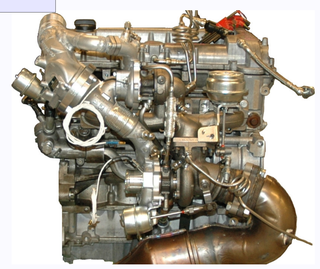
Modeling and Control of Advanced Turbocharged Engines

Oskar Leufvén, Lars Eriksson, Lars Nielsen (Linköping University)
Anders Larsson, Per-Inge Larsson, Johan Andre, Henrik Flemmer (Scania AB)

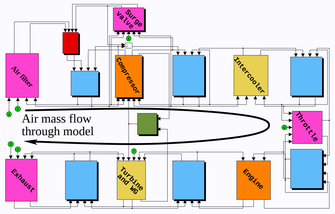
Project background and status



The ever increasing focus on fuel efficient vehicles forces the automotive industry towards more advanced engine concepts. Downsizing and turbocharging has been one possible solution. To still be able to provide the desired vehicle and engine behavior a single turbo is more often insufficient. This project focuses on modeling and control of turbo systems with more than one turbo.

The work, therefore, evolves around development of component models capable of reproducing control relevant phenomenons (surge, choke, low speed and restriction operation etc.), and extensions of the available Mean Value Engine Model framework. The extended MVEM is suitable for investigation of both instability issues and control principles, for advanced turbocharged engines. The availability of experimental facilities within LINK-SIC is greatly appreciated, and used during the model development.

The fifth stage of the project has been devoted to further develop and analyze the compressor model structure. Focus has been on measuring and preparing data from different sources, with the goal of developing a model that is general to the automotive community. The same model structure should thus be usable for both small car sized compressors, and up to heavy truck applications. Compared to the previous efforts, focus has been on the high flow behavior, and restriction operation.

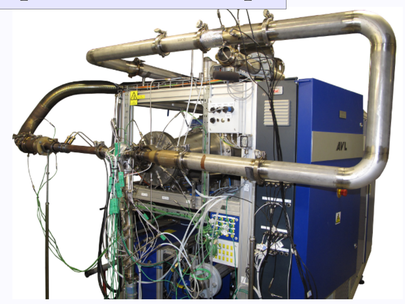


Map database and comprehensive maps

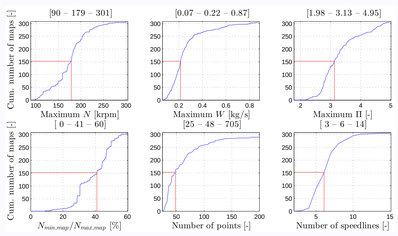
A 300+ compressor map database has been used in the model development. The maps sizes range from small automotive applications and up to large heavy duty application.

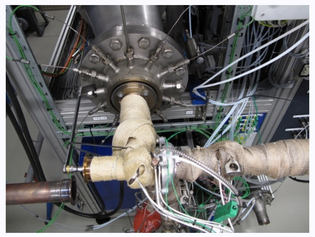
A measurement series was conducted in a gas stand, during the fall of 2011. Three different automotive sized turbochargers, considered representable for car applications, were selected for the study. The following measurements were conducted

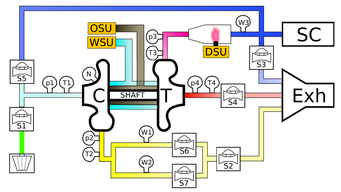
- Pressure ratio below unity $\Pi_c < 1$
- Cold maps $T_{oil} = T_2$
- Hot maps $T_3 = \{300, 450, 600, 750\}^o$C
- Choke flow $\Pi_c \approx 1$

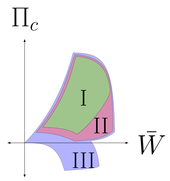


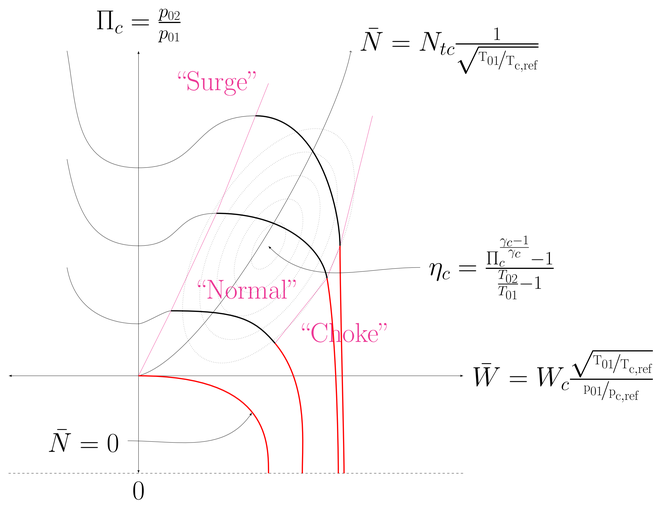
Apart from the normal gas stand sensor setup, a number of extra temperatures were measured, e.g.: eleven turbo surface (both compressor, center housing and turbine housing), four extra compressor inlet air temperature, a special surge indication compressor inlet air etc.



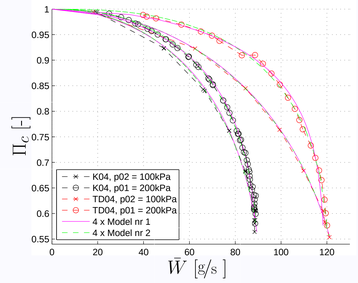


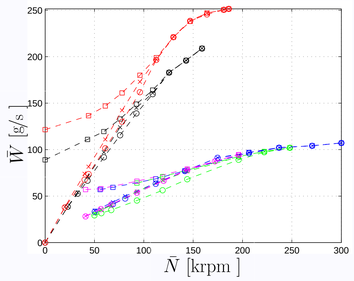


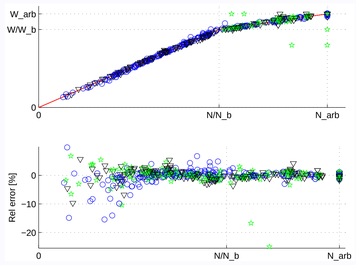


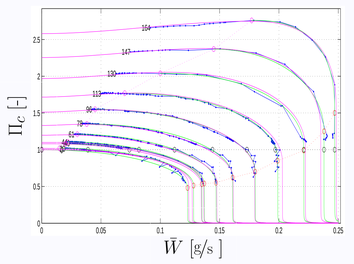


Choke and restriction operation

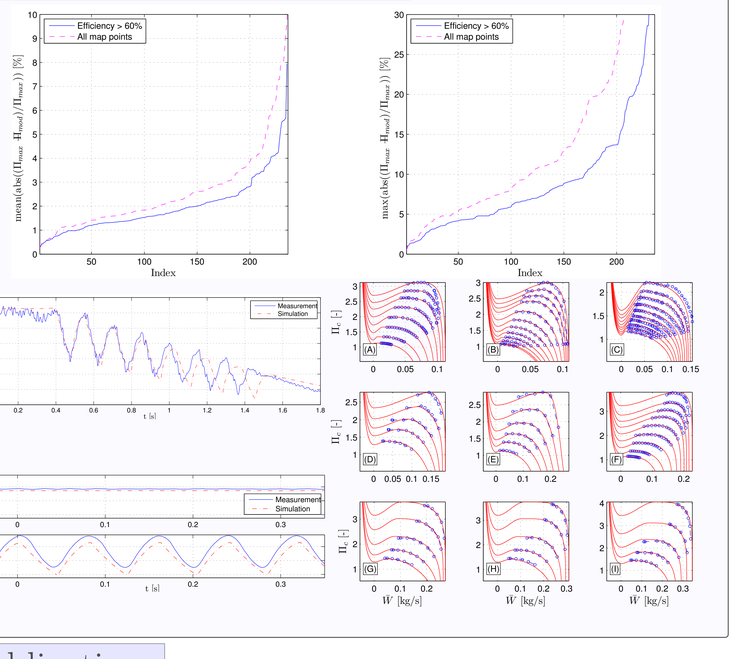








Normal and surge operation



Publications

Submitted publications

- O. Leufvén, and L. Eriksson, **A surge and choke capable compressor flow model - Validation and extrapolation capability**, Under review, Control Engineering Practice

Publications

- A. Thomasson, O. Leufvén, I. Criscuolo, and L. Eriksson, **Modeling and validation of a boost pressure actuation system for a series sequentially turbocharged SI engine**, Accepted for publication, Control Engineering Practice
- O. Leufvén and L. Eriksson, **Investigation of Compressor Correction Quantities for Automotive Applications**, International Journal of Engine Research, 2012, Vol. 13, Num. 13
- L. Eriksson, T. Lindell, O. Leufvén, and A. Thomasson, **Scalable Component-Based Modeling for Optimizing Engines with Supercharging, E-Boost and Turbocompound Concepts**, SAE International Journal of Engines, 2012 Vol. 5, Num. 2 (2012-01-0713)
- O. Leufvén, and L. Eriksson, **Surge and Choke Capable Compressor Model**, IFAC World Congress, 2011
- O. Leufvén, **Compressor Modeling for Control of Automotive Two Stage Turbochargers**, Licentiate thesis, 2010
- O. Leufvén, and L. Eriksson, **Engine Test Bench Turbo Mapping**, SAE WC (2010-01-1232)
- A. Thomasson, L. Eriksson, O. Leufvén, and P. Andersson, **Wastegate Actuator Modeling and Model-Based Boost Pressure Control**, IFAC Workshop, 2009
- O. Leufvén, and L. Eriksson, **Time to surge concept and surge control for acceleration performance**, IFAC WC 2008

Masters theses examples in collaboration with Scania

- C. Carlsson, **Modeling and Experimental Validation of a Rankine Cycle Based Exhaust WHR System for Heavy Duty Appliations**, 2012
- M. Kågebjer, **Diagnosis of a compressed air system in a heavy vehicle**, 2011
- D. Elofsson & E. Lindén, **Model-based turbocharger control - a common approach for SI and DI engines**, 2011