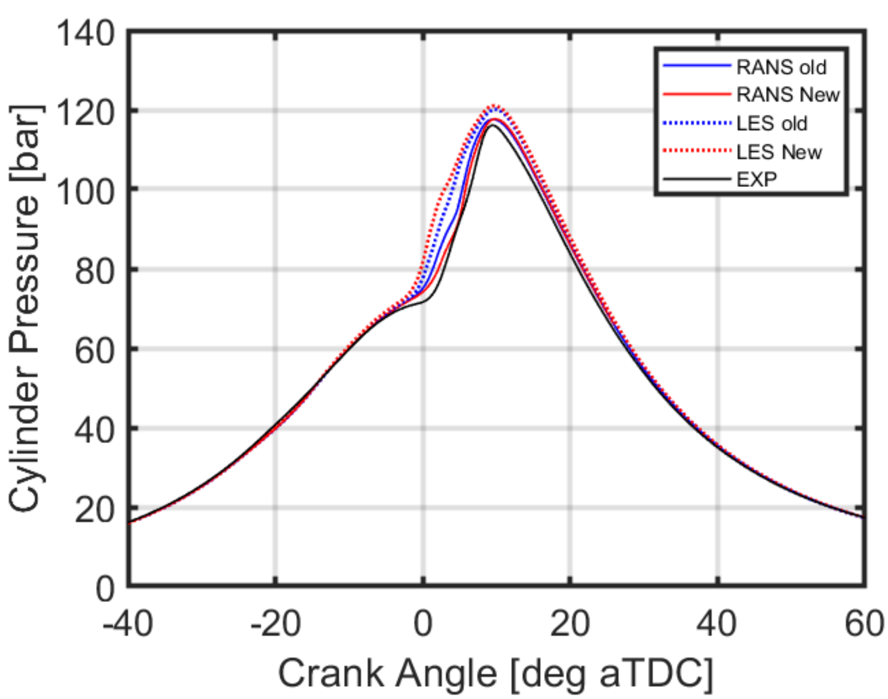
TURBULENCE MODELING OF GASOLINE COMPRESSION IGNITION (GCI) COMBUSTION UNDER MEDIUM LOAD OPERATING CONDITIONS

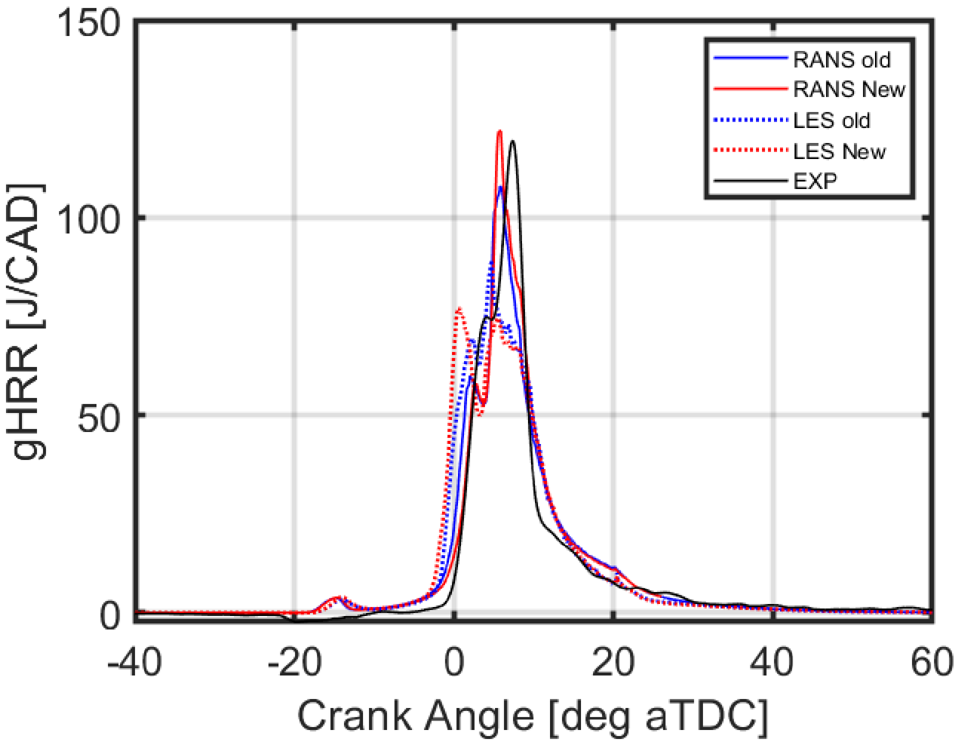
Abstract

GCI is an advanced combustion mode that is efficient and produces low emissions. In this project, different turbulence models, specifically RANS and LES available in CONVERGE, were implemented to observe any differences in results. The model validations for the heat release rate were not perfectly accurate at 10 bar operating load, prompting a turbulence modeling study. In addition, for more accurate prediction of near-wall thermal boundary conditions, the LES Dynamic Structure model was studied with a finer mesh grid size. Overall, the RANS RNG k-ε model showed better agreement with the experimental results. Two different gasoline fuels were used: previously, a PRF blend of 87% isooctane and 13% n-heptane was used, but for the new model, CSI Gasoline v1 available in CONVERGE was used to mimic the overall behavior of the fuel. When comparing, thermal efficiency was calculated to be higher than RANS under the same operating conditions. An intake temperature sweep was also performed to adjust the combustion phasing for RANS. Thus, no significant difference in model validations was found between these models, but RANS agreed better with the experiment than LES. For more accurate results, a detailed analysis of all the models available could be performed in a future study.

Results

Model Validations





The figures above shows the cylinder pressure and gross heat release rate for RANS and LES with the experimental trace (black). The 'old' in index signifies the PRF blend of 87% isooctane and 13% n-heptane, whereas 'new' signifies CSI Gasoline v1 fuel.

RANS (RNG k-ε) with 3mm base grid and LES (Dynamic Structure) with finer grid of 2.5mm was used. All other parameters was kept constant. (Pinj = 670 bar, Inj. duration = 5.7 deg., Ti = 365K, MIT = 2 CAD aTDC, PIT = -25 CAD aTDC). Overall, RANS New model was in good agreement with the HRR profile with (ΔHRR)peak = 2.737 J/CA whereas with old RANS it was 11.517 J/CA.

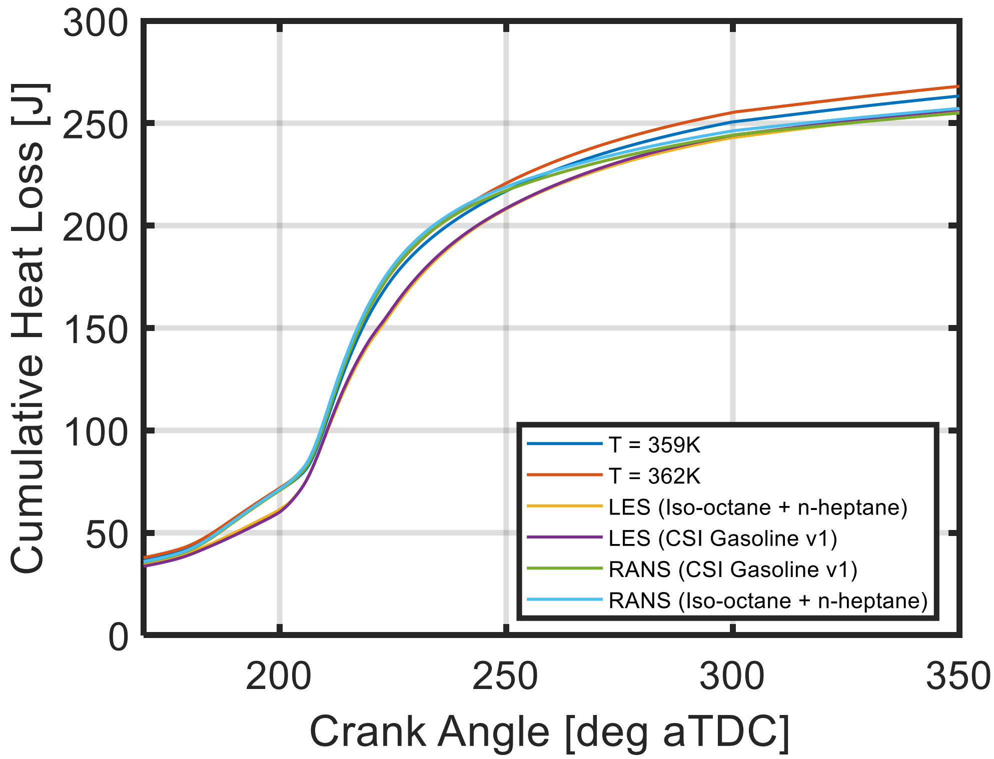
Performance Parameters

Turbulence Models	**RANS**	**LES**	**RANS (New)**	**LES (New)**	**EXP**
Net IMEP [bar]	10.52	10.60	10.52	10.71	9.84
IVC Pressure [bar]	1.8150	1.8151	1.8152	1.8154	1.831
Peak Pressure [bar]	117.665	120.132	117.632	121.014	116.11
MPRR [bar/CAD]	8.0534	6.7887	9.6914	8.1674	10.337
Net fuel efficiency [%]	46.782	47.125	46.767	47.589	43.68
Net thermal efficiency [%]	46.986	47.325	46.983	47.732	44.31
Combustion efficiency [%]	99.56	99.57	99.49	99.70	99.16
CA10 [CAD aTDC]	1.2	0.5	1.9	0.1	3
CA50 [CAD aTDC]	6.8	6.2	7.1	6	7.5
CA90 [CAD aTDC]	18.4	16.2	18.2	16.1	26.5
CA10-90 burn duration [CAD aTDC]	17.2	14.8	16.3	16	23.5

In addition to this, an intake temperature sweep was also performed for adjusting the combustion phasing for RANS.

Intake Temperature	**359K**	**362K**	**365K**	**EXP**
Net IMEP [bar]	10.51	10.49	10.52	9.84
IVC Pressure [bar]	1.8157	1.8151	1.8150	1.831
Peak Pressure [bar]	117.665	118.013	117.72	116.11
MPRR [bar/CAD]	10.992	8.895	8.053	10.337
Net fuel efficiency [%]	46.73	43.63	46.78	43.68
Net thermal efficiency [%]	46.98	47.85	47.66	44.31
Combustion efficiency [%]	99.47	99.54	98.15	99.16
CA10 [CAD aTDC]	2.3	1.8	1.4	3
CA50 [CAD aTDC]	7.3	7	5	7.5
CA90 [CAD aTDC]	18.3	18.3	14.7	26.5
CA10-90 burn duration [CAD aTDC]	17.2	14.8	13.3	23.5

From the results, thermal efficiency was higher for CFD for all the cases compared to the experiment. Combustion efficiency somewhat closer to EXP but decreases for Ti = 365K. Heat Loss was almost similar for all the turbulence models about 258 J, but with Ti = 362K, it was higher of 270.33 J. Figure below shows cumulative heat loss through combustion chamber for all the models.


Cumulative Heat Loss [J]
300
250
200
150
100
50
0
200
250
300
350
Crank Angle [deg aTDC]
T = 359K
T = 362K
LES (Iso-octane + n-heptane)
LES (CSI Gasoline v1)
RANS (CSI Gasoline v1)
RANS (Iso-octane + n-heptane)

*****