Modeling and Control of Advanced Turbocharged Engines

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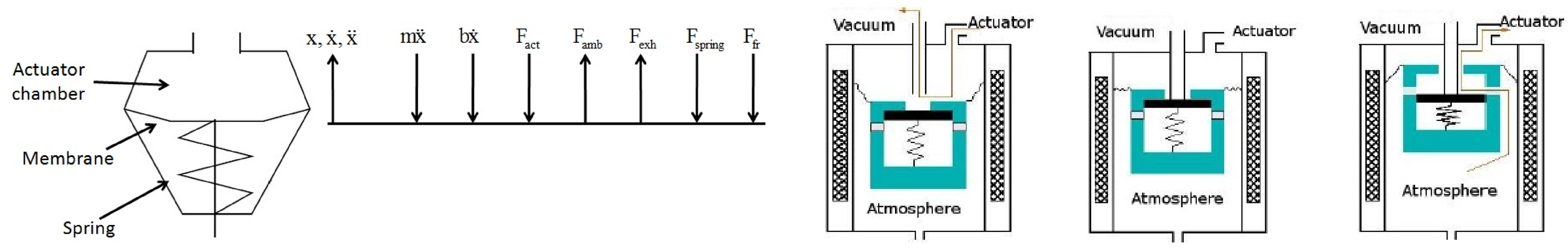
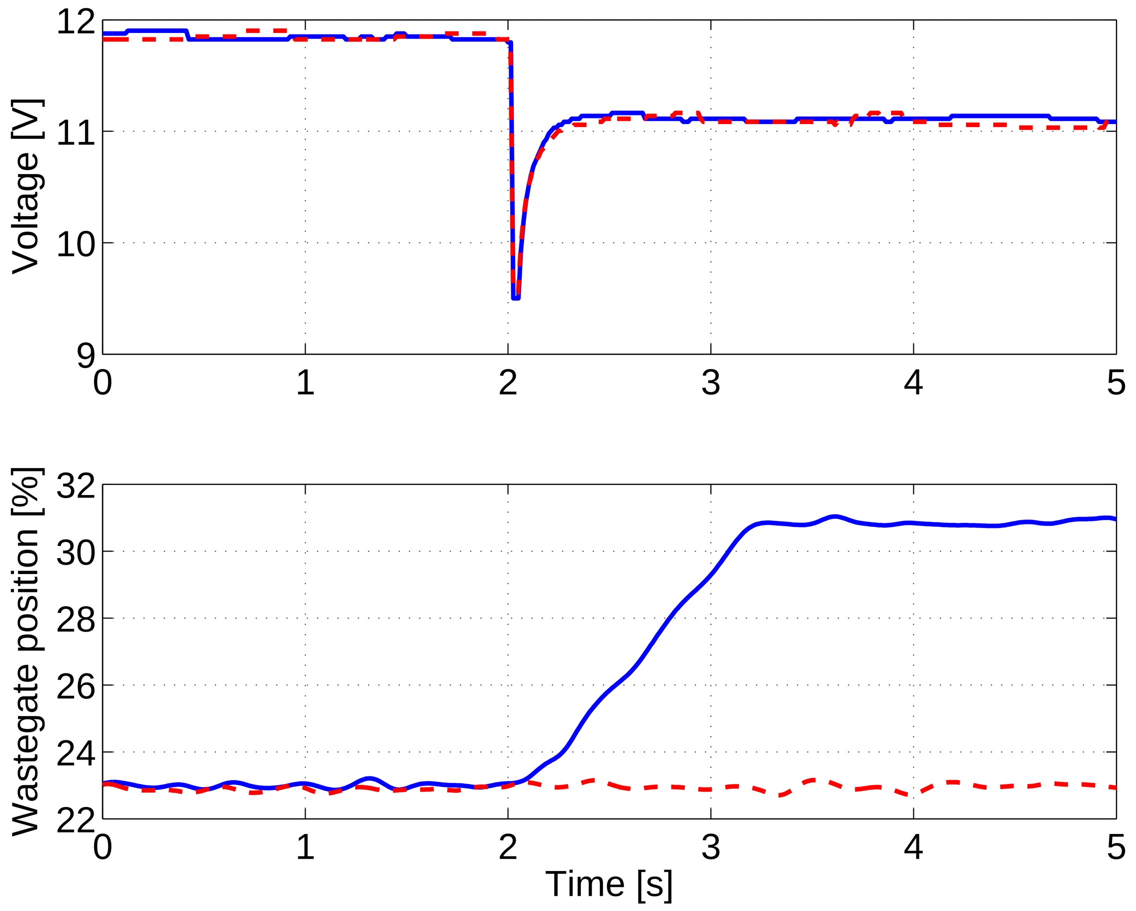
Boost Pressure Actuator Modeling

Actuation systems for automotive boost control incorporate a vacuum tank and PWM controlled vacuum valves to increase the boosting system flexibility. Physical models for the actuator system are constructed using measurement data from a dynamometer with an engine having a two stage turbo system. The actuator model is integrated in a complete Mean Value Engine Model and a boost pressure controller is constructed.

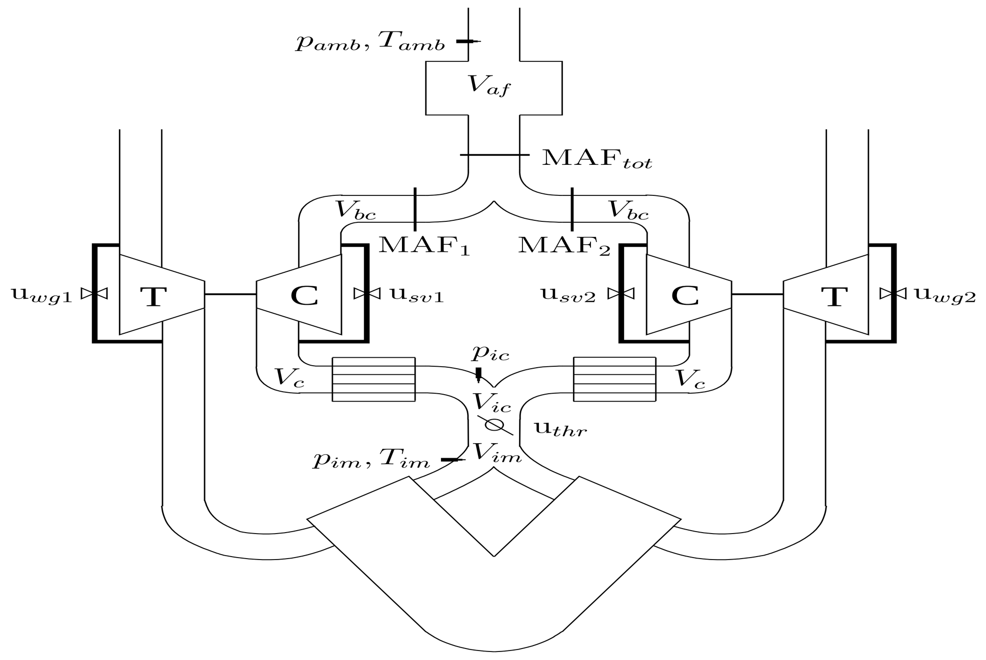


Based on the actuator model a nonlinear compensator, capable of rejecting disturbances from system voltage, is developed. A boost pressure controller is developed for the vacuum actuator and engine, using IMC. The complete controller is evaluated in an engine test cell where its performance is quantified and system voltage disturbance rejection is demonstrated[1].

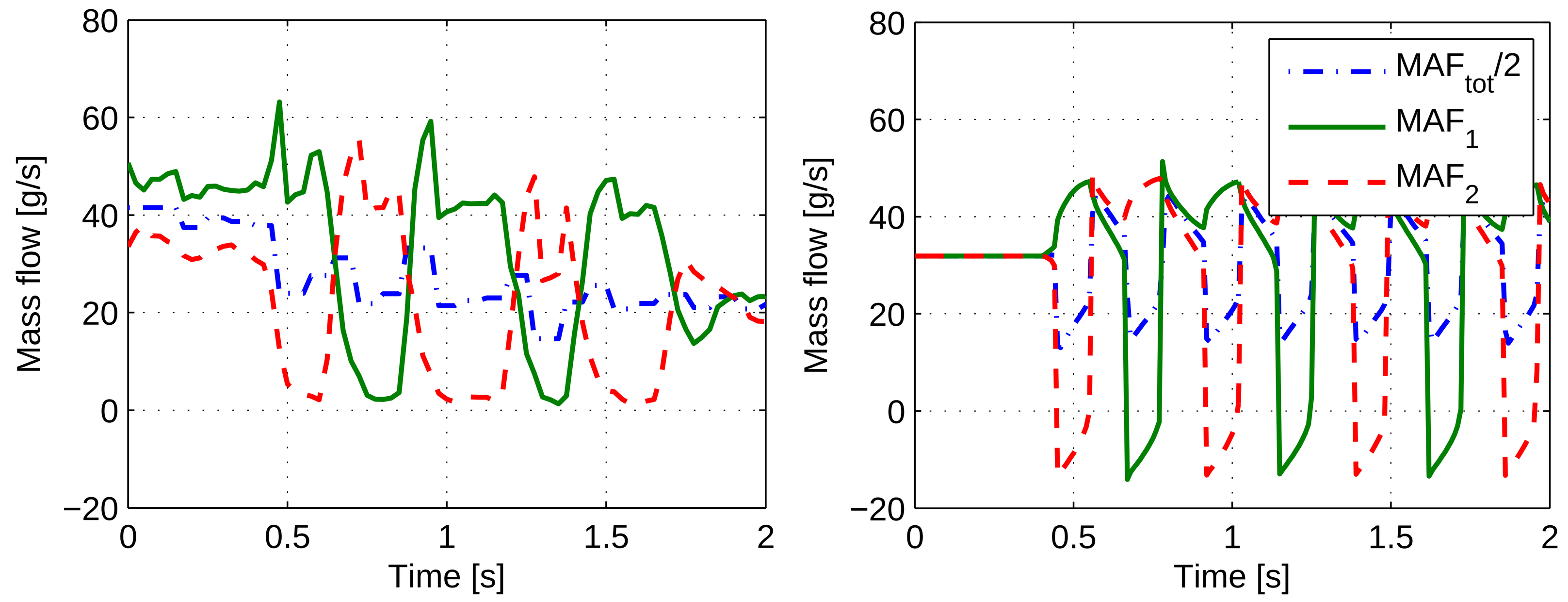


Co-Surge in Bi-Turbo Engines

Co-surge is a phenomena in a parallel turbocharged engine where the mass flow in the two turbochargers alternately reverses. This can occur when operating close to the surge line, if there is a disturbance between the two mass flows.



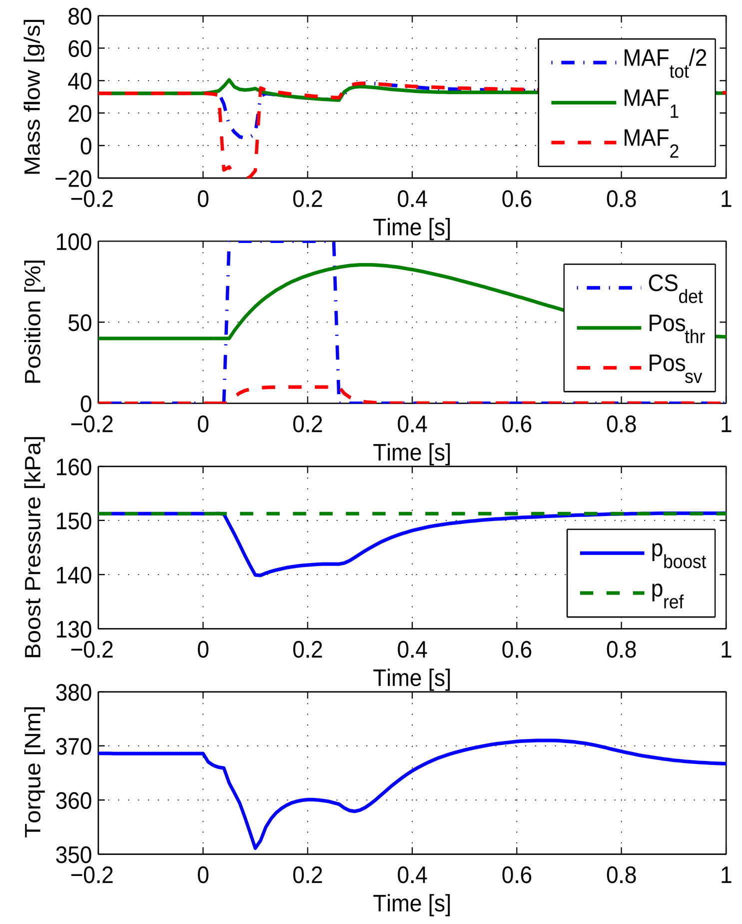
If co-surge is detected the control system should act to quell the oscillation and return the system to a stable operating point. To investigate this phenomena a mean value engine model capable of capture the qualitative properties of co-surge behavior has been developed.



The model predicts an oscillation in turbocharger speed and the next step is further measurements with turbocharger speed sensors included.

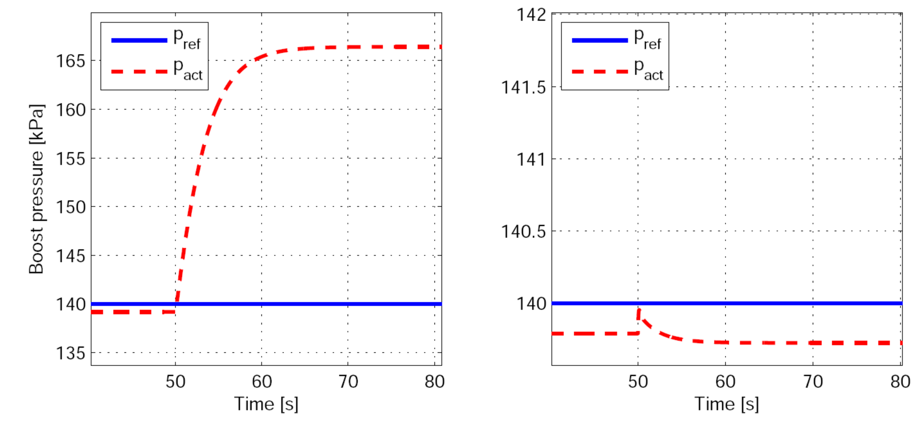
Detection and Control

If the mass flow in both air paths are measured, a filtered difference can be used to detect co-surge. To quickly quell the oscillation it is proposed to use both the throttle and surge valves. Opening the throttle gives a larger margin to the surge line and also compensate for the reduction in mass flow during surge. A simulated with a detection and control algorithm implemented is shown in the figure to the right.



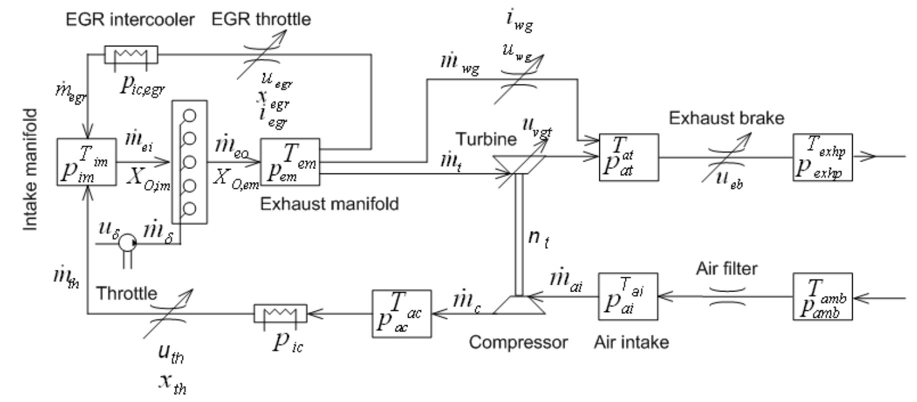
Enthalpy-based boost pressure control:

A model based controller is developed that calculates the desired turbine power from the boost pressure reference and then, by observing the available exhaust energy, controls the generated turbine power to match the desired power. A Mean Value Engine Model has been used to make simulation with the developed controller implemented. Steps between different boost pressure references are used to evaluate controller performance. Tests in a car have also been made to make sure the simulation results are consistent in a real environment[2].



Model-based turbocharger control – a common approach for SI and DI engines

A turbine model and a common control structure for the turbocharger for SI and CI-engines is developed. By using a common structure, development and calibration time can be reduced. The non-linearities have been reduced by using an inverted turbine model in the control structure, which consists of a PI-controller with feedforward. The controller can be tuned to give a fast response for CI engines and a slower response but with less overshoot for SI engines, which is preferable[3].



Diagnosis of a compressed air system:

The diagnosis system that is developed in this thesis is based on model based diagnosis and uses a recursive least mean square method to estimate the leakage area. The results from the validation show that the algorithm works well for leakages of the size 1-10 litres/minute. The innovative isolation algorithm gives full fault isolation for a five circuit system with only three pressure sensors[4].

[1]Model-based boost pressure control with system voltage disturbance rejection, Ivan Criscuolo, Oskar Leufven, Andreas Thomasson and Lars Eriksson, IFAC WC2011
[2]Enthalpy-based boost pressure control, Emil Hilding, Master Thesis
[3]Model-based turbocharger control - a common approach for SI and DI engines, David Elofsson & Erik Lindén, Master Thesis
[4]Diagnosis of a compressed air system in a heavy vehicle, Martin Kågebjer, Master Thesis