KTH ROYAL INSTITUTE OF TECHNOLOGY

Beichuan’s presentation

Beichuan Hong

Ph.D. student at CCGEx & Department of Engineering Design

Supervisors: Andreas Cronhjort, Mihai Mihaescu

Education and work experience

- **KTH Royal Institute of Technology** *2018.11 – Present*

  Ph.D. Student in CCGEx & Engineering Design Department

  (Defense time scheduled on Nov. 26th, 2023)

  Research Topic: *Exergy Analysis on Propulsion System Applications*

  Major Work Content: Engine and propulsion system modelling, Exergy losses analysis

- **KTH Royal Institute of Technology** *2016.02 – 2018.05*

  Research Engineer in Transport Department

  Project Topic: Sustainable Construction Operations for Reduced Emissions

  Major Work Content: Vehicle path optimization, Construction operations simulation, Emission model

- **Cummins East Asian Research & Development Center** *2014.06 – 2015.12*

  Development Engineer in Advanced Engine & Technology Department

  Major Work Content: Engine simulation & calibration, Pneumatic boost system, Driving cycle analysis

- **Wuhan University of Technology** *2008.09 – 2014.06*

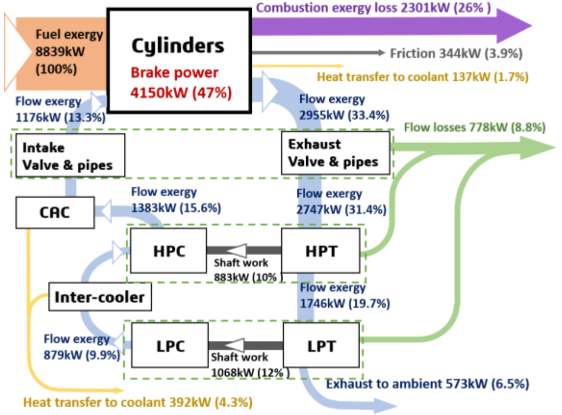
  Master in Marine and Power Machinery Engineering

  Bachelor in Energy Power System and Automation

Beichuan Hong

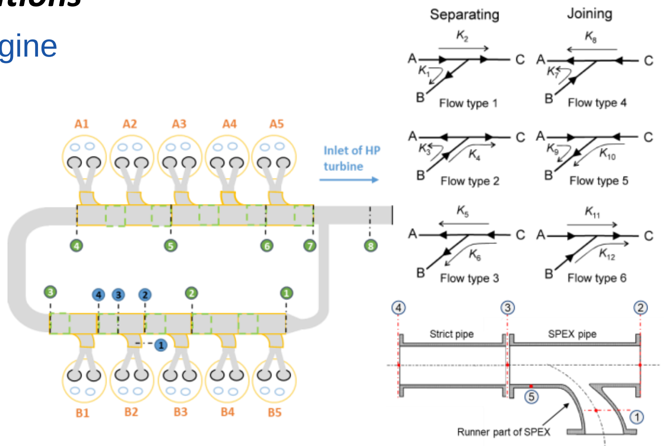
Research Topic: *Exergy Analysis on Propulsion System Applications*

- Energy and exergy losses identification in a dual-fueled marine engine



Sankey diagram of engine exergy flow in gas mode at 75% load

Wärtsilä 31V10DF marine engine (Full load: 5500 kW)

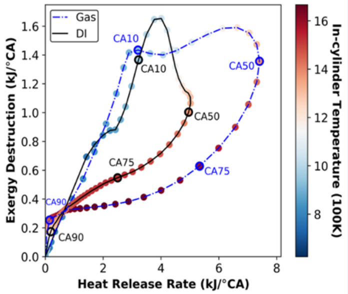


Pressure measurement in exhaust manifold for GT-model calibration

Fraction of different irreversibilities to fuel exergy

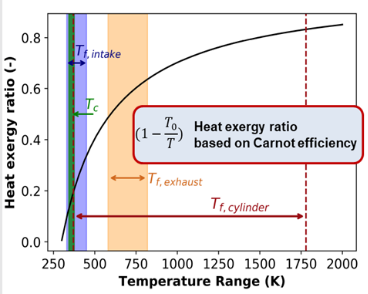
% of fuel exergy		Engine Loads 25%	50%	75%	100%
Combustion exergy loss	Gas mode	27.5	26.5	26	25.3
	DI mode	29.8	28.3	27.8	26.7
Losses in gas-exchange	Gas mode	7.1	7.9	8.8	9.3
	DI mode	7.8	8.1	8.9	9.2
Heat dissipation	Gas mode	4.4	3.6	3.7	3.7
	DI mode	3.8	3.3	3.5	3.5
Mechanical friction	Gas mode	8.3	5.1	3.9	3.3
	DI mode	7.2	4.7	3.6	2.9
Total irreversibility	Gas mode	47.4	43.1	42.4	41.5
	DI mode	48.6	44.4	43.8	42.3
Magnitude of total irreversibility (Unit: kW)	Gas mode	1594	2615	3751	4802
	DI mode	1775	2908	4202	5282

Combustion losses



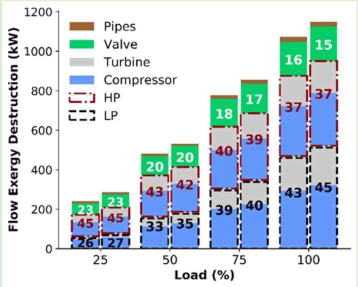
Combustion losses caused by different modes: Gas mode (dash), Diesel mode (solid)

Heat transfer losses



Heat exergy loss ratio within temperature ranges of engine flow and coolant

Gas-exchange losses



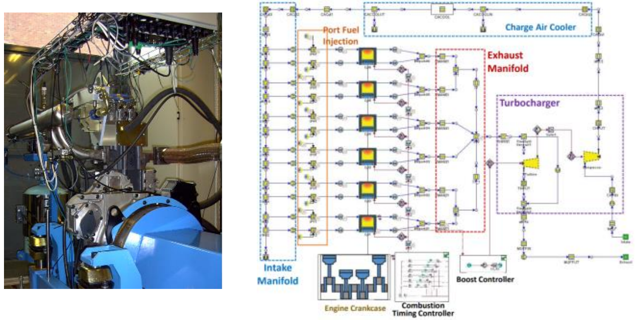
Flow exergy destruction (other than heat transfer) in gas exchange system.
Numbers on bar are fractions of segments.
Left-side: Gas mode, Right-side: Diesel mode

*Exergy refers to the maximum part of energy that can be obtained from a system.

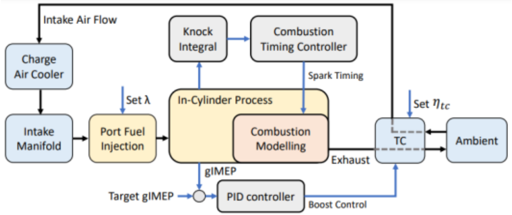
Research Topic: ***Exergy Analysis on Propulsion System Applications***

- Combustion assessment of a lean-burn ethanol-fueled HD SI engine

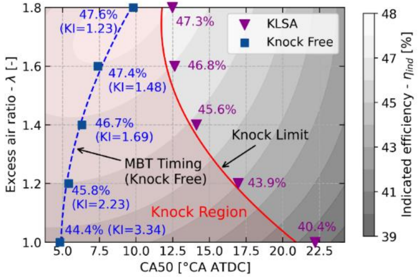
Purpose: to analyze the lean-burn combustion efficiency and losses in a HD SI ethanol-fueled engine



Tested Scania D12 research engine and GT-Power model

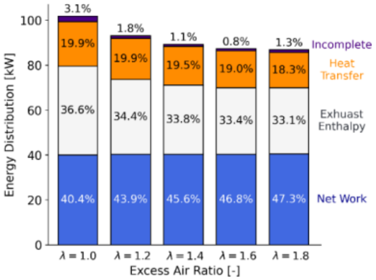


Control logic for lean burn application

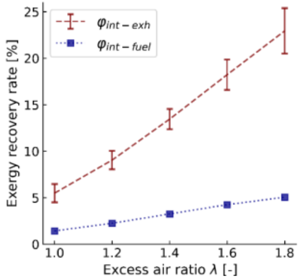


Efficiency comparison of KLSA and knock-free MBT across excess air ratios up to λ = 1.8

- Combustion assessment of lean-burn at 20 bar IMEP
- Experimentally calibrated two-zone predictive combustion model
- Lean-burn combustion at KLSA with excess air ratios up to 1.8
- Exhaust exergy recovery through turbocharging at lean burn



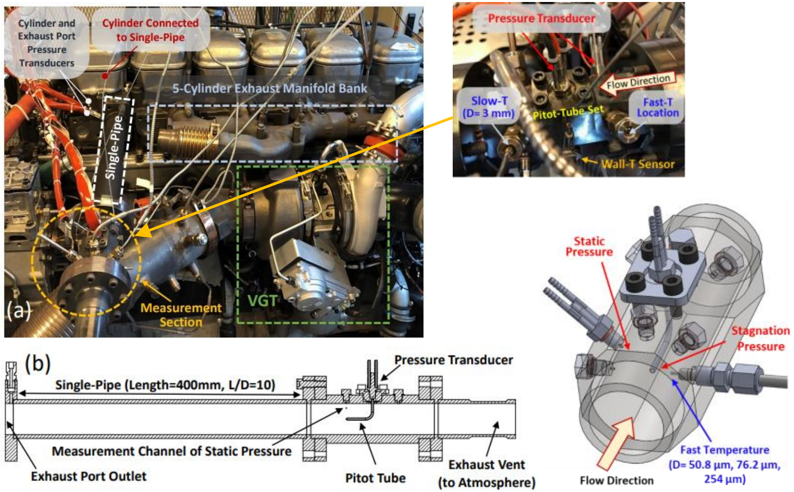
Energy distribution per cylinder at KLSA timing across the dilution range



Exergy recovery rate across the dilution range. The error bar of $\varphi_{int-exh}$ represents the variation caused by sweeping η_{tc} from 0.5 to 0.7.

Research Topic: *Exergy Analysis on Propulsion System Applications*

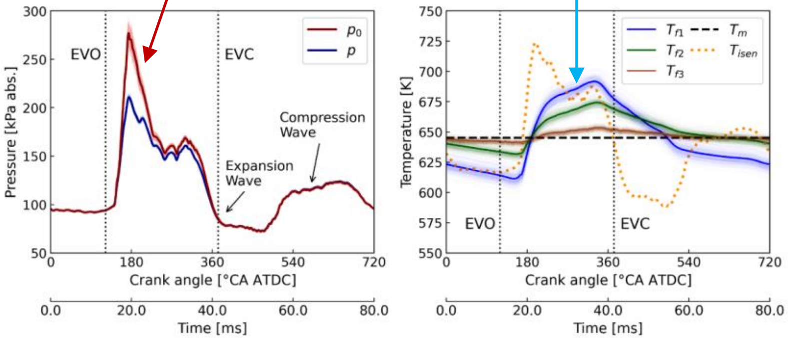
❑ Engine exhaust pulses measurement and analysis (Scania D13 at KTH engine lab)



Schematic of experimental setup and the single-pipe measurement system

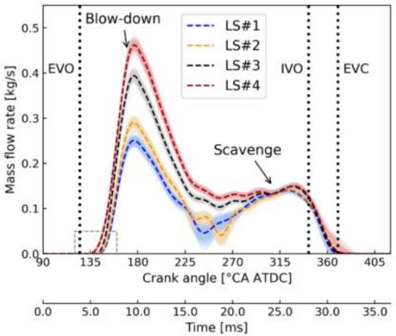
The dynamic pressure between total and static pressures indicates the exhaust flow.

Due to increased thermal inertia, the attenuation of the thermocouples' response became more obvious as the wire diameters increased.



T_{f1} 50.8 µm
T_{f2} 76.2 µm
T_{f3} 254 µm
T_m 3 mm

Pressure and temperature of the engine exhaust pulsation at 1500rpm / 12 bar nIMEP

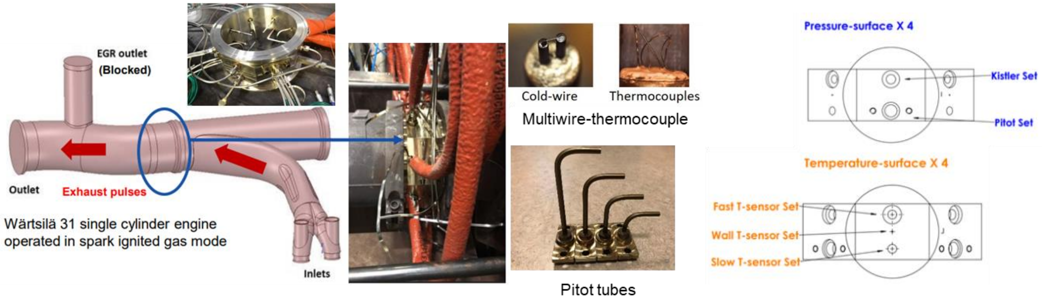


Mass flow rates over the pulse duration. The dashed line is the cycle-averaged mass flow rate of 300 cycles, while the shaded area represents the variation in mass flow pulses over cycles.

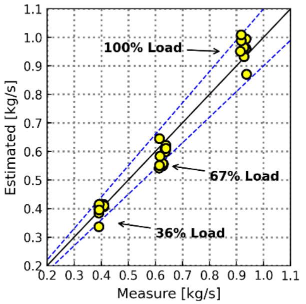
- ❑ Pitot tube for measuring time-resolved engine exhaust flows
- ❑ A single-pipe system for on-engine pulsating flow measurement
- ❑ Pulse characteristics in blow-down and scavenge phases

Research Topic: *Exergy Analysis on Propulsion System Applications*

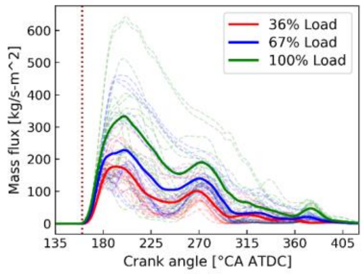
❑ Engine exhaust pulses measurement and analysis (Wärtsilä single-cylinder marine engine)



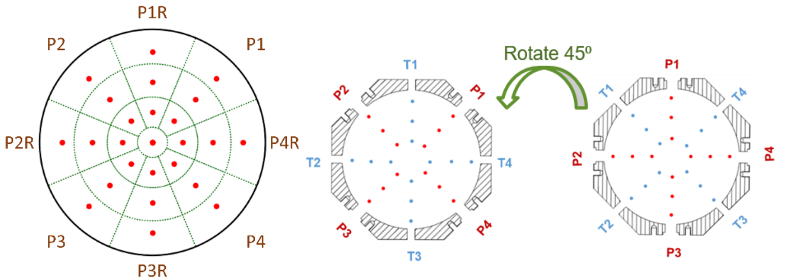
Experimental setup and the single-pipe measurement system



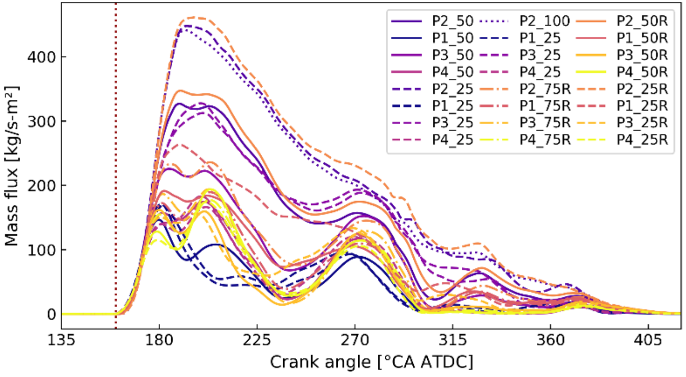
Trap mass comparison across the test matrix



Mass flux rates across the load sweep



Spatial measurement with different P,T sensors traversal lengths



Mass flux derived from the Pitot tube measurements

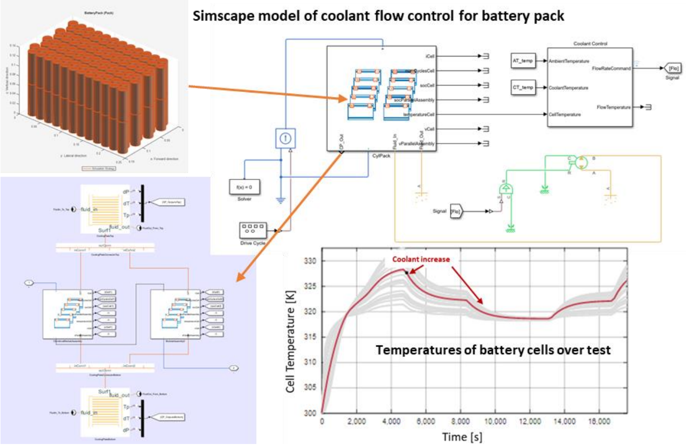
- ❑ Pitot tube and thin-wire thermocouples for capturing time-resolved exhaust flows
- ❑ Exhaust flow field characteristics related to loads, backpressures, exhaust valve timings and profiles
- ❑ A single-pipe system to temporally and spatially measure on-engine pulsating flow

KTH Royal Institute of Technology *(2021.09 – 2023.11)*

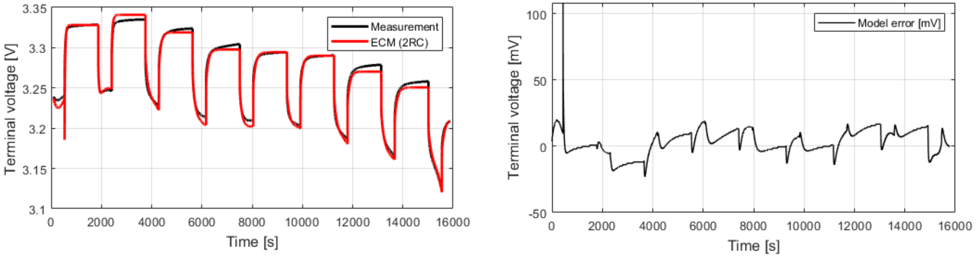
Ph.D. student in Mechatronics Unit

Project Topic: Hybrid Powertrain System Modeling and Control

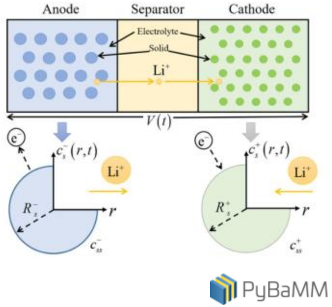
- Electric powertrains modeling and optimization
- Model-based dynamics and control for a motor system
- Model Building and Parameters Estimation for Li-ion Battery

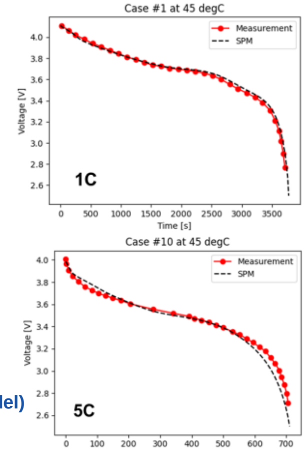


Optimizing coolant flows under various driving conditions



Battery Characterization using Equivalent Circuit Model (ECM)





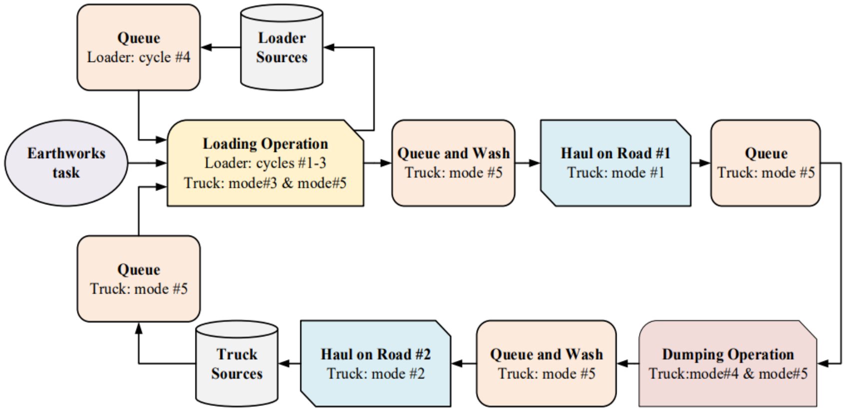
Battery Single Particle Model
(simplified Doyle–Fuller–Newman model)

KTH Royal Institute of Technology (*2016.02 – 2018.05)*

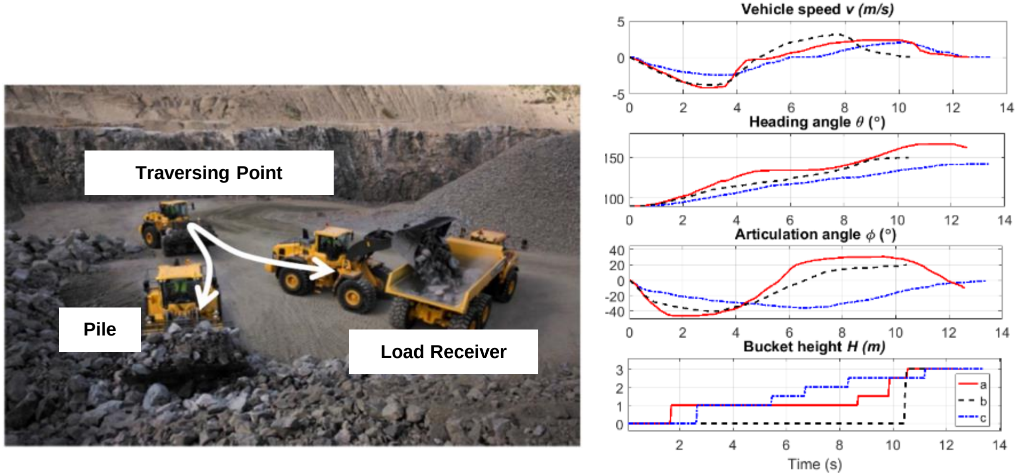
Research engineer in Transport Department (Funded by Volvo CE)

Project Topic: Sustainable Construction Operations for Reduced Emissions

- Emission model of HDVs according to real-world measurement
- Discrete-event simulation platform for evaluating construction project
- Optimal construction operations of an autonomous wheel loader



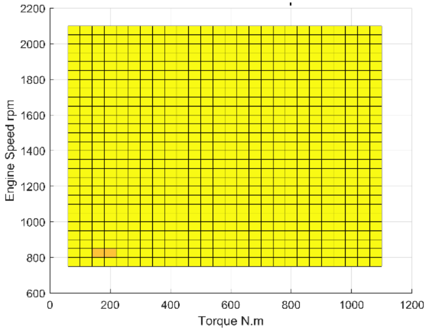
Discrete-event simulation platform for evaluating construction project



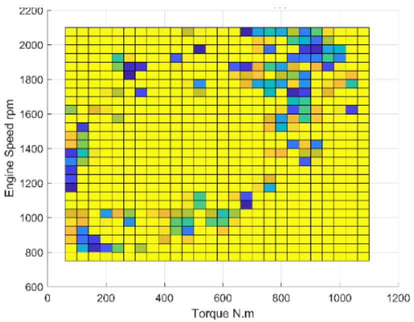
Optimal control strategy of an autonomous wheel loader

KTH Royal Institute of Technology (*2016.02 – 2018.05*)

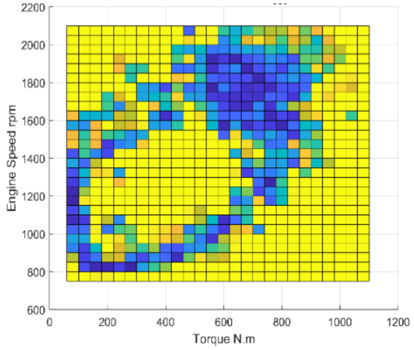
Research engineer in Transport Department (Funded by Volvo CE)



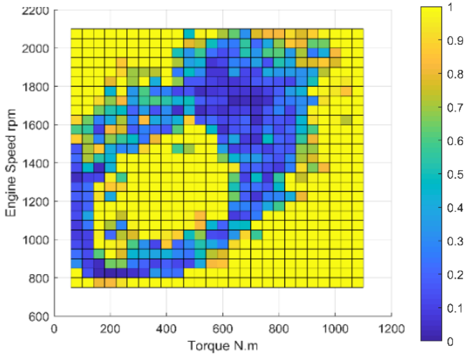
1st iteration



40th iteration



130th iteration



1260th iteration

Covariance matrix update after iteration

Prediction step

$$\hat{x}_{k|k-1} = F_k \cdot \hat{x}_{k-1|k-1} + B_k \cdot u_{k-1} + \omega_k$$

$$P_{k|k-1} = F_k \cdot P_{k-1|k-1} \cdot F_k^T + Q_k$$

Update step

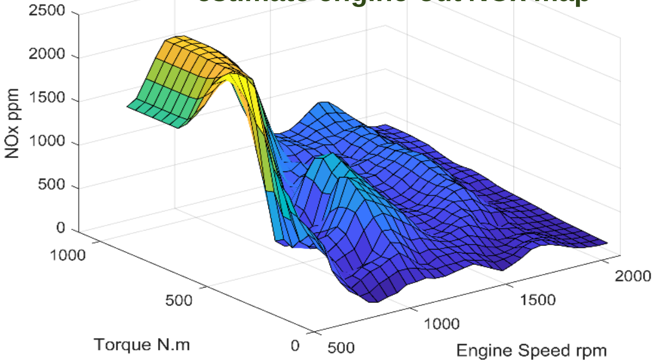
$$\tilde{z}_k = H_k \cdot \hat{x}_{k|k-1} + v_k$$

$$K_k = \frac{P_{k|k-1} \cdot {H_k}^T}{H_k \cdot P_{k|k-1} \cdot {H_k}^T + R_k}$$

$$\hat{x}_{k|k} = \hat{x}_{k|k-1} + K_k \cdot (\tilde{z}_k - H_k \cdot \hat{x}_{k|k-1})$$

$$P_{k|k} = (I - K_k \cdot H_k) \cdot P_{k|k-1}$$

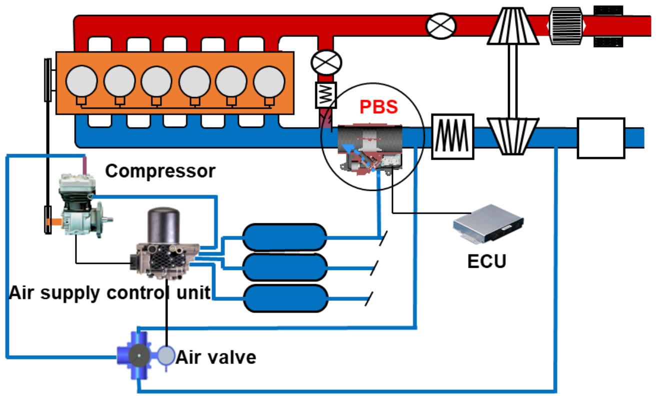
Extend Kalman filter method to estimate engine-out NOx map



Cummins East Asian Research & Development Center (*2014.06 – 2015.12)*

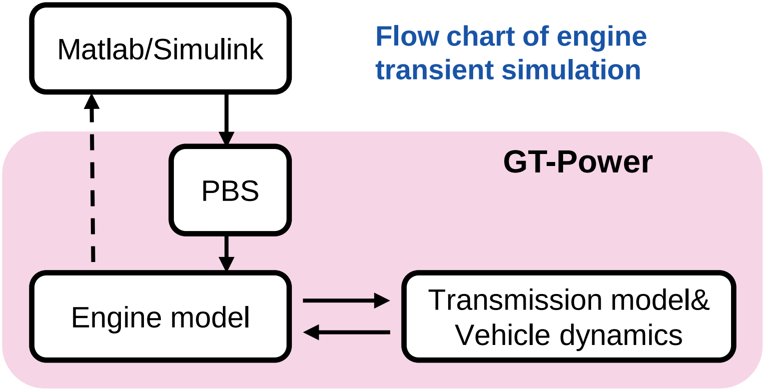
Development Engineer in Advanced Engine & Technology Department

Major Work Content: Engine simulation & calibration, Pneumatic boost system, Driving cycle analysis



Pneumatic boost system (PBS) for reducing turbocharger lag

Flow chart of engine transient simulation



This assignment involves:

- ❑ Engine simulation with PBS system in GT-Power
- ❑ PBS flap valve design and its control method for boosting
- ❑ Experimental data analysis to evaluate engines and vehicle transient performances by using PBS system

Publication List

1) *Experimental investigation on time-resolved mass flow characterization of engine exhaust pulses using Pitot tube and unsheathed thin-wire thermocouple*, Applied Thermal Engineering, 2023.
2) *Analyzing engine exhaust gas temperature pulsations and gas-dynamics using thin-wire thermocouples*, submitted & under review, 2023.
3) *Energy and exergy characteristics of an ethanol-fueled heavy-duty SI engine at high-load operation using lean-burn combustion*, Applied Thermal Engineering, 2023.
4) *Numerical analysis of engine exhaust flow parameters for resolving pre-turbine pulsating flow enthalpy and exergy*, Energies, 2021.
5) *Quantification of losses and irreversibilities in a marine engine for gas and diesel fueled operation using an exergy analysis approach*, in Internal Combustion Engine Division Fall Technical Conference, American Society of Mechanical Engineers, 2020.
6) *Assessment of emissions and energy consumption for construction machinery in earthwork activities by incorporating real-world measurement and discrete-event simulation*, Sustainability, 2022
7) *Path optimization for a wheel loader considering construction site terrain*, in 2018 IEEE Intelligent Vehicles Symposium (IV), IEEE, 2018, pp. 098–2103.
8) *Path planning for wheel loaders: A discrete optimization approach*, in 2017 IEEE 20th International Conference on Intelligent Transportation Systems (ITSC), IEEE, 2017, pp. 1–6.
9) *Quantification of emissions for non-road machinery in earthwork: Modeling and simulation approaches*, in Transportation Research Board (TRB) 96th Annual Meeting, Transportation Research Board (TRB), 2017.
10) *Modeling of dynamic NOx emission for nonroad machinery: A study on wheel loader using engine test data and on-board measurement*, in Transportation Research Board (TRB) 95th Annual Meeting, Transportation Research Board (TRB), 2016

Comments & Questions

Welcome!

Thanks for your time!