Ethanol Boosted Turbo Gasoline Engines: Diesel Equivalent Efficiency, Clean And Low Cost

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Objective:
Highest Efficiency Gasoline Engine

Replacement of a standard gasoline engine…

… with a much smaller, turbocharged engine with same or greater power

Highly turbocharged, high compression ratio

On-Demand Octane Boost Removes Knock Limit on Engine Performance

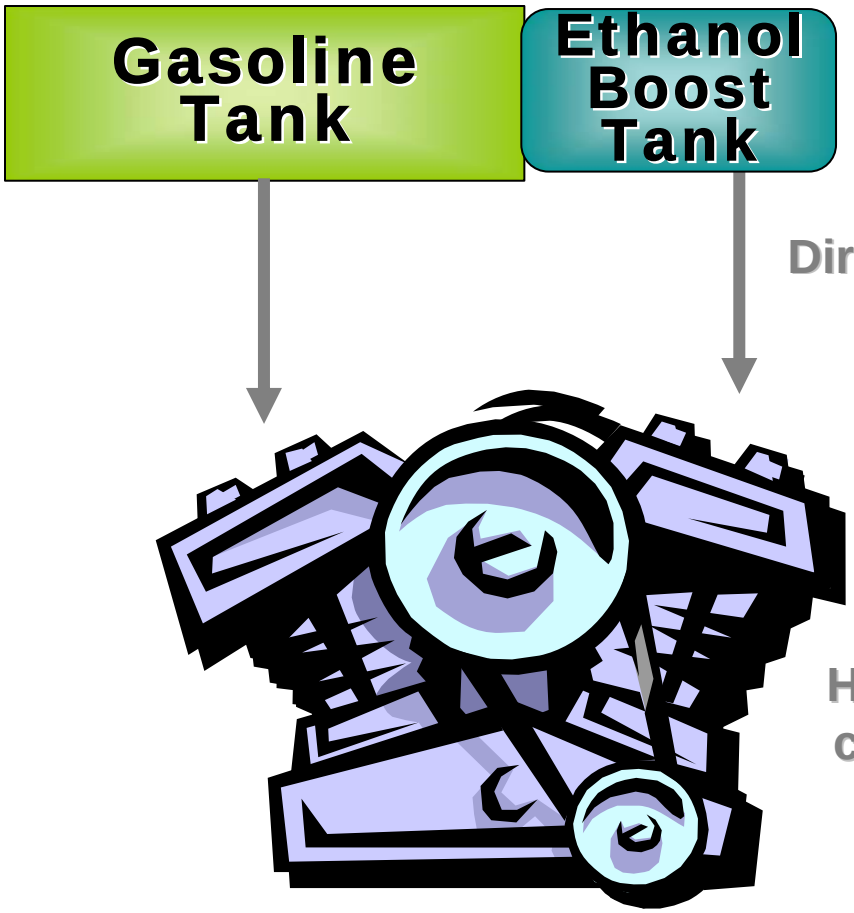
- Directly injected ethanol essentially removes knock limit
- Allows highly turbocharged, high compression ratio operation
- Ethanol provided by second tank or fuel compartment (can be in form of E85)
- Ethanol consumption can be intentionally minimized by using only at higher levels of torque where knock would otherwise be a problem
- Equivalent to an on-demand octane increase to >150 octane rating

Turbo-Diesel Equivalent Efficiency And Performance At Low Cost

Baseline Naturally aspirated PFI at comparable torque	Gasoline Turbo Direct Injection (GTDI)	Ethanol Boost Turbo Gasoline	Clean Turbo Diesel
Efficiency gain ☆ relative to gasoline PFI	10 - 15% (15% - premium gas)	25 - 30% (regular gas)	25 - 30%
Vehicle air pollutant emissions	Very low (can be lower than diesel)	Very low (can be lower than diesel)	Needs advanced exhaust treatment
Power relative to gasoline PFI	~ same	~ same or greater	~30% less
Extra fluid additive	——	Ethanol	Urea
Additional cost rel to gasoline PFI	~$1,000	~$1,400	$3,000 - $4,500

☆ **Efficiency in miles/BTU or miles/kg CO_2**

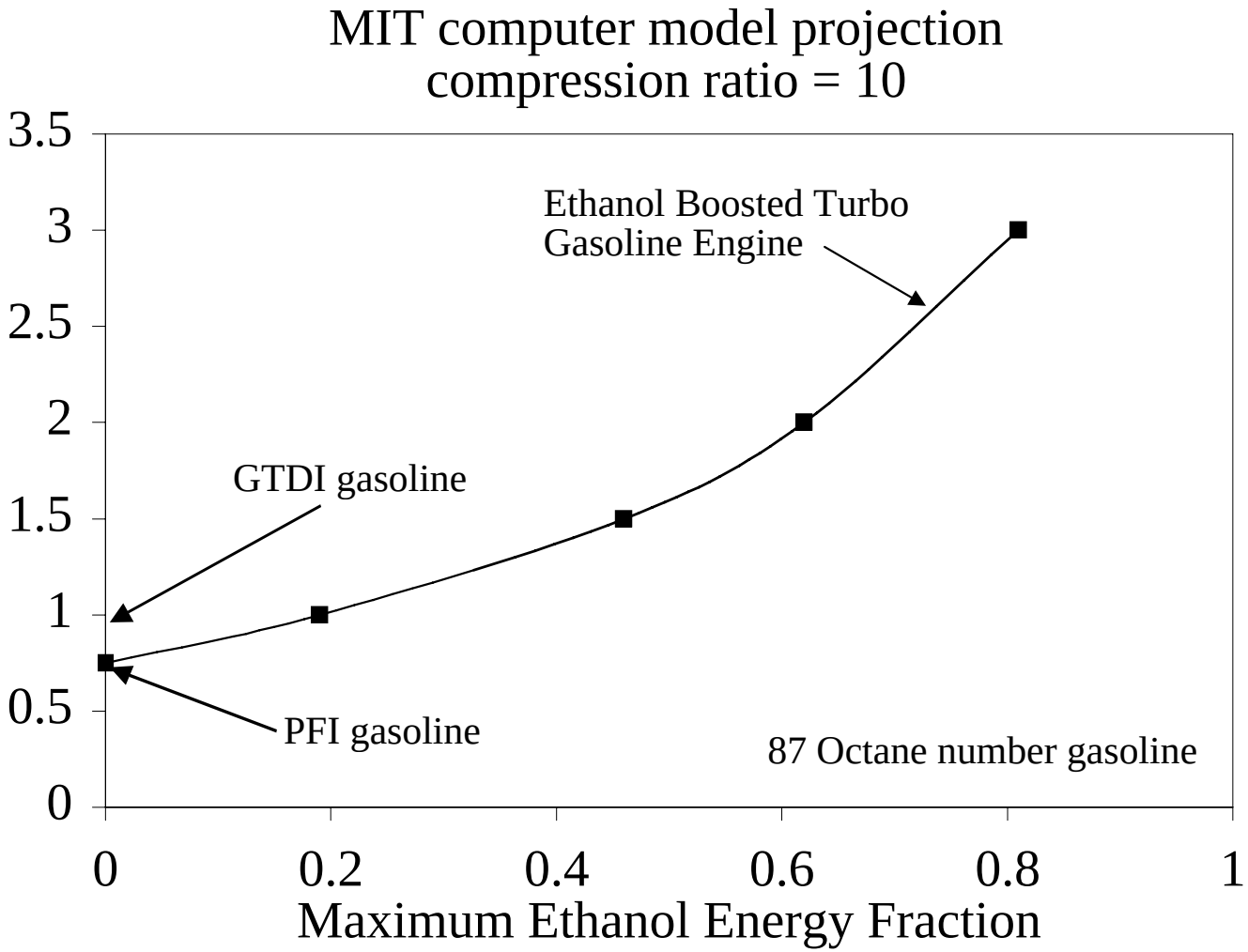
On-Demand Octane Boost Using DI Ethanol Injection



Direct Injection suppresses knock at high torque

Highly turbocharged, high compression ratio engine

Large Projected Increase in Knock-Free Manifold Pressure And Torque



Ethanol Requirements

- Special fuel management system provides capability to limit required ethanol consumption to a small fraction of gasoline consumption over a drive cycle
  - Initial system (PFI regular gasoline, DI ethanol): 5% or less
  - Advanced system: 2.5% or less
- Illustrative ethanol (E85) consumption (4% ethanol use)
  - 10 gallons/5000 miles for large pick up truck
  - 5 gallons/5000 miles for sub-compact car

Ethanol Boost Tank Refill Options

- Refill with ethanol (E85) every 4 to 6 months at dealer, garage (similar to proposed urea refill for diesel SCR)
- Service station attendant or driver refills using containers
- Refuel using E85 pumps where available (could also use E85 in primary tank and operate as flex fuel vehicle)
- In worst case of no ethanol/E85, vehicle would still be highly drivable with less than maximum torque/power (use would not be prohibited by EPA as in case of urea-SCR diesel)

Illustrative Applications

- Large engines for SUVs, light-medium duty trucks (*e.g.* $\geq$ 5 liter)
  1. Replace diesel engines with lower cost, cleaner and more powerful gasoline engines
  2. Replace present gasoline engines with much smaller engines that provide at least 25% greater efficiency and 25% more torque

- Small engines for cars (*e.g.* 2 liter or less)
  1. Replace present gasoline engines with much smaller engines that can provide very high mpg plus higher torque

     (*e.g.* increase mpg from 36 mpg to 45 mpg)
  2. Provide much greater power/torque

     (*e.g.* 330 hp, 360 ft-lbs peak torque from 1.9 liter engine)

Commercialization

- Ethanol Boosting Systems, LLC (EBS) spun-off from MIT in 2005

- EBS team:
- Dr. Paul N. Blumberg, Vice President (formerly Ford)
- Dr. Leslie Bromberg (MIT)
- John Casesa, Andy Shapiro (Casesa Shapiro Group)
- Dr. Daniel R. Cohn, CEO (MIT)
- Dr. John B. Heywood (MIT)
- Sen. (ret.) J. Bennett Johnston
- Dr. Neil W. Ressler (formerly Ford)

EBS Commercialization Plan

- Verification- engine measurements at Ford confirmed large increases in knock-free torque consistent with predictions of MIT computer model
- Build on growing interest by auto and truck manufacturers
- Collaborative R & D programs leading to prototypes and further advancements
- Licensing
- EBS production vehicle target : 2012