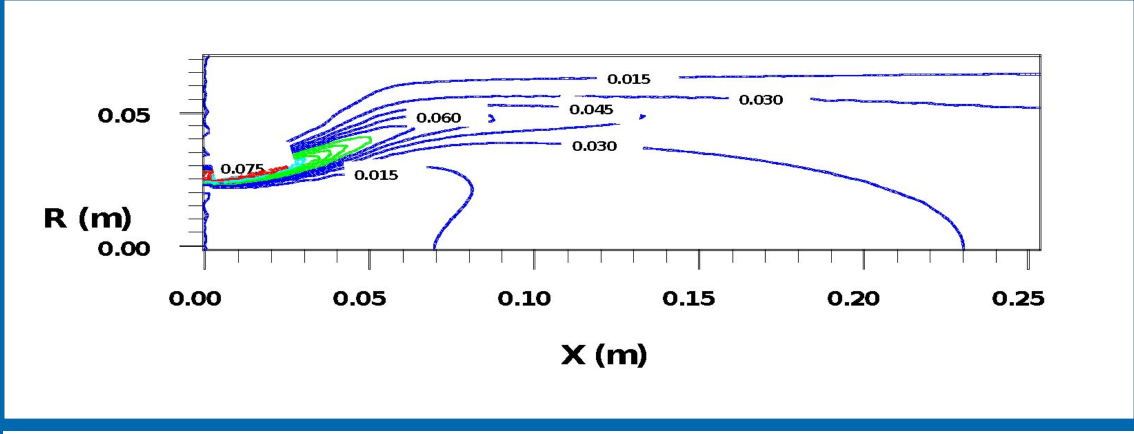
CO/H2/N2-Air Bluff Body Stabilised Diffusion Flame.

Effect of Strain Rate on Temperature (CH4/Air Diffusion Flame)

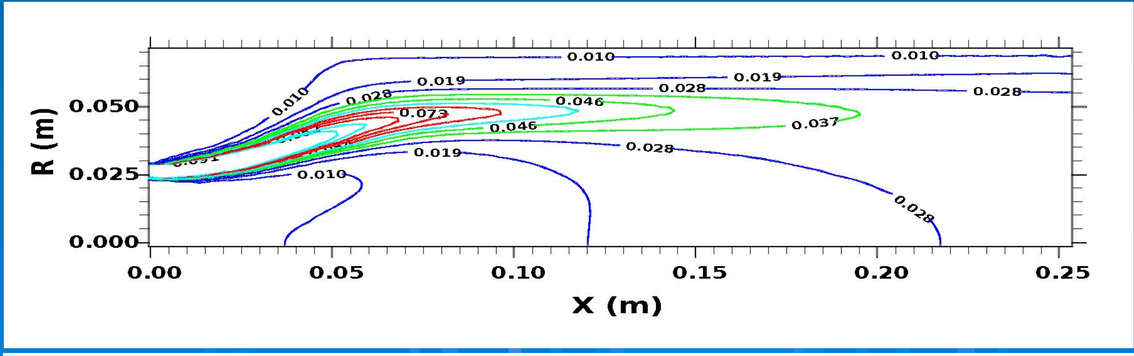
Pressure Effects on NO formation (Dump Combustor)



Andrews, G. E., Amin, E. M., Ahmed N. T., and Kowkabe M. (1991) “Counter Rotating Double Axial Swirlers with Fuel Injection in the Counter Swirler Shear Layer”. Proc. 1991, Japanese Int. Gas Turbine Congress, Yokohama, Vol. 3, pp. 34-45.

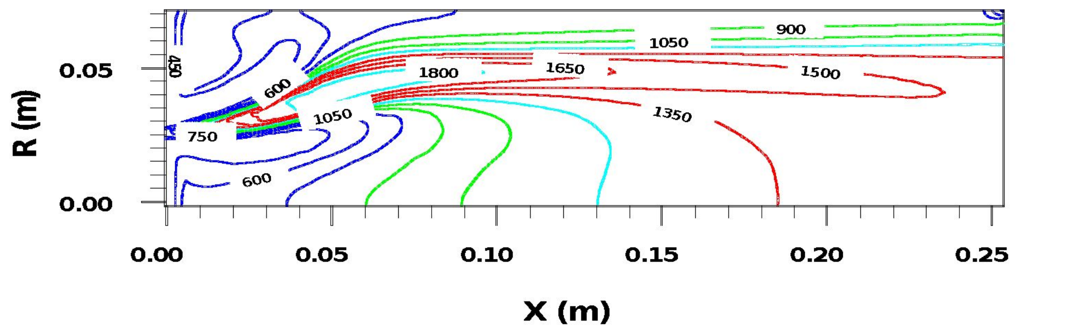


Contours of Favre weighted mixture fraction at 1 bar pressure.

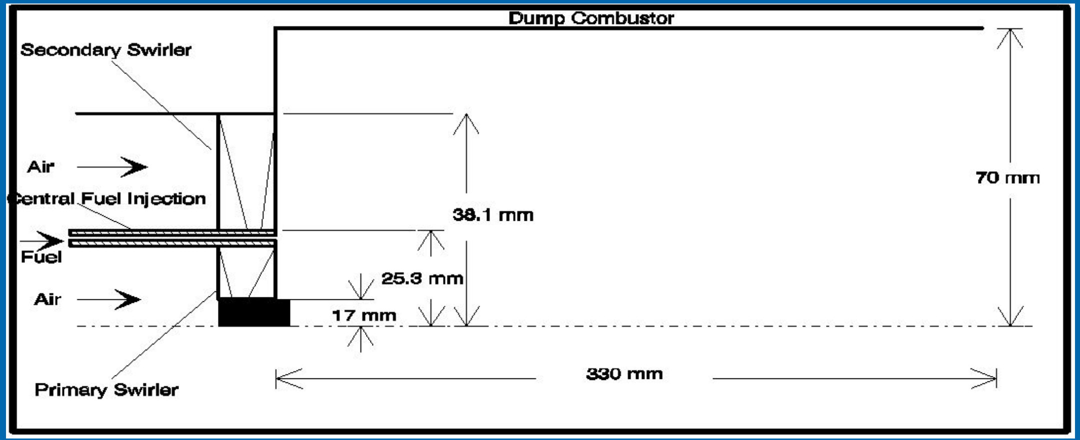


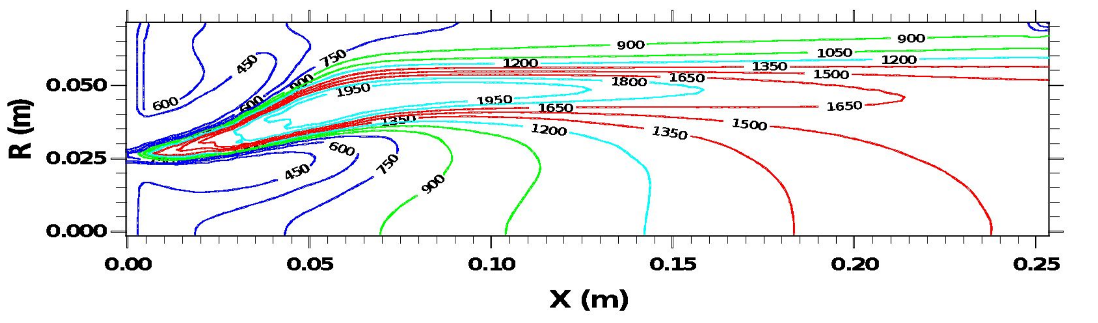
Contours of Favre weighted mixture fraction at 10 bar pressure.

Pressure Effects on Temperature (Dump Combustor)



Contours of Favre weighted temperature in deg. K at 1 bar pressure





Contours of Favre weighted temperature in deg. K at 10 bar pressure.

- Amin, E. M., Andrews, G. E., Pourkashanian, M., Wiliams, A., and Yetter, R. A. (1995) "**A Computational Study of Pressure Effects on Pollutants Generation in Gas Turbine Combustors**", RA JOURNAL OF ENGINEERING FOR GAS TURBINES AND POWER-TRANSACTIONS OF THE ASME 119 (1): 76-83 JAN 1997.

Examples of a Technical input to the Simulation Code Development Process

- Provide suggestions and recommendations from customer point of view o software vendors. (for example: suggested adding random location generator to AKTIM spark ignition model to improve cycle to cycle combustion variability).
- Developed a methodology to predict the auto-ignition phenomena when modeling large compression ration spark ignition engines. The method involves using compression ignition and auto-ignition models till spark timing then switching to the usual spark ignition modeling.
- Modeling of NOx emissions from diesel engines based on detailed chemistry tabulation joined with a simplified form of the PDF integral of lamina reaction rates (published as a technical paper in SAE 2006 conference).

Technical Papers in Conferences and Archived Journals.

SELECTED PUBLICATIONS:

- Amin, E. M., Andrews G. E., Escott N. H., Kim, M. N. and Pourkashanian M. (1994) "**Thermal and Prompt NOx 3D CFD Predictions for an Ultra Low NOx Lean Radial Swirl Gas Turbine Combustion Primary Zone**", ASME IGTI 1994 International Gas Turbine and Aero Engine Congress.
- Amin, E. M., Andrews, G. E., Pourkashanian, M., Richardson, A. P., Williams, A. and Yap, L. (1994) "**Fuel Preheat as NOx Abatement Strategy**", Pacific Rim International Conference on Environmental control of Combustion Processes.
- Amin, E. M., Andrews, G. E., Pourkashanian, M., Wiliams, A., and Yetter, R. A. (1995) "**A Computational Study of Pressure Effects on Pollutants Generation in Gas Turbine Combustors**", RA JOURNAL OF ENGINEERING FOR GAS TURBINES AND POWER-TRANSACTIONS OF THE ASME 119 (1): 76-83 JAN 1997.
- Amin, E. M. and Wen, J. (1996) "**3-D CFD Modelling of Large Scale Offshore Compartment Jet Fires**", CFX International user's conference, UK.
- Amin, E. M., Celik, I. (1999) "**A Computational Study of Strain Rate Effects on Thermal NOx Formation**", Proceedings of 1999 ASME-ICED Spring Technical Conference April 25-28, 1999, Columbus, Indiana.
- Amin, E. M., Celik, I. (1999) "**A Validation Study for a Turbulent Mixing Model Based on the Probability Density Function Approach**" Paper no. 1999-01-0231, SAE International Congress and Exposition Detroit, MI.
- Amin, E. M., Celik, I. (1999) "**Validation of Sub-Grid Scale Finite-Rate Chemistry Models for Turbulent Diffusion Flames**", Proceedings of the 14th AIAA Computational Fluid Dynamics Conference, June 1999, Norfolk, Virginia.
- Amin, E. M., Celik, I. (2000) "**Finite-Rate Chemistry Modelling of Bluff-Body Stabilised Gas Turbine Engine Combustion**", Presented at the spring 2000, ASME-ICED conference, San Antonio, Texas.
- Amin, E. M., Celik, I., and Yavuz, I., (1998) "**Towards LES of A Round Turbulent Free Jet Using Kiva-III Code**", Proceedings of ASME Fluids Engineering Division Summer Meeting. - Paper no. 4970.
- Amin, E. M., Celik, I., Yavuz, I., and Smith, J. (1998) "**Application of A Variable EBU Coefficient For Turbulent Combustion Modeling in A Direct Injection Diesel**", Proceedings of ASME-ICE Spring Technical Conference, April 26-29, Fort Lauderdale, FL.
- Andrews, G. E., Amin, E. M., Ahmed N. T., and Kowkabe M. (1991) "**Counter Rotating Double Axial Swirlers with Fuel Injection in the Counter Swirler Shear Layer**". Proc. 1991, Japanese Int. Gas Turbine Congress, Yokohama, Vol. 3, pp. 34-45.
- Celik, I., Yavuz, I., Smirnov, A., Smith, J. Amin, E. and Gel, A. (2000) "**Prediction of In-Cylinder Turbulence for IC Engines"** Combust, Sci and Tech, Vol. 153, pp.339-368.
- Wen, J. X., Huang, L. Y., Amin, E. M., and Nolan P. (1998) "**Modelling Sooting Jet Fires in a Large Scale Offshore Compartment**", Twenty-Seventh Combustion Symposium (International) Poster Presentation, P033, Univ. of Colorado at Boulder, Aug. 2-7.
- Amin, E. M., Pecheny, V., Gravante, S. and Siow Y. (2006) "**A Computational Procedure for Predicting Nitrogen Oxide Emissions from Diesel Engines**", Paper no. 2006-01-0240, SAE International Congress and Exposition Detroit, MI.

Examples of Successful Projects

- Prediction of Auto-ignition of Natural Gas in SIE Pre-chamber using a hybrid approach between CI and SI models. The predictions trend was in excellent agreement with measurements (Cummins 2014).
- Development of a Colliding fuel injection system to produce homogenous breakup of diesel fuel at high swirl ratios (Achates Power 2010).
- Prediction of Knock and thermal efficiency increase with a CHT analysis using STAR-CD es-ice and STAR CCM+ (Cummins 20015).
- Prediction of fuel post-injection oil dilution effects (Navistar 2008).
- Development of an improved piston crown for Honda racing that increased the output power by 10% and lead to winning INDY 500 race on 2017.


Thank You
for your time


QUESTIONS
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