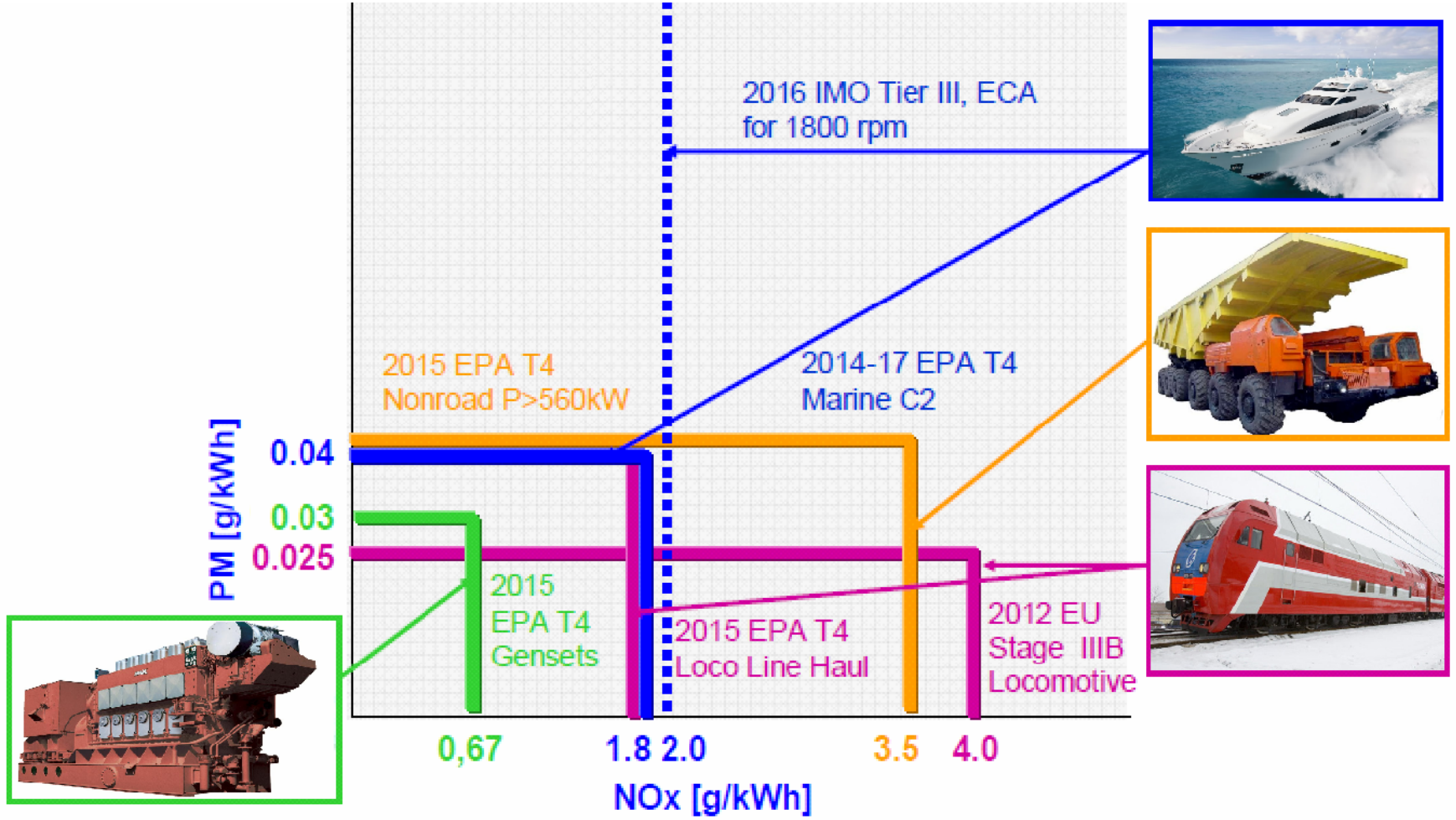
Optimization of engine parameters to meet the 2012 EU Stage III B

Use of DIESEL-RK to search for optimum technical solutions, to emissions control corresponding with 2012 EU Stage IIIB regulations.

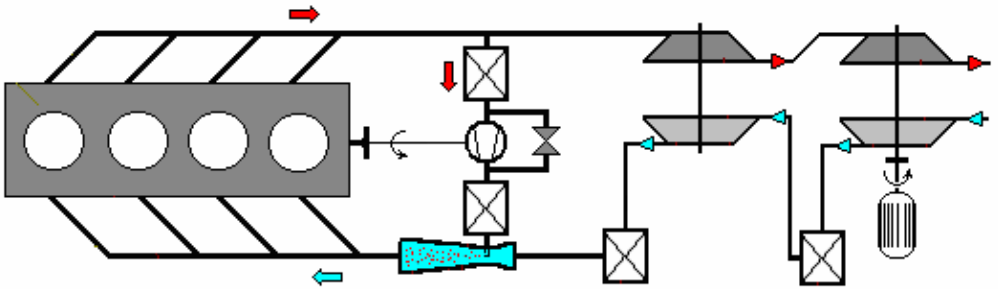
Limits for locomotive diesels: NOx + CH < 4 g/kWh; PM < 0.025 g/kWh



Optimization of engine parameters

Object : A locomotive diesel engine with PMEP = 26,0 bar @ 1000 RPM

Layout :



Boost : Two-stage electrically assisted turbocharger with total PR ~ 5.8

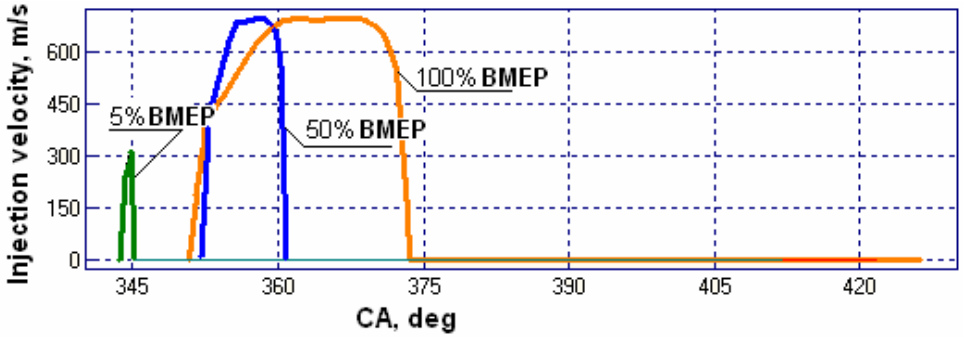
EGR : Venturi nozzle + mechanically driven EGR pump; EGR ratio ~ 0,22

Miller cycle : IVC ~ 10^0 before BDC (allows decrease SFC on 5-7 g/kWh)

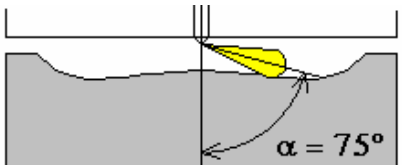
Fuel Injection System : CR with maximum rail pressure ~ 1800 bar

Injection profile : optimal shape:

Injection timing : optimal at every operating mode



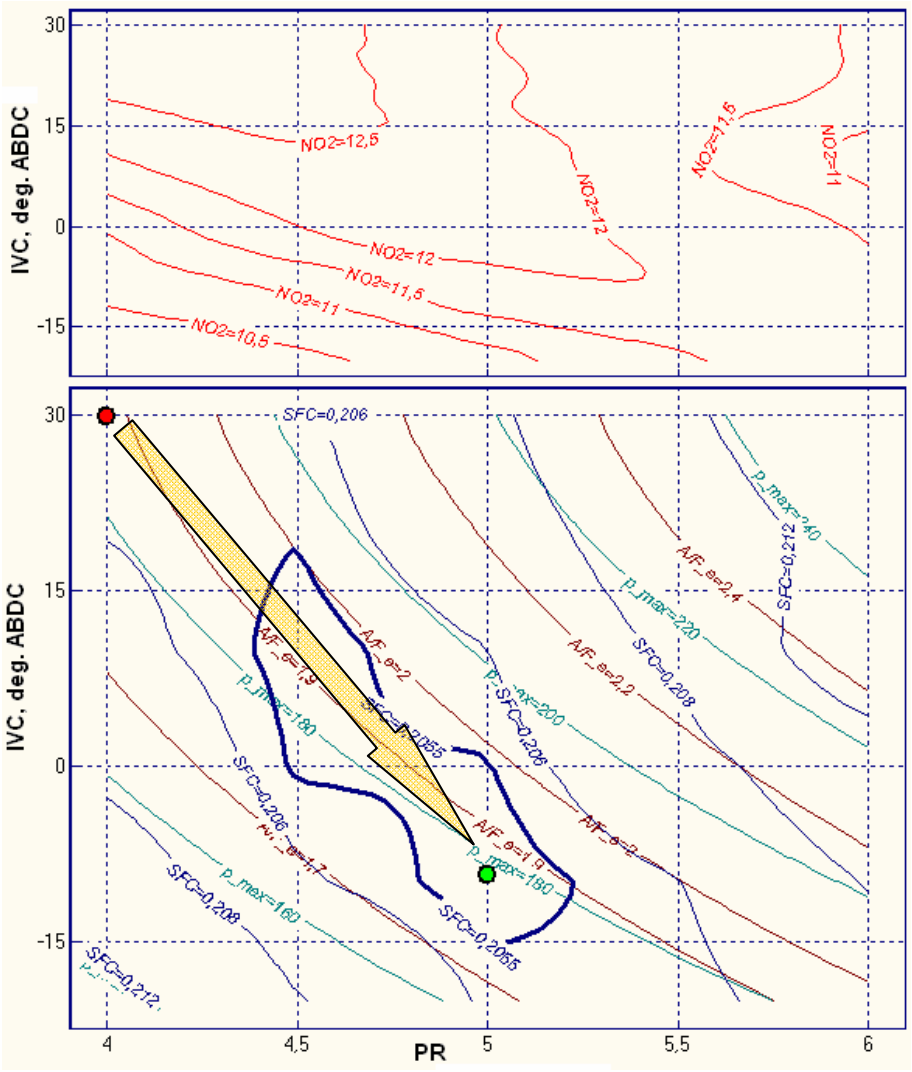
Injector design : should be matched with piston bowl and optimized together with parameters noted above.



Optimization of engine parameters

Miller cycle ⇒ ΔSFC = -5...7 g/kWh, ΔNOx = -0,8 g/kWh

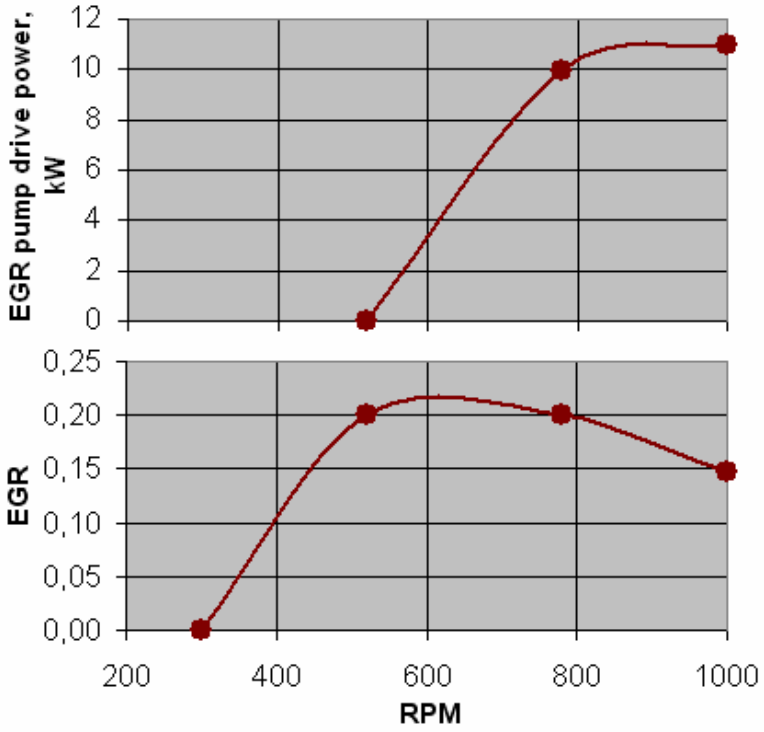
EGR 0,15 … 0.2 ⇒ NOx < 3,5 g/kWh



Effect of a Miller cycle and EGR on required boost compressor pressure ratio

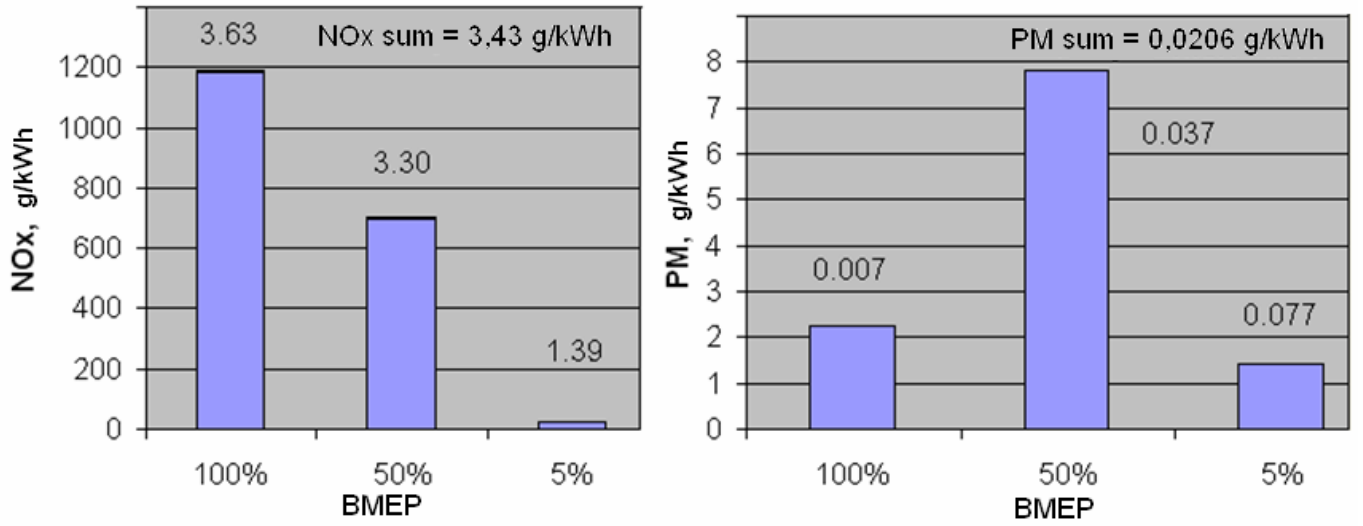
$$PR = 4_{norm} + 1_{Miller} + 0.9_{EGR} = 5.9$$

EGR control at locomotive performance



Optimization of engine parameters

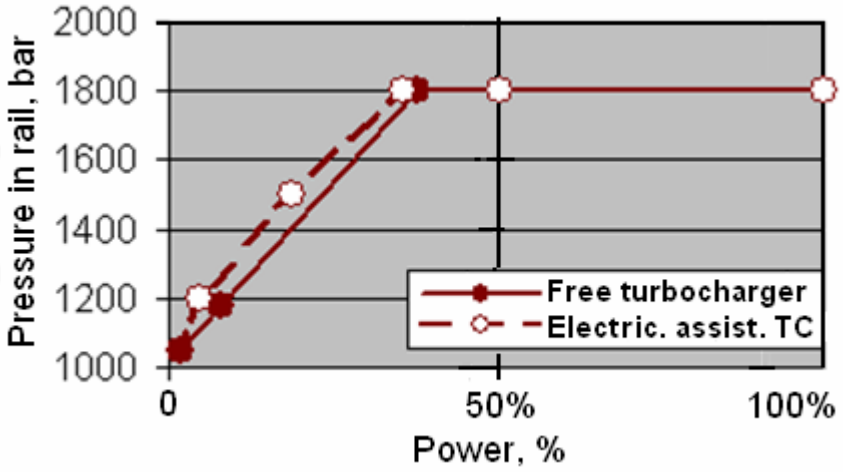
Contribution of different operating points into total emission

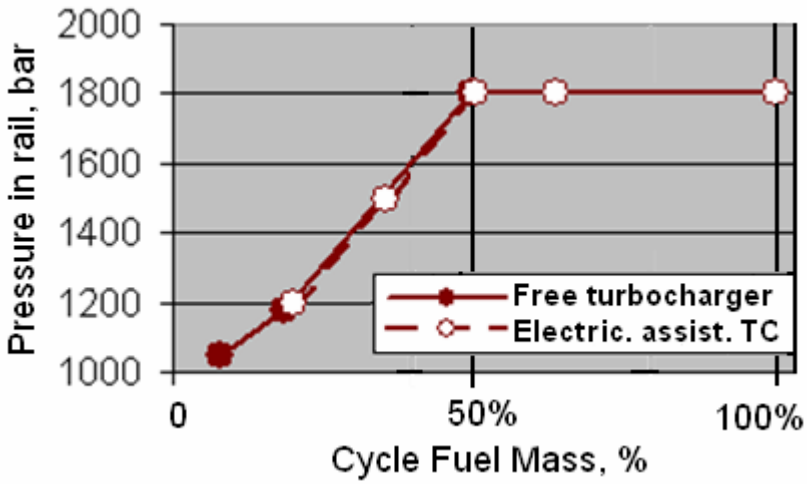


At the part load operating points the Rail Pressure has to be increased

to

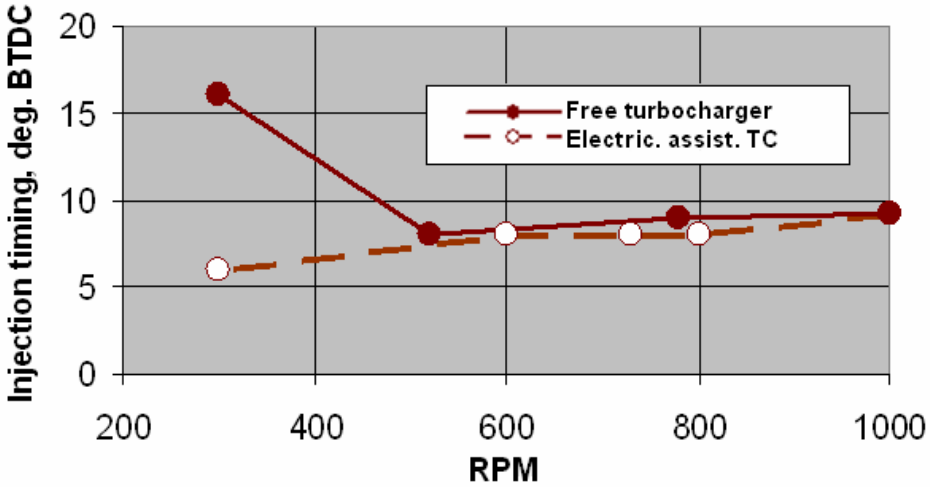
decrease SMD and PM emission





Optimization of engine parameters

Injection timing is optimized at every operating point to reach minimum SFC and bound emissions.

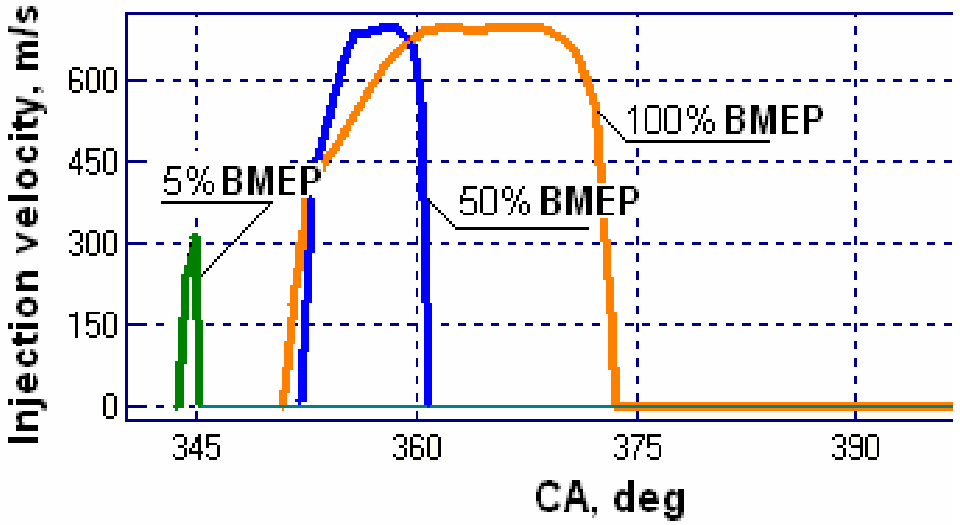


Injection profile shaping

1. Back front of injection profile should be as rapid as possible to minimize amount of fuel injected under a small pressure and having large SMD.

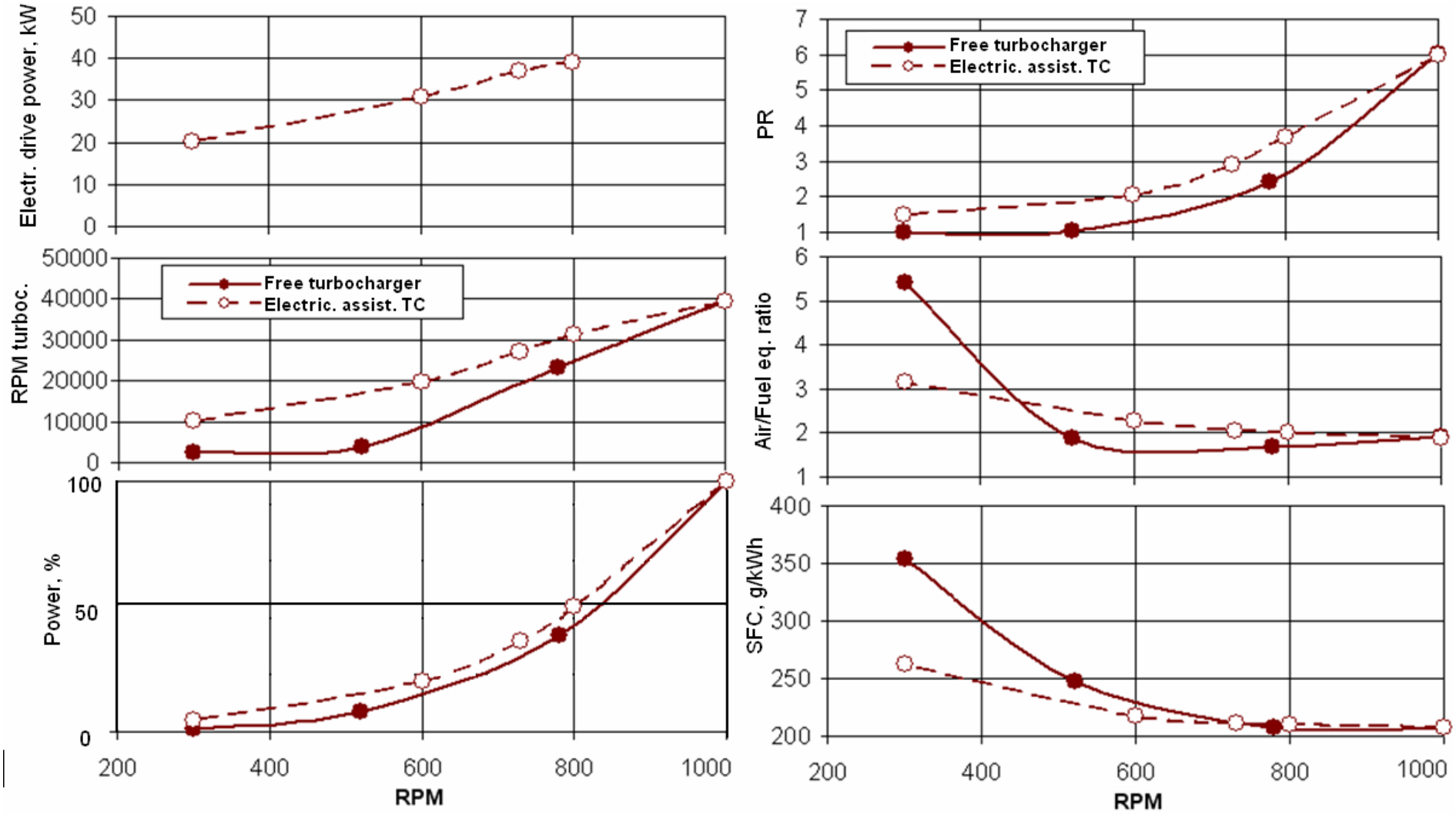
2. Forward front of injection profile should have 2 phases:

- "Rapid pitched" phase:
  - to minimize amount of fuel injected under a small pressure and having large SMD.
- "Low-pitched" phase:
  - to limit amount of fuel injected at the delay period,
  - to limit pressure rise and maximum cylinder pressure,
  - to bound NOx emission.



Optimization of engine parameters

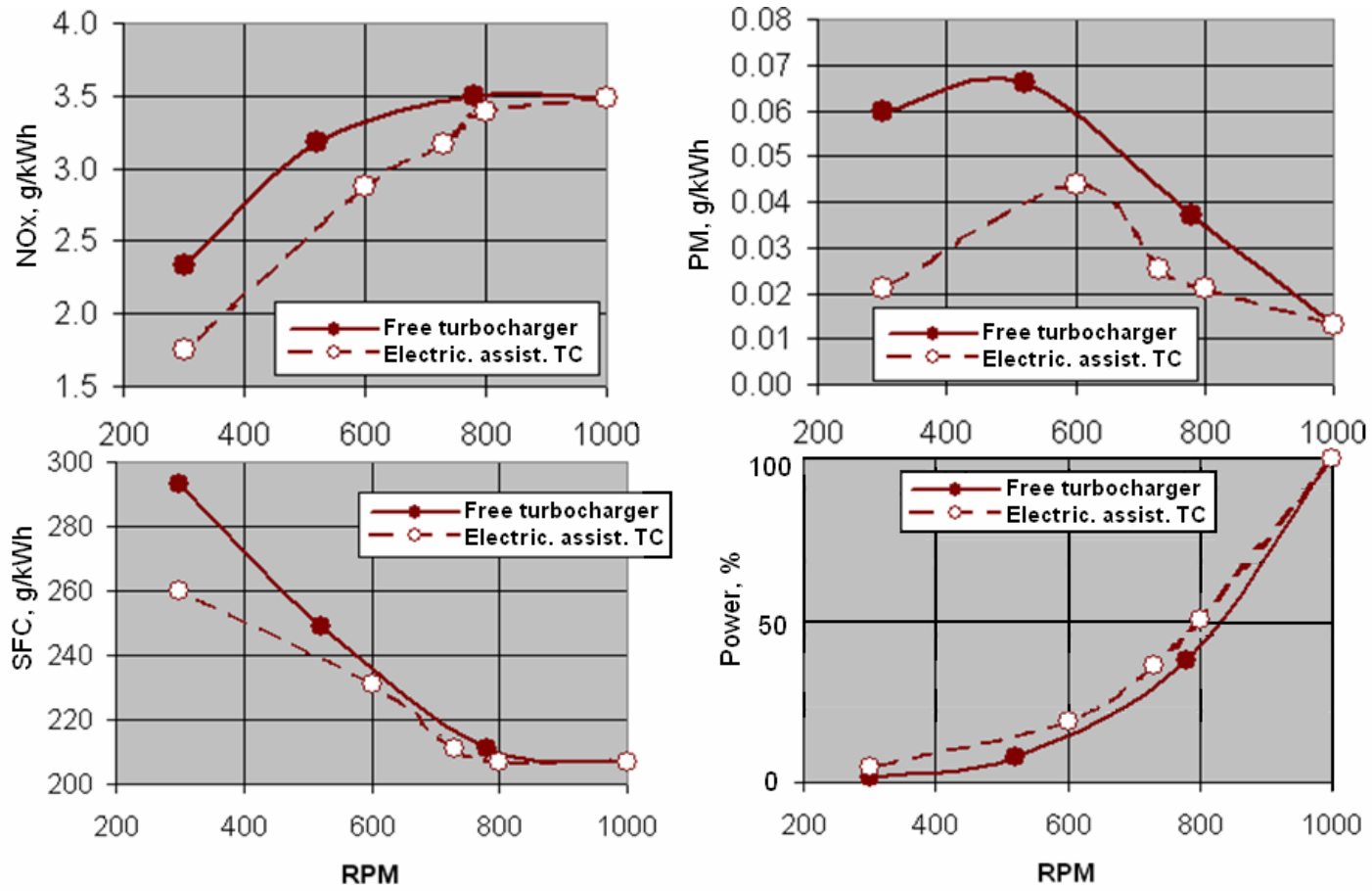
Electrically assisted turbocharger



Optimization of engine parameters

Electrically assisted turbocharger allows:

- Refuse mechanism of variable valve timing (keep Miller cycle at low loads).
- Increase power at part loads.
- Decrease SFC, PM and NOx emissions at part loads.



Optimization of engine parameters

Sequence of optimization:

1. Miller cycle parameters optimization for full load (IVC, Boost).
2. Matching of nozzles number and their orientation with Piston Bowl at Full Load point.
3. Common optimization of Boost, CR, Injection timing, Nozzles diameter, Rail pressure and EGR at Full Load. The target function is complex:

$$SE = MAX\left(1, \frac{NOx}{NOx_0}\right)^{n1} + MAX\left(1, \frac{PM}{PM_0}\right)^{n2} + \frac{SFC}{0.2} \quad ,$$

   where PM_0 and NOx_0 are specified so, to decrease critical values of corresponded emissions contributions into total emission.
4. Design of fuel injection system to provide required injection profile. Prediction of injection profiles at Part Load and Idling. Iteration of item 3.
5. Formation of turbine and compressor maps for simulation of the engine performance accounting turbine and compressor behavior.
6. Common optimization of Injection timing, Rail pressure and EGR at Part Load operating points.
7. Common optimization of Injection timing and Rail pressure at Idling.
8. Research of Electrically Assisted Turbocharger effect.

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Conclusions:

1. It is necessary to carry out complex optimization of Boost, EGR, Valve Timing, CR, Fuel Injection Profile, Sprayer Design, Piston Bowl Shape to make an engine passing modern standards. All these parameters should be optimized together for every operating point.

2. Making these optimization by computer simulation the software should have:
   - advanced combustion model and advances emissions formation models including detail chemistry simulation;
   - small computational time;
   - library for automatic multidimensional optimization.

3. DIESEL-RK can do it all, within a short timing and budget.

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