Introduction to the SuperTurbo

- Alternative approaches
- The SuperTurbocharger
  - Supercharging function
  - Energy recovery function
  - Rapid transient response
- Modeling work
- Experimental results
  - Part load
  - WOT
  - Transient operation
- First round challenges
- Where are we going next
Alternative Approaches

• Electric Turbochargers
  – Attractive features
    • Size
  – Drawbacks
    • Higher inertia
    • Thermal constraints
    • High current and high voltage

• Turbocompounding
  – Attractive features
    • Relatively simple
  – Drawbacks
    • Cost
    • Packaging/weight
Super Charging Mode

- Acceleration of the engine from low load to high load.
- Hydraulic pressure spools up the turbo.
- Creates a rapid throttle response.
- Compensates for an oversized turbine that would normally create a longer turbo lag time.
Energy Recovery Mode

- Without a waste gate the turbine energy exceeds the power needed by compressor.
- The high pressure switches to the other side of the Hydraulics.
- Up to 6% of engine power is added to the crankshaft at full throttle.
- Fuel efficiency is improved up to 5.6%.
SuperTurbo Benefits

• Supercharging
  – Improves load acceptance
  – Reduces soot emissions

• Turbo Compounding
  – Improves fuel economy
  – Controls backpressure

• Engine Down-sizing
  – 30% more low end torque available
  – Lower engine mass
Modeling Follow-up

- Simulated improvements in BSFC

SuperTurboCharger BSFC Improvement
Hyundai C6AB NG with Mitsubishi Turbocharger
Transmission efficiency - 60%

We'll come back to this point later
Assembly Drawing
Design Features:

Only a 20% increase to the inertia of the base turbocharger

Only a 50% increase in the length of the turbine shaft
Results

• Comparison between baseline engine with stock turbo and the SuperTurbocharger
  – Transient response
  – WOT performance
  – Fuel economy
Super Charging Results

Up Transient Performance

- Step change at 1600 rpm from 50 ft-lb to 400 ft-lb
- Dramatic reduction where turbo performance counts
Power Test Results

Wide Open Throttle Performance
- SuperTurbocharger as supercharger
  - Up to 1400 rpm acted as supercharger
- SuperTurbocharger recovered power
  - From 1600 to 2000 rpm power was returned to the crank
Efficiency Test Results

Part-load Fuel Economy
- Ran from 1000 to 2000 rpm
  - Min engine speed ~650 rpm, max engine speed ~2000 rpm
- Torque levels tested from 100 to 600 ft-lb
Exhaust System Changes

Turbine Backpressure Difference

Inlet pressure to the turbine at 1800 rpm represents more pumping work lost with SuperTurbo.
Transmission Challenges

Swash plate pumps are attractive until ...
Transmission Challenges

Now add in the efficiency of the gear pump …
Turbomachinery Selection

- Compressor matching could have been better
- This is real test data overlaid on the map
- Turbocharger choice was too big for this engine
Modeling Follow-up

Simulated Improvements in BSFC

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Transmission efficiency - 60%

% gains in BSFC

- 2000 rpm
- 1500 rpm
- 1000 rpm

0% 2% 4% 6% 8% 10% 12%

BMEP (bar)

We’re back to this point
Conclusion

• Dramatic improvement in transient response
  – Possible high level natural gas load acceptance
  – Reduced Soot spike on a diesel engine

• Fuel economy improvement encouraging
  – Parallel between modeling and experiment with appropriate transmission efficiency
  – Results hurt by poor performance of hydraulic transmission and the higher back pressure

• WOT results are encouraging

• New transmission alternatives under review

• Better turbo matching will improve performance
  – Requires better turbo matching to the engine than we have achieved in this first prototype
Future of Energy Recovery

- Elimination of waste gate losses.
- Reduction of throttling losses.
- More efficient turbine design (narrow rpm).
- More efficient compressor design (narrow rpm).
- Optimize backpressure to improve EGR loop.
- Lower speed to achieve greater efficiency.
- Optimum speed for the boost condition can be controlled for maximum compressor and turbine efficiency.
Diesel Engine Potential

• With a high pressure loop EGR system, the higher back pressure across the turbine can be recovered for better efficiency

• The supercharging benefit can lower the up transient Soot emissions

• The efficiency gains on a diesel will not be as big as on natural gas or gasoline engine because of the lower exhaust enthalpy

• The CO$_2$ reduction potential is substantial for the world, based on the much greater fuel use per year for trucks vs. cars
Next Generation Design
Thank you for your attention!

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Questions???