Diesel Turbo-compound Technology

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Improving the Fuel Economy of Heavy-Duty Fleets II
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Volvo D12 500TC

What is Turbocompound?

Key Components of a Mechanical Turbocompound System

- Exhaust
- Conventional Turbocharger Compressor
- Conventional Turbocharger Turbine
- Axial Flow Power Turbine
- Fluid Coupling
- Speed Reduction Gears
- Final Gear reduction to crankshaft
## How Turbocompound Works

- 20-25% of Fuel energy in a modern heavy duty diesel is exhausted
- By adding a power turbine in the exhaust flow, up to 20% of exhaust energy recovery is possible (20% of 25% = 5% of total fuel energy)
- Power turbine can actually add approximately 10% to engine peak power output
  - A 400 HP engine can increase output to ~440 HP via turbocompounding
  - However, due to added exhaust back pressure, gas pumping losses increase within the diesel, so efficiency improvement is less than T-C power output
  - Maximum total efficiency improvement is 3-5%
- Turbine output shaft is connected to crankshaft through a gear train for speed reduction
  - Typical maximum turbine speed = 70,000 RPM; crankshaft maximum = 1800 RPM
- An isolation coupling is required to prevent crankshaft torsional vibration from damaging the high speed gears and turbine
Turbocompound Thermodynamics

- When exhaust gas passes through the turbine, the pressure and temperature drops as energy is extracted and due to losses.
- The power taken from the exhaust gases is about double compared to a typical turbocharged diesel engine.
- To make this possible the pressure in the exhaust manifold has to be higher.
- This increases the pump work that the pistons have to do.
- The net power increase with a turbo-compound system is therefore about half the power from the second turbine.
  - E.G. for 10% power increase, there is a 5% efficiency improvement.
- The higher pressure in the exhaust manifold results in slightly more of the exhaust gases being trapped in the cylinder during scavenging.
  - This can be seen as a kind of internal EGR.
TURBOCOMPOUND ADVANTAGES

- High power density (more power for a given displacement)
- Good fuel consumption in right application
  - Best in highly loaded applications
  - Estimate of 3% less fuel consumption in long haul application
  - Minimal or negative impact at light load
- Very good engine response and drivability
- Since exhaust manifold pressure is increased above intake manifold pressure
  - Higher EGR-flow can be achieved more easily to facilitate low NOx emissions
  - The internal EGR mentioned earlier decreases NOx in a non-EGR engine
TURBOCOMPOUND ISSUES

- Gear train, fluid coupling, and power turbine add weight, complexity (reliability concern), and cost
- Minimal to negative efficiency gain in light load applications
- Exhaust energy decreases with cooled EGR due to energy extracted into cooling system.
  - Less energy available to power turbine
- Space requirements further constrain packaging of EGR and turbochargers
- Added complexity in Design, Control, Service
- Additional cooling of exhaust reduces the effectiveness of exhaust aftertreatment systems
  - May require more active regressions for particulate filter
  - Reduces the time when NOx systems are effective (LNA, SCR, or LNC)
Electric Turbocompound Alternatives

E Turbocompound System:
- Instead of driving mechanically through a gear train, the turbine output shaft is connected to an electrical generator.
- Power can be fed into the vehicle electrical demand or stored in batteries.

Advantages of ETC
- Increases ability to control turbine power output and speed independently of engine load and speed
- Can use motor/generator to speed up turbo when desired
  - Potential for better performance and emissions control

Separate Turbine with Generator
- Adds flexibility in locating and packaging
- Increases control flexibility

Integrated into Turbocharger Bearing Housing
Electric Turbocompound with Electric Auxiliaries and Mild Hybrid for Long Haul Trucks

Advantages of Combined System

- Electric Auxiliaries can be modulated to meet system demand
- Mild hybrid motor takes electric capacity above auxiliary requirements
- Energy Storage can be used to run auxiliaries needed for hotel function to avoid idling for driver needs.
- Increase fuel savings up to 10% depending on idling reduction savings

Electric Auxiliaries Possible

- Cooling pump
- Oil pump
- Cooling fans
- Power steering
- Air conditioning
- Air compressor
- Hotel power supply

Issues

- Significant increase in cost and complexity
- Added weight
- Need better batteries

Energy storage: Battery, ultracap
Turbocompound Production Status

Many Engine Manufacturers have or will have Turbocompound Engines:

- **Detroit Diesel** announced TC available in USA on new DD15 engine.
- **Iveco** in production for Case-New Holland (off-highway).
- **Scania** in production (Euro only).
- **Cummins, CAT, Merceded, and International** have demonstrated technology.
Turbocompound Future
Expect to see more application due to:

- Fuel Costs
- Lower CO\textsubscript{2}
- Electrification of Auxiliaries
- Better control capability

Thank You!