Modeling and Control of Co-Surge in Bi-Turbo Engines

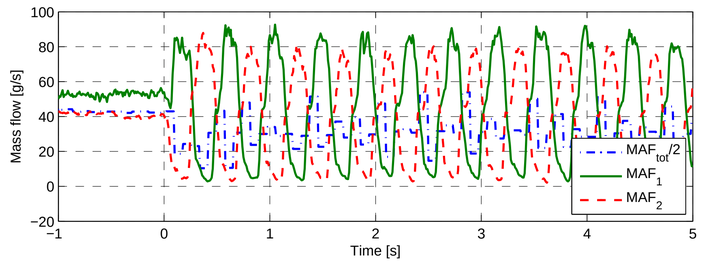
Andreas Thomasson and Lars Eriksson
(Vehicular Systems, LiU)

Why Bi-Turbocharged Engines?

More advanced turbocharging concepts are constantly being developed to increase power density, and to reduce fuel consumption and emissions of internal combustion engines. For V-type engines, using a bi-turbocharged configuration makes for better utilization of the exhaust energy and a faster torque response.

The Co-Surge Phenomena

In a bi-turbocharged engine the two air paths are connected before the throttle. If a disturbance alters the mass flow balance, when operating close to the surge line on an otherwise stable operating point, one compressor can be pushed into the surge region and the mass flow reverses.



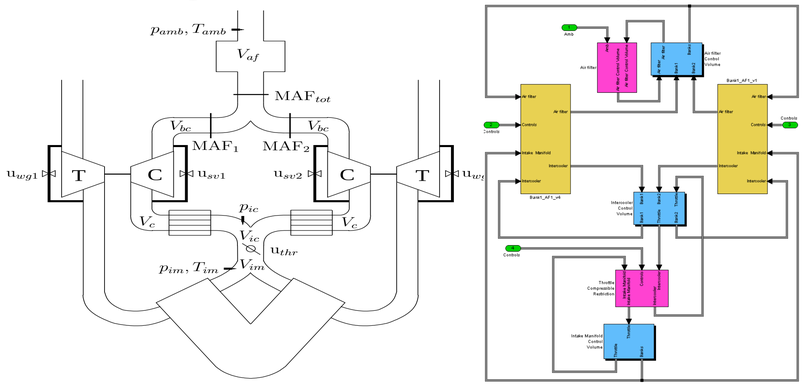
When the first compressor recovers it pushes the other into surge, starting an oscillation where the two mass flow alternately reverses.

Vehicle Dynamometer Setup

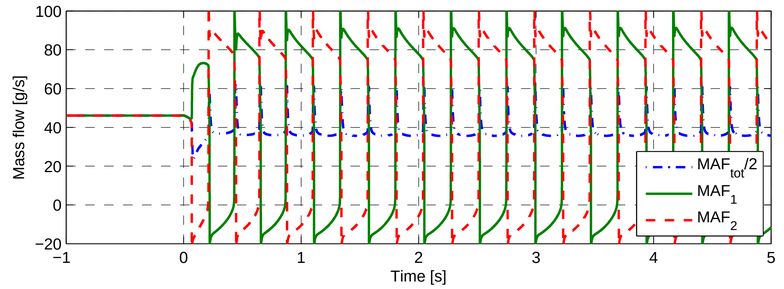
The experiments is performed in the new vehicle propulsion lab at Vehicular Systems. Electric wheel dynamometers gives the flexibility to do a wide variety of tests. In the measurement above they are used to keep a constant wheel speed to simulate tip-out behavior.

Mean Value Engine Model

To investigate the effect of different engine components on co-surge, a physical model of the system has been developed. The modeling approach taken is the component based Mean Value Engine Model.



To model surge the compressor model must handle the reverse mass flow. This is achieved by the well known and well tested More-Greizer model.



The simulation model manage to capture the qualitative behavior although the shape of the mass flow differs. The frequency is roughly the same and the pressure and turbo speed oscillation is very similar.

Co-Surge Detection and Control

To avoid co-surge the mass flows should be kept balanced. Still co-surge can occur when operating close to the surge line due to disturbances between the two mass flows. In that case the control system needs to detect the co-surge oscillation and take proper actions. The simulation model is used to evaluate detection and control algorithms, which are then tested in vehicle.