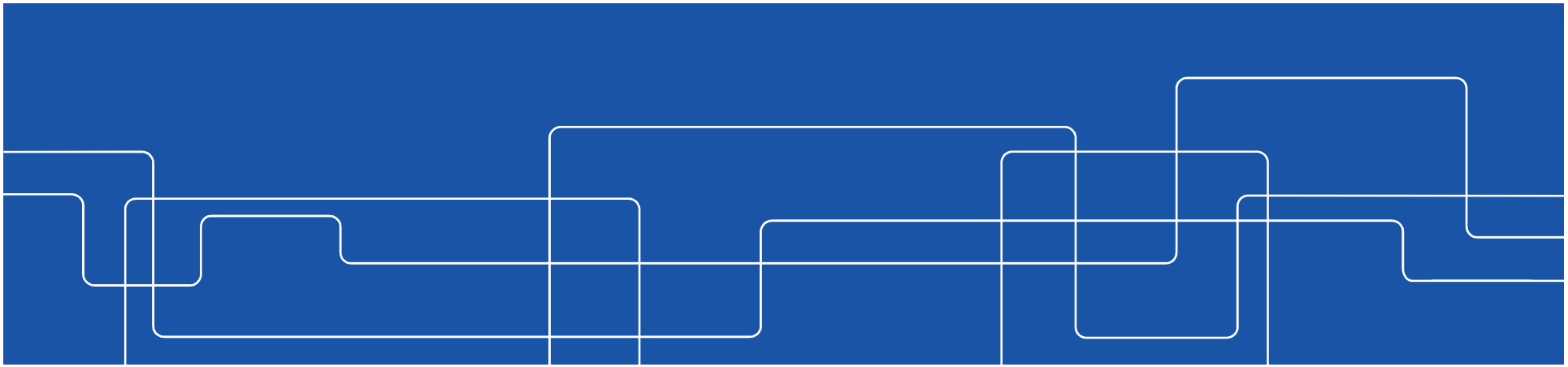
KTH ROYAL INSTITUTE
OF TECHNOLOGY

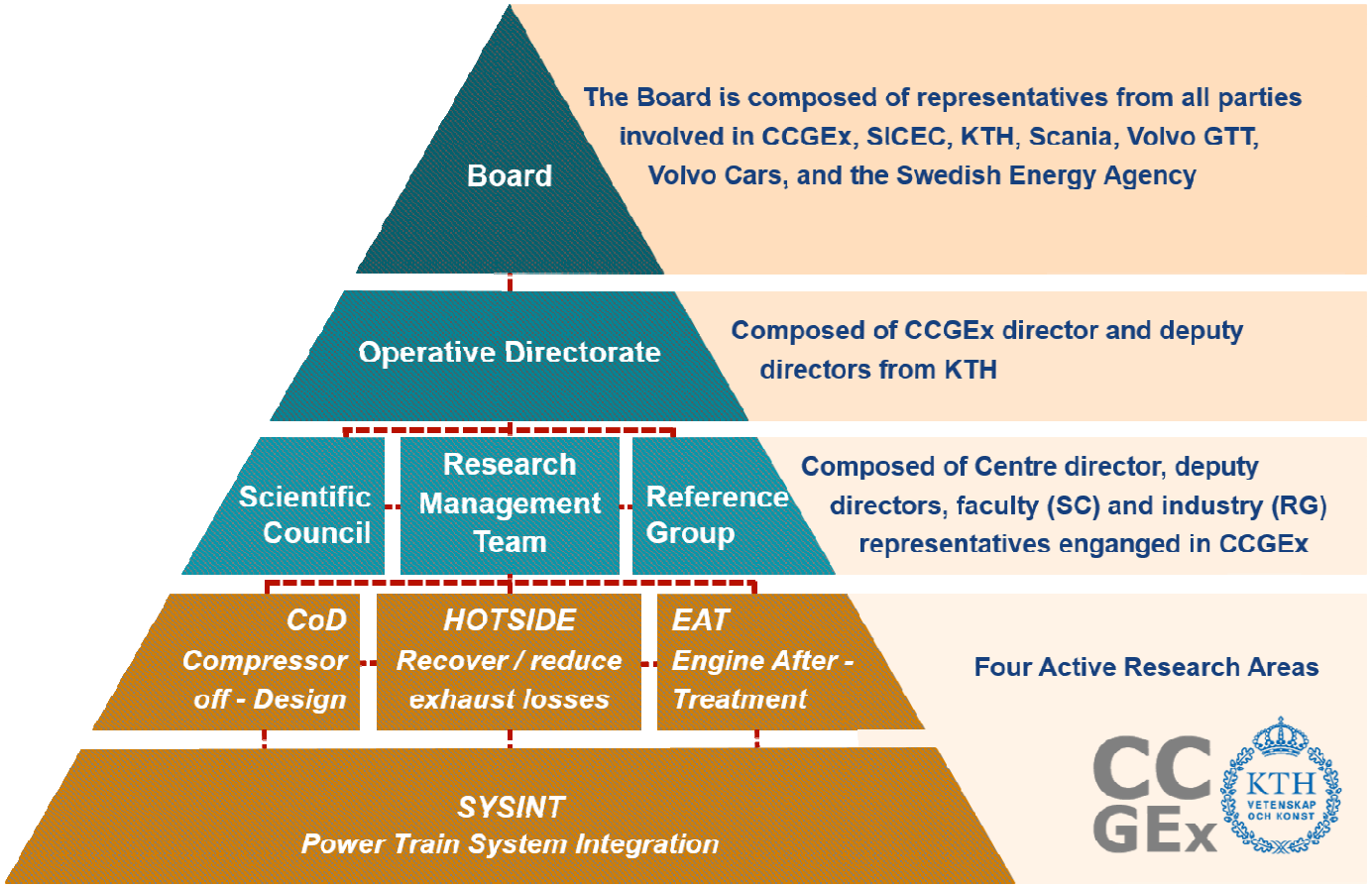
CCGEx Research Status Updates

Mihai Mihaescu, Mikael Karlsson, Anders C. Erlandsson

7th - 8th of September, 2017, CCGEx – Research Days



CCGEx Organization 2014-2017



Research areas & projects

Research Area	2015				2016				2017				2018				2019				2020			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Compressor Off-Design: Mihai Mihaescu																								
Bertrand Kerres, PhD student, ICE, Exp/1D										PhD														
Elias Sundström, PhD student, Mek, CFD					Lic							PhD												
Raimo Kabral, PhD student, MWL, Exp										PhD														
Asuka Pietroniro, Ind. PhD stud Volvo Cars, MWL/Mek, CFD/CAA																	Lic							PhD
Valeriu Dragan, Post-doc BW, Mek, CFD on non-axisymmetric diffusers																								
HOTSIDE: Mihai Mihaescu																								
Ted Holmberg, PhD student, ICE, 1D/Exp										Lic						PhD								
Marcus Winroth, PhD student, Mek-CICERO, Exp										Lic					PhD									
Shyang Maw Lim, PhD student, Mek, CFD									Lic						PhD									
Nicholas Anton, Ind. PhD stud Scania, ICE, 2D AeroDesign													Lic						PhD					
EAT: Mikael Karlsson																								
Ghulam Majal, PhD student, MWL/Mek, Numerics												Lic							PhD					
Arun Prasath, PhD student, ICE, Exp														Lic							PhD			
Mireia Altimira, Researcher, Mek, SCR																								
Zhe Zhang, modeling, Assoc. Project, MWL																				PhD				
SYSINT: Anders Christiansen Erlandsson																								
Senthil Mahendar, PhD student (Volvo GTT), ICE, 1D Intr Turbo															Lic							PhD		
Sandhya Thantla, Assoc. Project, ICE															Lic							PhD		

Overview: Compressor off-Design (CoD)

GOAL — Increase compressor stable operation range, improve inter-cooling performance, enable silent operation and optimize unit energy efficiency

STRATEGY — From physics-based understanding, build knowledge on critical operation conditions & enable viable control to mitigate flow instabilities and surge

TOOLS

- High-fidelity simulations & detailed experiments
- Methods for stall/surge identification

→

- Flow & Acoustic characterization
- System diagnostics in ICE & Turbocharg

Industry Input
Volvo Cars (engine maps)
Borg Warner (geometry, maps) SCANIA & Volvo GTT

Activities

Compressor inlet piping

HT 2017

CFD, surge, piping (Mek)
Elias Sundström, PhD stud
High-fidelity LES, models

Turbomachinery response

- compressor map
- flow instabilities
- aeroacoustics
- flow control

back pressure / pulses

Intake engine manifold

Internal Combustion Engine

CFD non-axisymmetric vaneless diffuser (Mek)
Valeriu Dragan, BW Postdoc

Aeroacoustics (MWL/Mek)
Asuka G. Pietroniro, Ind
PhD stud Volvo CC
CAA & 1D modeling

CoD: Overall aims

- Improve understanding of the compressor flow at off-design conditions
  - high-fidelity simulations and experiments
  - quantify the flow instabilities with advanced mode decomposition techniques
- Quantify the geometry installation effects on the on-set of flow instabilities and surge
  - effect on compressor performance
- Aeroacoustics characterization of compressor surge
- Develop and /or adopt methods for stall/surge identification
- Surge inception scenario definition

PhD Students / Postdoc:
Elias Sundström, (CFD), Mek
Asuka Pietroniro, (Aeroacoustics), MWL/Mek
Valeriu Dragan (CFD), Mek
Bertrand Kerres (Exp), **PhD: 2017/06**
Raimo Kabral, (Acoustics), **PhD 2017/06**

CCGEx Coordinator: Mihai Mihaescu

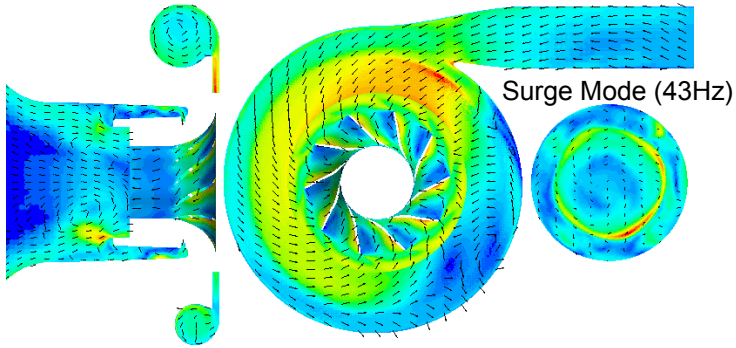
Reference group:
Habib Aghaali, Volvo Cars
Magnus Knutsson, Volvo Cars
Magnus Ising, Volvo GTT
Per-Inge Larsson, Scania
Jonas Holmborn, Scania
Tom Heuer, Borg Warner
Thomas Lischer, Borg Warner

CoD: Individual projects

LES of Centrifugal Compressor Flows at Low Mass Flow Rate

Doctoral student:
Elias Sundström (CFD), Mek

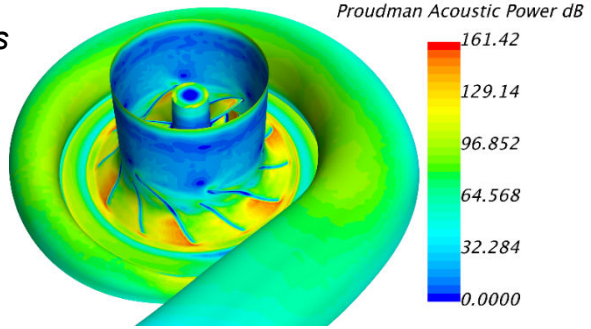
Supervisors:
Mihai Mihaescu, Laszlo Fuchs



On the aerodynamically generated sound of centrifugal compressors

Ind. Doctoral student (Volvo Cars); started 05/12/2016:
Asuka Gabriele Pietroniro (CFD/CAA)

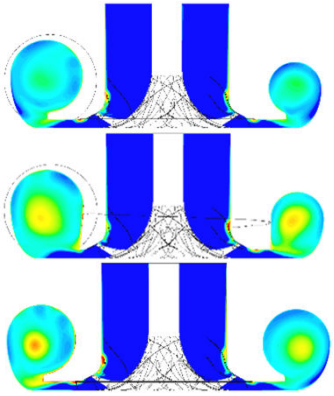
Supervisors:
Mihai Mihaescu, Mats Åbom, Magnus Knutsson (VCC)



Analysis of non-axisymmetric vaneless diffuser configurations – impact on range of operability and performance

Post-Doctoral student; started 14/11/2016:
Valeriu Dragan (CFD-integrated design / optimization), Mek

Supervisors:
Mihai Mihaescu, Thomas Lischer (BW)



CoD: Highlights

- Quantification of flow phenomena and instabilities precursor to surge in a large ported-shroud compressor by means of LES.
- Demonstrated capability of extracting acoustics from the LES data.
- Validity range established for RANS & theoretical models for predicting compressor maps; comparisons with gas-stand experimental data (Mek-MWL-ICE).
- Determination of aeroacoustic coupling and system's characteristics (compressor-piping arrangement) @ design and off-design.
- An efficient and compact noise control solution, based on the optimal flow channel wall impedance was developed and proposed.
- A surge criterion based on the fractal properties of time-resolved pressure signals was developed.

CoD: Future Plans

- Experimental & computational efforts on the BorgWarner geometries (flow & acoustics), including assessment of non-axisymmetric vaneless diffuser configurations
- Noise generation mechanisms; quantification of the acoustic noise sources at off-design; acoustic sources - sound propagation correlations; develop noise supression technologies with impact at the source
- Evaluation / calibration /development of improved compressor surge models & assess the mechanisms for losses in centrifugal compressors
- PhD defense of Elias Sundström (HT17)

Overview: HOTSIDE

GOAL — Maximize heat and pressure recovery from the exhaust gas flow

STRATEGY — From physics-based understanding, build knowledge of the unsteady exhaust flow interaction with the turbine, waste-heat-recovery systems and exhaust

TOOLS

- Integrated high-fidelity simulations with predictive models
  - riments
  - em models

- Flow characterization & heat transfer effects
- System optimization incl. ICE, Turbo, WHR

Exhaust valve strategies (ICE)
Ted Holmberg, PhD stud
1D Gas Dynamics / On engine Exp

CFD, manifold & turbine (Mek)
Shyang Maw Lim, PhD stud
High-fidelity LES, models

Industry Input
Volvo Cars (engine maps)
Borg Warner (geometry, maps) SCANIA & Volvo GTT

Activities

HT 2018
exhaust valve strategy

pulsed flow characteristics

HT 2018

Internal Combustion Engine

Exhaust port & valve (CICERO)
Marcus Winroth, PhD stud
Exp. Fluid Mechanics

Exhaust engine manifold

back pressure

HT 2018

Turbine resp

- upstream flow instabilities
- exhaust valve strategy used
- heat transfer effects
- turbine maps / torque / efficiency

Turbomachinery design, 2D (ICE)
Nicholas Anton, Ind PhD stud (SCANIA) **HT 2019**
2D simulations & turbo aero-design

HOTSIDE: Overall aims

- Improve understanding of the pulsating flows in complex manifolds
  - high-fidelity simulations / experiments
  - intermittent flows effects on heat transfer
- Quantify the characteristics of the pulsating flow and effect on turbocharger's efficiency
  - different exhaust valve strategies (1D/3D/Exp)
  - different turbine designs (1D + 3D aerodesign)
- Improve understanding of heat transfer and heat transfer related losses for unsteady, pulsating, hot flows in complex manifolds
- Develop better calibrated 1D models and reduced order models

Doctoral students:
Marcus Winroth, (Exp), Mek-CICERO
Ted Holmberg (GT-Power, Exp), ICE
Shyang Maw Lim, (CFD), Mek
Nicholas Anton (Turbo design), Scania

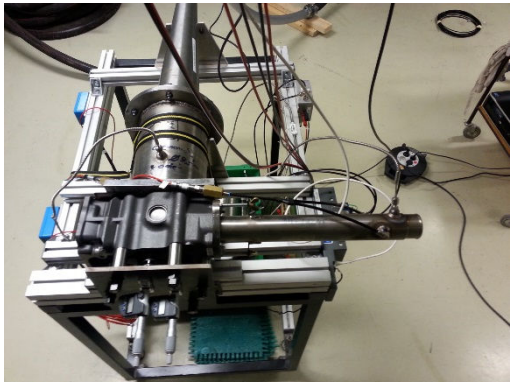
CCGEx Coordinator: Mihai Mihaescu

Reference group:
Habib Aghaali, Volvo Cars
Mattias Ljungqvist, Volvo Cars
Martin Bauer, Volvo GTT
Fredrik Rahm, Volvo GTT
Per-Inge Larsson, Scania
Marc Gugau, Borg Warner
Thomas Biesinger, Borg Warner

HOTSIDE: Individual projects

Gas Dynamics at the Exhaust Valves and Ports
Doctoral student:
Marcus Winroth (Exp), Mek-CICERO

Supervisors:
Henrik Alfredsson, Ramis Örlü



Valve Strategies and Exhaust Pulse Utilization
Doctoral student:
Ted Holmberg (1D modeling, Exp), ICE

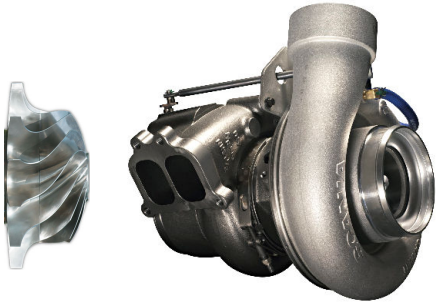
Supervisors:
Andreas Cronhjort, Anders Christiansen Erlandsson

Flow and Heat-transfer in a Turbocharger Radial Turbine
Doctoral student:
Shyang Maw Lim (CFD), Mek

Supervisors:
Mihai Mihaescu, Anders Dahlkild, Christophe Duwig

Engine Optimized Turbine Design
Ind. Doctoral student:
Nicholas Anton (Aero-design, Exp), SCANIA

Supervisors:
Anders Christiansen Erlandsson, Magnus Genrup, Per-Inge Larsson



HOTSIDE: Highlights

- Discharge coefficient has a strong dependency on both valve opening speed & pressure ratio; quasi-steady assumption used for modeling exhaust flow in the port is incorrect
- Surface flow visualizations indicate shock patterns in the exhaust port; the shock pattern is altered when using a static geometry
- Evaluation of the adiabatic & diabatic turbine performance under continuous flow conditions and some pulsating flow conditions
- Developed an exergy-based method to evaluate exhaust gas utilisation in turbine by means of 3D and 1D simulations
- Shyang Maw Lim (Licentiate Seminar, 19/01/2017); Marcus Winroth (Licentiate Seminar, 24/03/2017)

HOTSIDE: Near-future Plans

- Dynamic measurements of the discharge coefficient: dynamic valve experiments with a double valve set-up; assess the influence of different valve lift profiles (CICERO Lab)
- Schlieren measurements for investigating shock patterns in the exhaust port under static and dynamic valve conditions (CICERO Lab)
- Complementing simulations for assessing the effect of pressure ratio on valve flow coefficients
- Detailed computational efforts on the BorgWarner turbine integrated with the manifold under realistic flow conditions; Boundary Conditions provided by Volvo Cars (VEP-MP engine; different exhaust valve strategies)
- Quantify the associated losses and impact on turbine performance

Research areas & projects

Research Area	2015				2016				2017				2018				2019				2020			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Compressor Off-Design: Mihai Mihaescu																								
Bertrand Kerres, PhD student, ICE, Exp/1D										PhD														
Elias Sundström, PhD student, Mek, CFD					Lic							PhD												
Raimo Kabral, PhD student, MWL, Exp										PhD														
Asuka Pietroniro, Ind. PhD stud Volvo Cars, MWL/Mek, CFD/CAA																	Lic							PhD
Valeriu Dragan, Post-doc BW, Mek, CFD on non-axisymmetric diffusers																								
HOTSIDE: Mihai Mihaescu																								
Ted Holmberg, PhD student, ICE, 1D/Exp										Lic						PhD								
Marcus Winroth, PhD student, Mek-CICERO, Exp										Lic					PhD									
Shyang Maw Lim, PhD student, Mek, CFD									Lic						PhD									
Nicholas Anton, Ind. PhD stud Scania, ICE, 2D AeroDesign													Lic						PhD					
EAT: Mikael Karlsson																								
Ghulam Majal, PhD student, MWL/Mek, Numerics												Lic							PhD					
Arun Prasath, PhD student, ICE, Exp														Lic							PhD			
Mireia Altimira, Researcher, Mek, SCR																								
Zhe Zhang, modeling, Assoc. Project, MWL																				PhD				
SYSINT: Anders Christiansen Erlandsson																								
Senthil Mahendar, PhD student (Volvo GTT), ICE, 1D Intr Turbo															Lic							PhD		
Sandhya Thantla, Assoc. Project, ICE															Lic							PhD		

Overview: EAT - Particle Characterization and Agglomeration

GOAL

Remove health critical sub-micron particles

STRATEGY

Build knowledge on particles evolution along the exhaust line of IC engines. Develop innovative methods to stimulate and promote the agglomeration of particles for easier removal

TOOLS

- Simulations (high-fidelity as well as 1D)
- Detailed experiments (lab-scale as well as engine cell)
- System integration (close cooperation with industry partners)

Activities

Arun Prasath, ICE (VT2020)
Experimental characterization and simplified 1D modelling

Characterization of base engine particle distribution
-experimental campaign of evolution along exhaust line
-steady state and transient, fuel quality etc.

Parameter studies (agglomeration)

Validation experiment

Industry Input

Engine, raw emissions

System knowledge

Concept development

Fundamentals of particle grouping

Numerical framework

Novel concept development
-Hydrodynamic and/or acoustic forcing

Ghulam Majal, MWL/Mek (HT2019)
Numerical modelling - 1D – 3D

Zhe Zhang, MWL (HT2019)
Acoustic metamaterials
Modelling and experiments

EAT-PCA: Overall aims

- Characterize and understand particle evolution along the exhaust line
  - high-fidelity simulations and experiments
  - Steady state and transients
- Understand particle agglomeration due to hydrodynamic and acoustic forcing
  - 1D to high fidelity simulations and validation experiments in generic designs
- Novel concepts for particle agglomeration
  - Hydrodynamic and/or acoustic
  - Acoustic metamaterials

PhD Students / Postdoc:
Ghulam Majal, (CFD), MWL/Mek
Arun Prasath (Exp), ICE
Zhe Zhang, (Acoustics), MWL

CCGEx Coordinator: Mikael Karlsson

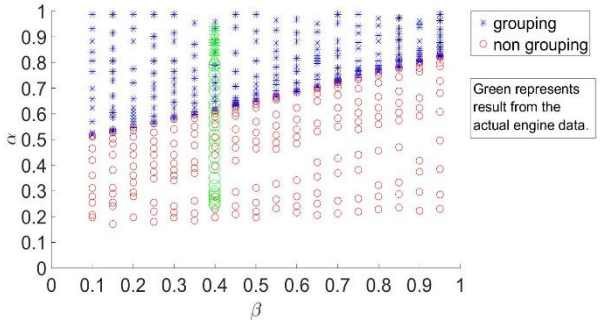
Reference group:
Mats Laurell, Volvo Cars
Sharif Nahidh, Volvo GTT
Klas Olofsson, Scania

EAT-PCA: Individual projects

Control of particle agglomeration with relevance to after-treatment gas processes

Doctoral student:
Ghulam Majal (CFD), MWL/Mek

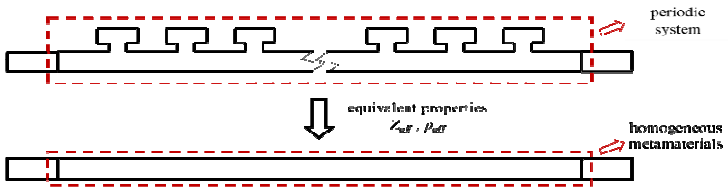
Supervisors:
Mihai Mihaescu, Mats Åbom, Mikael Karlsson and Lisa Prahl Wittberg



Control of particle agglomeration with the direct application of engine noise and acoustic metamaterials

Doctoral student:
Zhe Zhang (Sim and exp), MWL

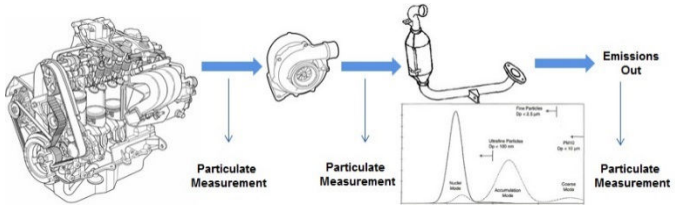
Supervisors:
Mats Åbom, Hans Bodén and Mikael Karlsson



Characterization of particulates in the gas exchange system of DI/SI engines

Doctoral student:
Arun Prasath (Exp), ICE

Supervisors:
Anders Christiansen Erlandsson
Ola Stenlåås



EAT-Particle agglomeration: Highlights

- 1D particle agglomeration model
  - Implemented and used for parameter studies
  - Now includes acoustic forcing as well
- Concept for particle agglomeration using acoustic metamaterials
- Slow sound experimentally validated
- First paper published
- First agglomeration prototype being built

EAT-PCA: Near-future Plans

- Base line characterisation of particles (steady state) in:
  - Exhaust line
  - Reference agglomeration device
  - Generic components (bends, expansions etc)
- Validation of 1D code against experiments (as above)
- Implementation of slow sound concepts
- 3D high fidelity modelling of particle agglomeration

SYSInt: Overall aims

- Improved understanding
  - Combustion process & gas exchange system interaction
  - System efficiency – thermodynamic, mechanical, electrical
  - Thermal integration & emissions reduction efficiency
  - Component interactions
  - Transients system dynamics & control
  - New Concept assessment

- Transition to model predictive engineering
  - Investigate/develop strategies for model aggregation
  - Development of reduced order Models
  - Model validation through experiments and simulation

PhD Students:
Senthil Mahendar, ICE
Sandhya Thantla, ICE

CCGEx Coordinator: A.C. Erlandsson

Reference group:
Habib Aghaali, Volvo Cars
Johan Engström, Volvo GTT
Johan Linderyd, Scania

SysInt Individual projects

Heavy Duty DISI Gas Exchange Processes with Alternative Fuels

Doctoral student:

Senthil Mahendar, Machine Design, ICE

Supervisors:

Anders C Erlandsson,

Low Temperature Waste Heat Recovery (WHR) in IC Engines

Doctoral student :

Sandhya Tanthla

Supervisors:

Anders C Erlandsson, Jens Fridh

SYSInt: Highlights and Plans

PROJECT HIGHLIGHTS (start fall 2016):

- Gas Exchange system for DISI HD engines - Senthil Mahendar
  - Modeling and calibration of combustion & gas exchange with real data ongoing
  - Development of modeling approach for WHR and HD DISI combustion.
  - Defining testing needs for understanding alcohols in HD DISI processes.
  - Abstract for WCX 2018 submitted
- Low Temperature Waste Heat Recovery LT-WHR – Sanhya Thantla
  - Establishing the ”state-of-art” for vehicular WHR systems
  - Modeling of themodynamic cycles and the Miller engine in place.

SHORT & LONG TERM PLANS:

- Detail planning of projects ongoing

“CoD and HotSide have nowadays reached state-of-the-art scientific levels, highly competitive when compared to other Centres that work in these fields”

“All projects are of high and actual relevance for the development of internal combustion engines, and therefore for the Swedish and international automotive industry. The research denotes high academic standards despite being of an applied nature in most fields.”

IAB Report 2016

Competence Center for Gas Exchange

CC GEx

”Charging for the future”