Application of KULI for Study of Cooling System in Heavy Duty Truck

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Background

❑ Emission Control Plan in Korea

- EURO III in 2004
- EURO IV in 2006
- EURO V in 2008

⇨ Modified Engine Configuration Requires Enhanced Cooling Performance

- Higher Heat Rejection By Coolant: 9.3% Increase
- Higher Pressure and Temperature for CAC Inlet: Pr. 13.2%, Temp. 35.3% Increase

⇨ Improve Cooling Package Capabilities

Model Set-Up

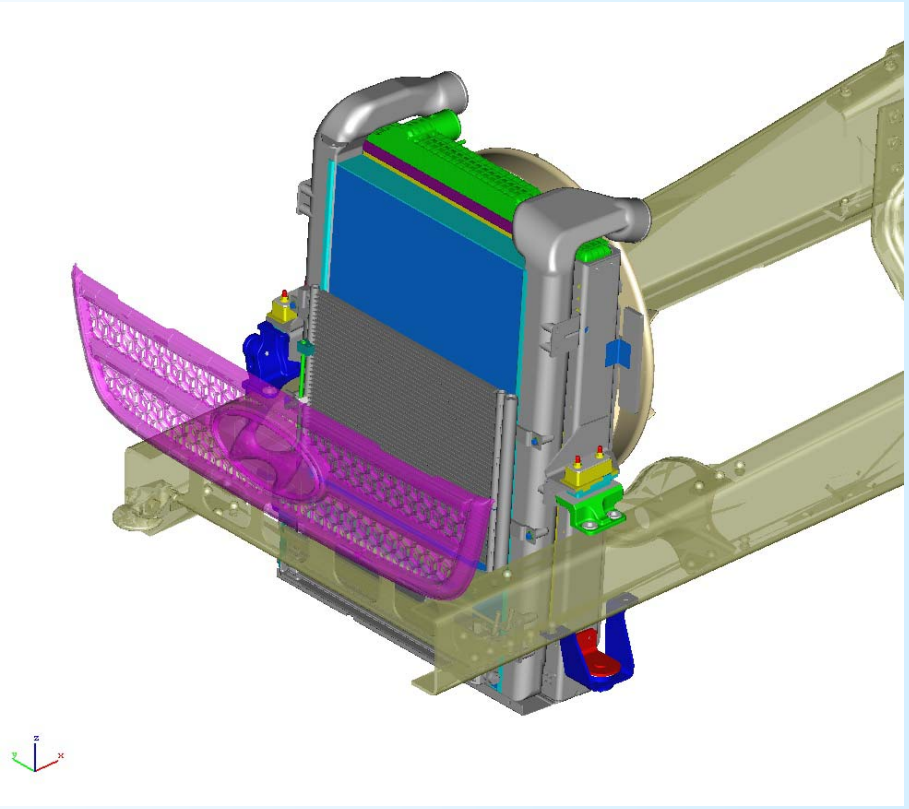
❑ Engine Specifications

	Cooling Circuit			Charge Air Circuit		
	Mass Flow (kg/s)	Inlet Pr. (hPa)	Heat Rejection (kw)	Mass Flow (kg/s)	Inlet Pr. (hPa)	Inlet Temp. (℃)
Old Engine	7.91	2030	128.2	0.48	2680	157.4
04 EM Engine	7.49	2030	140.1	0.527	3033	213.0
+/-(%)	+ 5.3	0	+ 9.3	+ 9.8	+ 13.2	+ 35.3

- Data for 04 EM Engine are estimated values

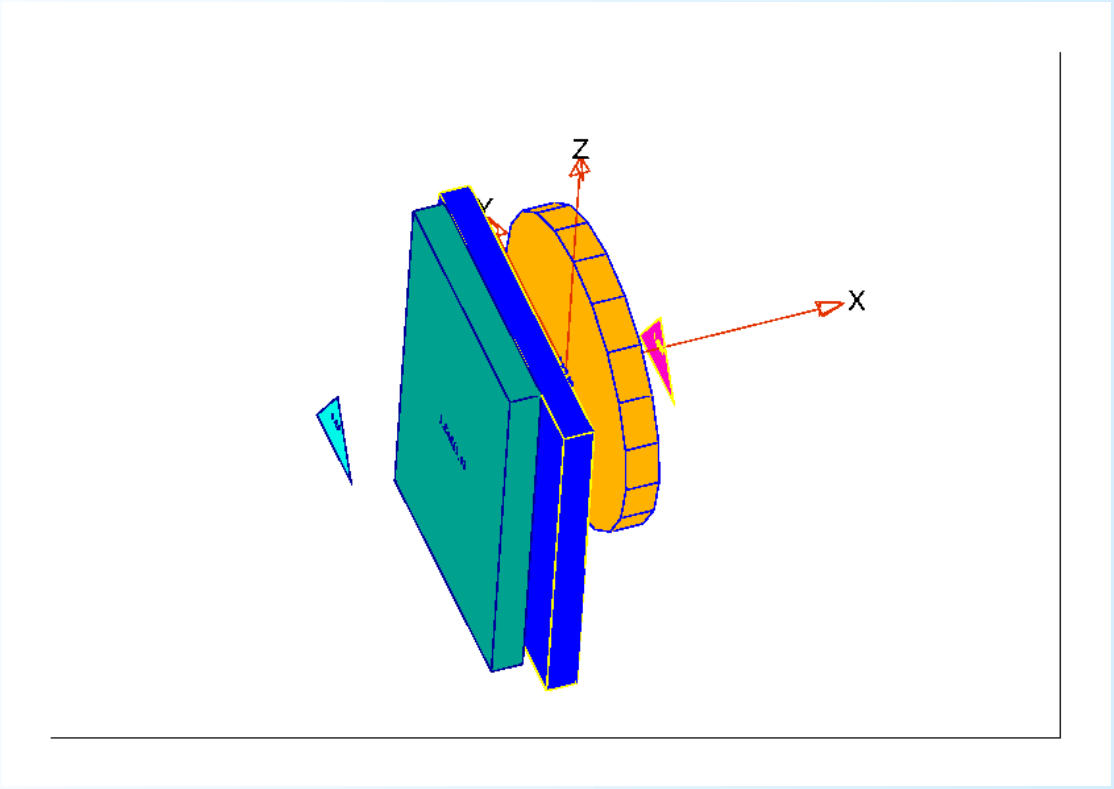
Model Set-Up

- Cooling Package Schematic



Model Set-Up

- Air Side Lay-out In KULI



Model Set-Up

❑ Major Characteristics of Model

- Cp = 0.9
- Radiator: Fin Tube type, -z direction
- CAC: Fin Tube type, -y direction
- BIR: Determined by correlation with Test data
- Fan: Eaton, Ring type, Transmission ratio,
  Viscous Clutch Locked

- Driving Speed: 22 Km/h, 1800 RPM
- Air Conditioner is off
- Warm-up Temp.: 2℃

Model Set-Up

❑ Model Correlation

- Determine Built-In-Resistance value to match ACT and IMTD values from the KULI Model to Test data, with an old engine

➡ $\triangle P\ (Pa) = K\ Q^2\ (m^3/s)$; K = 90

	Radiator			Charge Air Cooler		
	T_{in} (℃)	T_{out}	ACT	T_{in}	T_{out}	IMTD
Test	91	86	39	163	50	25
Model	91.09	86.16	38.95	163.00	50.41	25.41

※ ACT: Air Clearance Temp = 105 – (Rad. Inlet Temp – Amb Temp.)
IMTD: Intake Manifold Temp. Difference = CAC Outlet Temp – Amb Temp

Analysis I

Cu Radiator

- Target for ACT & IMTD
  - ACT: 43℃ ↑
  - IMTD: 21℃ ↓

- 04EM Engine + Current Cooling Package

		Margin
ACT	42.17 ℃	-0.83
IMTD	25.01 ℃	-4.01
Cooling Air	3.093 kg/s	

⇨ Need to improve Cooling Performance of Radiator and CAC!!

Analysis I

❑ Fan Drive Ratio Increase

1.14 → 1.33

		Margin
ACT	51.68 ℃	+ 9.68
IMTD	21.85 ℃	-0.85
Cooling Air	3.705 kg/s	

➡ Target almost satisfied!
But IMTD need to be improved!

Analysis I

❑ Radiator & CAC Size Increase

Approx. 10 % increase in Height

	Size (W×H×D, mm)	Core Type	Material
Rad.	729.5×897×66	Louver Fin (F.P = 2.8)	Cu
CAC	566×955×68	Wave Fin (F.P = 3.8)	Al

		Margin
ACT	41.59 ℃	-1.41
IMTD	16.23 ℃	+4.77
Cooling Air	3.049 kg/s	

⇨ ACT should be improved!

Analysis I

- Radiator & CAC Size Increase

  Approx. 10 % increase in Height

- Rad. Fin Pitch Increase 2.80 → 3.68 mm

		Margin
ACT	42.29 ℃	-0.71
IMTD	15.92 ℃	+ 5.08
Cooling Air	3.142 kg/s	

⇨ ACT slightly improved, but still need to be improved!

Analysis I

- What we found out from Analysis I

  ⇨ Increasing sizes of the heat exchangers only helps improve IMTD, but not much for ACT.

  To improve ACT, better increase cooling air flow.

- Radiator material change proposed

  ⇨ Due to weight saving and manufacturing issue in radiator supplier, Copper rad. is required to switch to Aluminum one.

Analysis II

Al Radiator

- Various Al Radiators Applied; Cu → Al

  - Rad. Specs.

Case No.	Radiator Size (W× H× D, mm)	Core Type	Material
1	718.2 × 894 × 48	Wave Fin (F.P = 4.0)	Al
2	718.2 × 894 × 60	Wave Fin (F.P = 4.0)	Al
3	718.2 × 894 × 48	Louver Fin (F.P = 4.0)	Al
4	718.2 × 894 × 60	Louver Fin (F.P = 4.0)	Al

Analysis II

- Various AL Radiators Applied; Cu → Al

  - Results

Case No.	ACT (℃)	IMTD (℃)	Air Flow (kg/s)
1	6.23 (-36.77)	17.50 (+3.5)	3.329
2	25.22 (-17.18)	17.63 (+3.37)	3.296
3	2.96 (-40.04)	17.46 (+3.54)	3.336
4	41.60 (-1.4)	18.36 (+2.64)	3.139

Analysis II

❑ Recommended Arrangement

Al Rad. Case 4 + Fan Drive Ratio 1.2

		Margin
ACT	44.89 ℃	+ 1.89
IMTD	17.38 ℃	+ 3.62
Cooling Air	3.357 kg/s	

⇨ Can meet the requirements !!

Conclusion

- The combination of
  AL Rad. (718.2×894×60, Louver Fin, F.P = 4.0),
  AL CAC (566×955×68, Wave Fin, F.P = 3.8), and
  Increased Fan Ratio 1.2 are recommended
  for the cooling package of a new engine.

- The characteristic data of the components are very crucial to accurate prediction of the cooling performance in KULI model.

- The results of KULI calculation should/will be compared with the test data to justify the use of BIR and air side simulation.