Electrically-Assisted Turbocharger Development for Performance and Emissions

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Turbocharger transient lag inherently imposes a tradeoff between a robust engine response to transient load shifts and exhaust emissions. By itself, a well-matched turbocharger for an engine has limited flexibility in improving this transient response. Electrically-assisted turbocharging has been seen as an attractive option to improve response and lower transient emissions.

This paper presents the results of a multi-year joint CRADA between DDC and ORNL. Virtual lab diesel simulation models characterized the performance improvement potential of an electrically assisted turbocharger technology. Operating requirements to reduce transient duration between load shift time by up to 50% were determined. A turbomachine has been conceptualized with an integrated motor-generator, providing transient burst boost plus energy recovery capability. Numerous electric motor designs were considered, and a prototype motor was developed, fabricated, and is undergoing tests. Power controls have been designed and fabricated.

Electrically Assisted Turbo-Charger Development for Performance and Emissions

Summary of CRADA # 1996-2000

Detroit Diesel Corporation,
Oak Ridge National Laboratory

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Outline

- **Motivation**
 - Transient Engine Operation
 - Engine & Turbocharger Matching
- **Transient Engine & Turbocharger Modeling**
 - Potential Improvements
 - Comparison of Results
- **Electric Machinery**
- **Power Electronics**
- **Status of Tests**

Motivation

- **Turbo Critical for Power density, Fuel economy, Emission and Driveability.**
- **Response Time during Transient Operation due to Turbine inertia.**
 - Improve driveability
 - Reduce engine smoke and high PM
- **Turbocharger Technology is a Key to Emission Reduction.**

HD FTP Transient Test

Transient Engine Operation
1st Quarter

Transient Engine Operation
3rd Quarter

Transient Engine Operation
2nd Quarter

Transient Engine Operation
4th Quarter

HD FTP Transient Test

FTP 3rd Quarter Operation

HD FTP Transient Test

Turbo Response

Turbochargers in Emissions Perspective

Electrical Turbo Assist

- Externally drive turbocharger during transient
 - Improve emission & performance at cost of BSFC
- Potentially Use Motor for Steady State BSFC Improvement.

ORNL - 1994 Sketch

Technical Approach - Virtual Lab

Baseline Engine During Transient Run

Simulated Baseline Transient Turbocharger Operation

- **Objective:**
 - up to 50% reduction in turbo spool-up time
- **What is the Motor Requirement?**

Ramp Acceleration Time for Two Typical Motors

Technology Comparisons Using Virtual Lab

10 HP Power Assist Gives 17% Reduction of Response

Electric Motor Design Goals : 10hp constant 20k-100k rpm

- **Motor/alternator options considered included**
 - Permanent magnet vs switched reluctance
 - Axial gap vs radial gap
- **Permanent magnet, radial gap, two-pole design selected, 1997.**
 - High power density and efficiency
 - Low polar moment of inertia
 - Shaft diameter can be larger
 - Facilitates design for high speed
 - Disadvantage is larger stator diameter

Electric motor major components

Preliminary motor performance results

Radial-Gap PM Turbomotor Power Test Data

Concluding Remarks

- **Electric Assisted Turbo is One of Promising Technologies to Achieve Fast Response.**
- **Motor & sensorless controller conceived, designed and developed.**
- **Demonstration hardware has been built and early validation achieved.**
- **Design enhancements have been identified which should lead to a more robust design.**

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