Diesel Turbo-compound Technology

ICCT/NESCCAF Workshop

Improving the Fuel Economy of Heavy-Duty Fleets II

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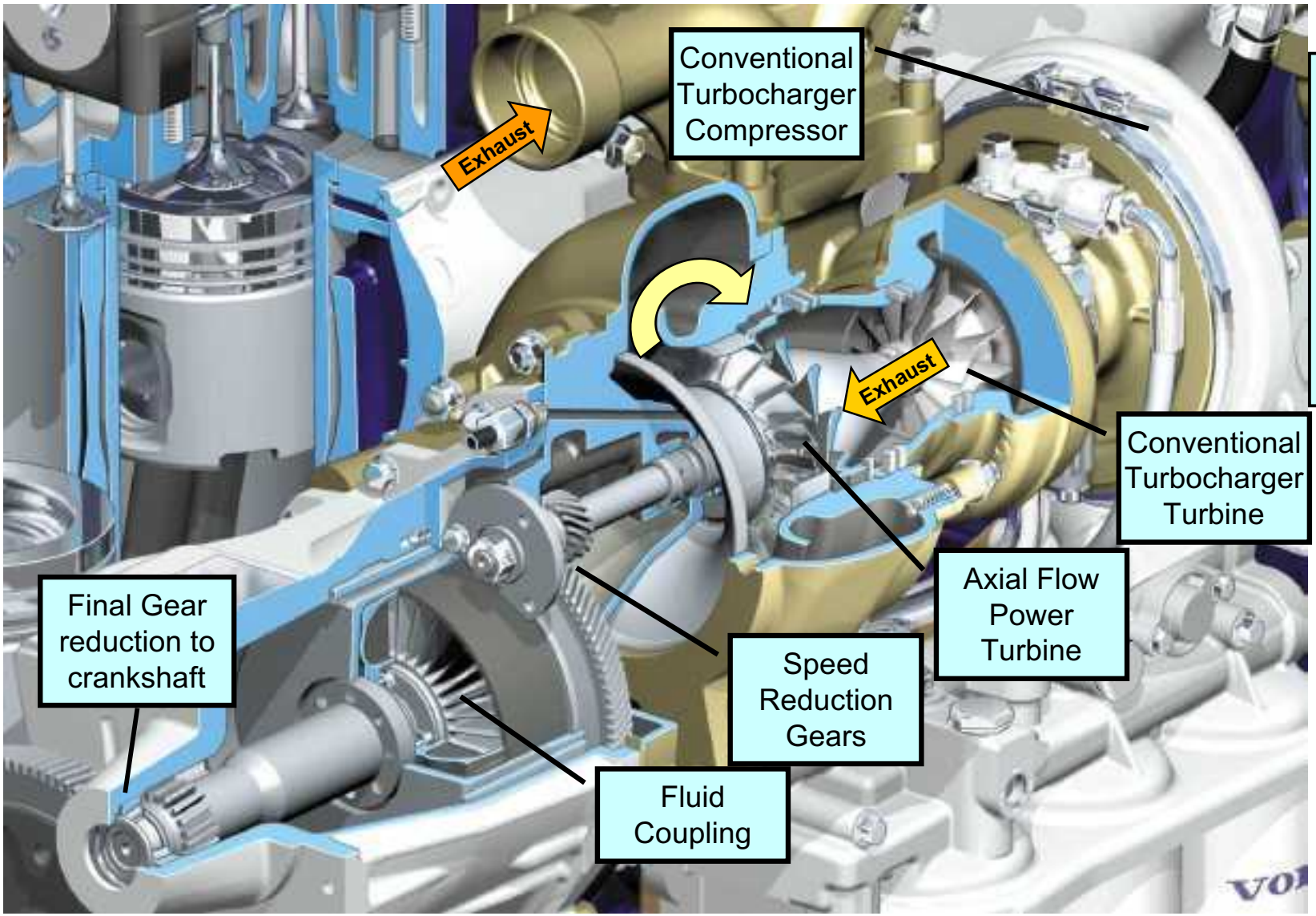
Volvo Powertrain Corporation
Anthony Greszler



What is Turbocom

Key Comp of a Mecha Turbocom System

Volvo D12 500TC

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 th 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 high
- 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

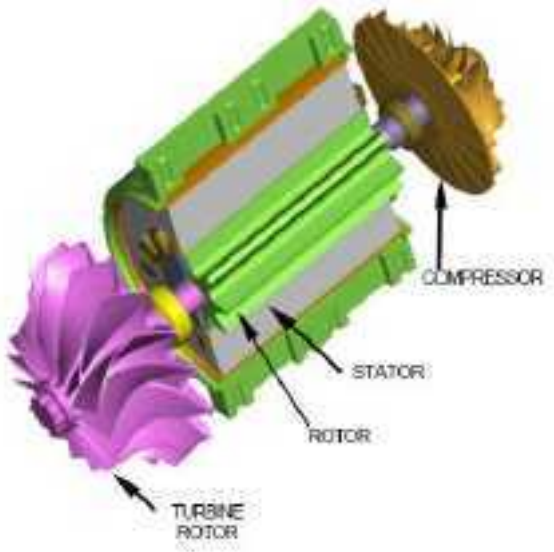
TURBOCOMPOUND ADVANTAGES

- 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

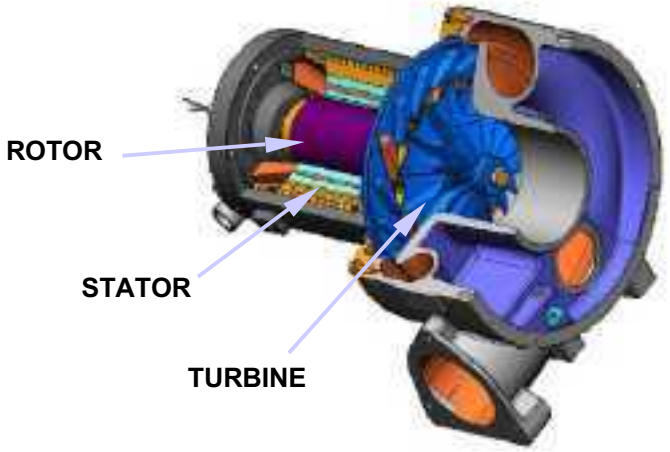
TURBOCOMPOUND ISSUES

- 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 turbocharge
- Added complexity in Design, Control, Service
- Additional cooling of exhaust reduces the effectiveness of exhaust aftertreatment systems
  - May require more active regenerations for particulate filter
  - Reduces the time when NOx systems are effective (LNA, SCR, or LNC)

Electric Turbocompound Alternatives



Integrated into Turbocharger Bearing Housing



Separate Turbine with Generator

- Adds flexibility in locating and packaging
- Increases control flexibility

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

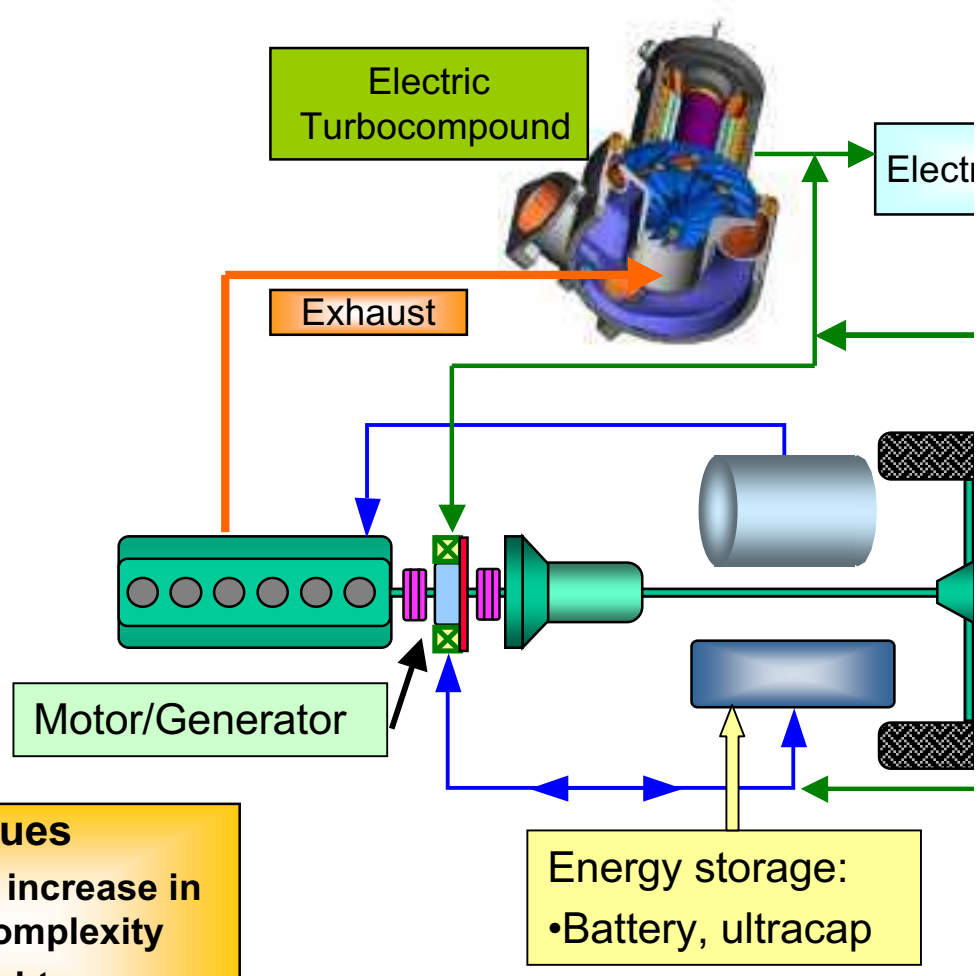
Electric Turbocompound with Electric Auxiliaries a
Mild Hybrid for Long Haul Trucks

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**

Turbocompound Production Status

Volvo D12 500TC

Detroit Diesel TC Engine for US07

Many Engine Manufacturers hav or will have Turbocompound E

- **Volvo produced D12 500TC from 2002 2006 (Euro only). Working to develop new Volvo D13**
- **Detroit Diesel announced TC available in USA on new DD15 engine**
- **Iveco in production for Case-New Holl (off-highway)**
- **Scania in production (Euro only)**
- **Cummins, CAT, Merceded, and Interna have demonstrated technology**

Turbocompound Future

Expect to see more application due to:

- Fuel Costs
- Lower CO_2
- Electrification of Auxiliaries
- Better control capability

Thank You!

FH truck with D12 500TC