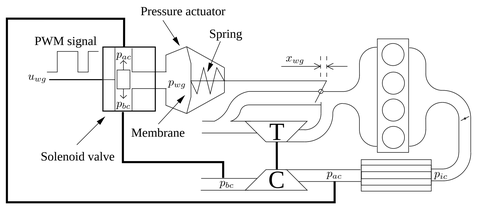
Modeling and Control of Advanced Turbocharged Engines

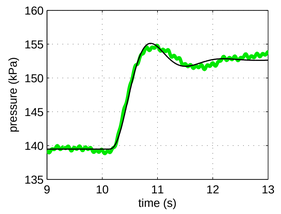
Lars Eriksson, Andreas Thomasson, Oskar Leufvén, Lars Nielsen (Fordonssystem, LiU)
Per Andersson (GM Powertrain)

Wastegate Actuator Modeling and Model-Based Boost Pressure Control

The torque response of turbocharged engines is tightly connected to the boost pressure control. For spark ignited engines the boost pressure is usually controlled by a wastegate valve connected to a pressure actuator. The actuator behavior therefore has large influence on the requirements and tuning of the control system.

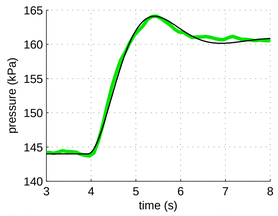


The wastegate model is divided into three submodels; the actuator pressure, the static position, and an additional position dynamics. This is a logical partitioning that simplifies the parameter estimation and gives physical insight into the problem. Together with a complete Mean Value Engine Model (MVEM), the response from control signal to boost pressure is accurately described.



Boost Controller Tuning

The investigated controller structure consists of a static feed forward and a gain scheduled PID controller. A tuning method for the PID-controller based on step responses has been developed and evaluated.



- Identify process model according to:

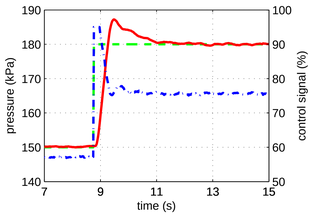
$$G(s) = \frac{K(N)}{T^2(N)s^2 + 2T(N)\zeta(N)s + 1}$$

- IMC-parameter choice for first degree reference system:

$$K_p = \frac{2T\zeta}{\lambda K} \quad K_i = \frac{1}{\lambda K} \quad K_d = \frac{T^2}{\lambda K}$$

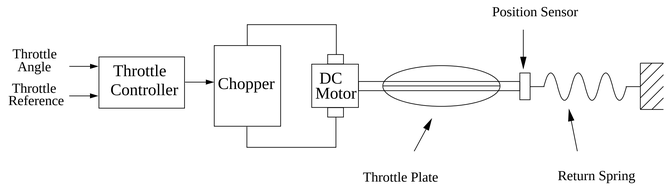
Objective - small overshot and no oscillations

Controller performance has been evaluated both in simulation and test car with similar result - the proposed method gives the desired behavior. The identification process is easily automated which decreases calibration time.

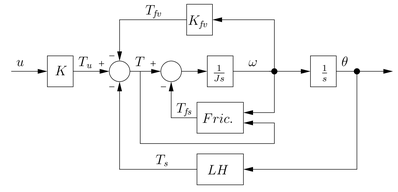


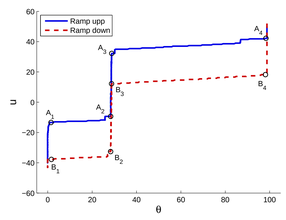
Model-Based Throttle Control using Static Compensators and IMC based PID-Design

The electronic throttle used in modern SI engines gives the ECU direct control of the air-flow and thereby engine torque. This puts high demand on the speed and accuracy of the controller that positions the throttle plate.



Two strong nonlinear effects, friction and limp-home torque, complicates the servo problem. Based on a relatively simple model of the system, a nonlinear feedforward is designed to counter these effects and approximately linearize the system. A PID controller is then used to control the linearized system.

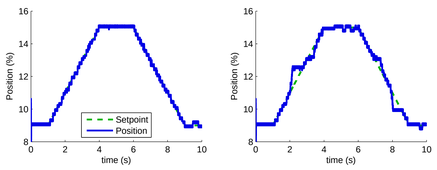




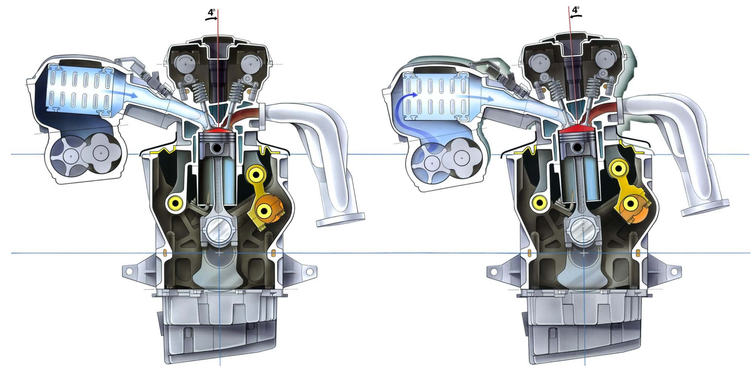
The feedforward is divided into two components, a limp-home and a friction compensator. Both parts are identified from a ramp-response up and down in control signal. A step response is performed in the linear region to identify the linear dynamics, and the IMC-framework is used to identify parameters for the PID-controller. Automatic tuning procedures for these identifications has also been developed.

Robustness Investigation

The robustness to parameter errors in the nonlinear compensators has been investigated. While less sensitive to errors in the friction estimation, it can be concluded that performance around the limp-home position requires a good estimate of this value. To compensate for aging of the throttle servo and position sensor, this value can easily be calibrated at each start-up.



Master Thesis and Student Project



During the year interesting thesis (MT) and student project (SP) have been running on the Rapid Prototyping system relevant the LINK-SIC project

- Tuning and Validation of an MVEM for Turbocharged Gasoline Engine (MT), Stefan Tuvesson, 2009-01
  The thesis includes parameterization of a MEAN value engine model for an engine it was not originally designed for, evaluation of the resulting performance and suggestions for improvements.
- Wastegate Actuator Modeling and Tuning of a PID Controller for Boost Pressure Control (MT), Andreas Thomssson, 2009-03
  A model for a wastegate actuator is developed and validated together with a complete MVEM. A tuning procedure for a boost controller, consisting of a gain scheduled PID and feedforward, based on step responses for different engine speeds is suggested.
- Mean Value Model of the Gas Temperature at the Exhaust Valve (MT), Filip Ainouz, Jonas Vedholm, 2009-09
  In this thesis a model for the gas temperature at the exhaust valve is developed and validated. The gas temperature dependences of different engine operating conditions are investigated.
- Modelbased Air and Fuel Path Control of a VCR Engine (MT), Tobias Lindell, in progress
  The thesis deals with air and fuel control of a variable compression engine (see figure above) that is currently running in the engine lab at Vehicular Systems, Linköping University.
- Development of observer and controllers for two stage turbo systems (SP), seven undergraduate students, in progress
  The project develops a boost controller and observers for pressures, temperatures and turbine speeds on a two-stage turbocharged engine.