New Compressor Concept Improves Efficiency and Operation Range

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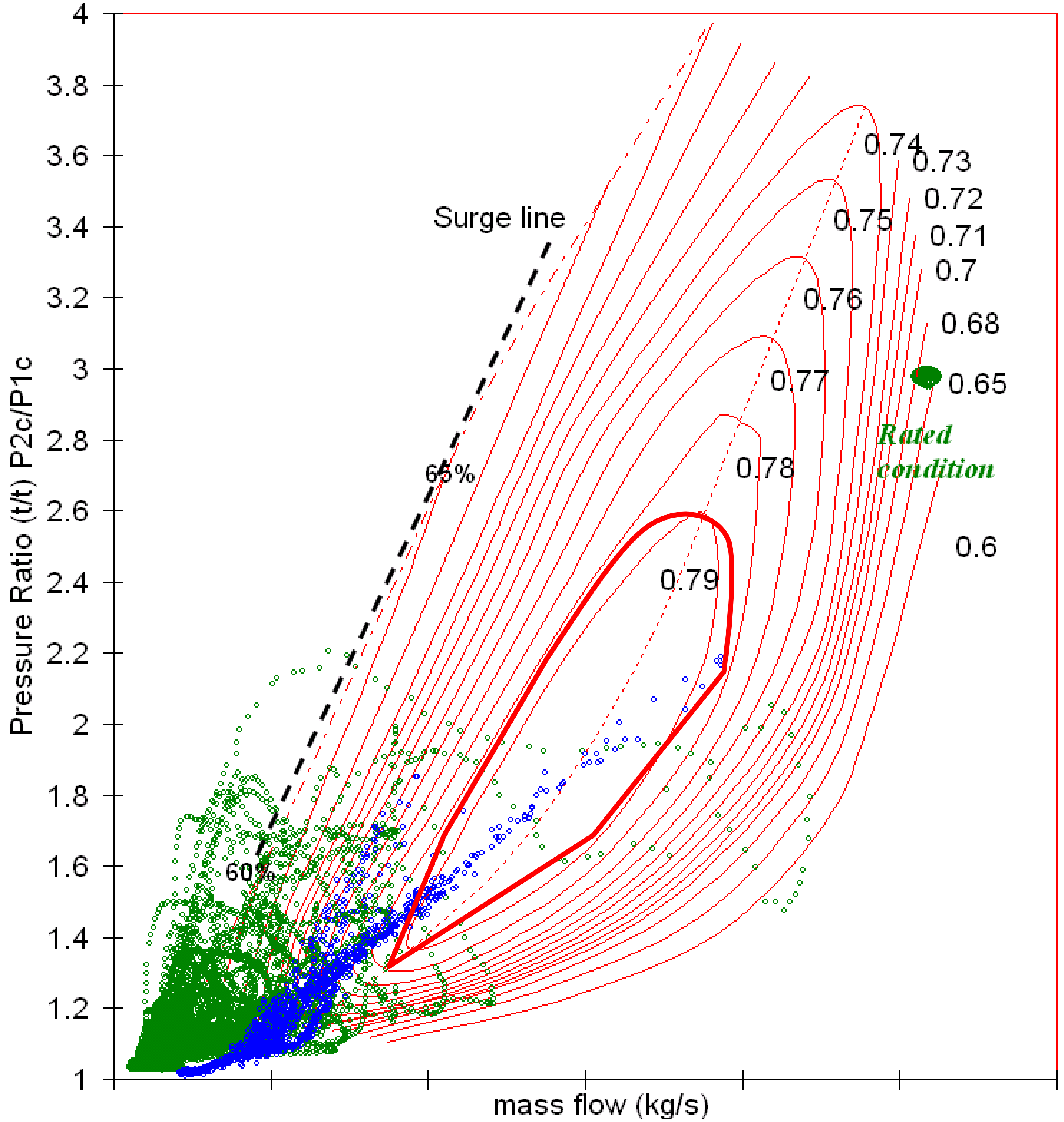
Emission regulation:
Heavy EGR needed for LTC pushes the operation points into less efficient or even surge area

Market competitiveness:
Bigger: for high power
Better: at customer driving cycles

Objectives:
2-3% fuel economy improvement on customer driving cycles and 15-20% extension of turbo operation range



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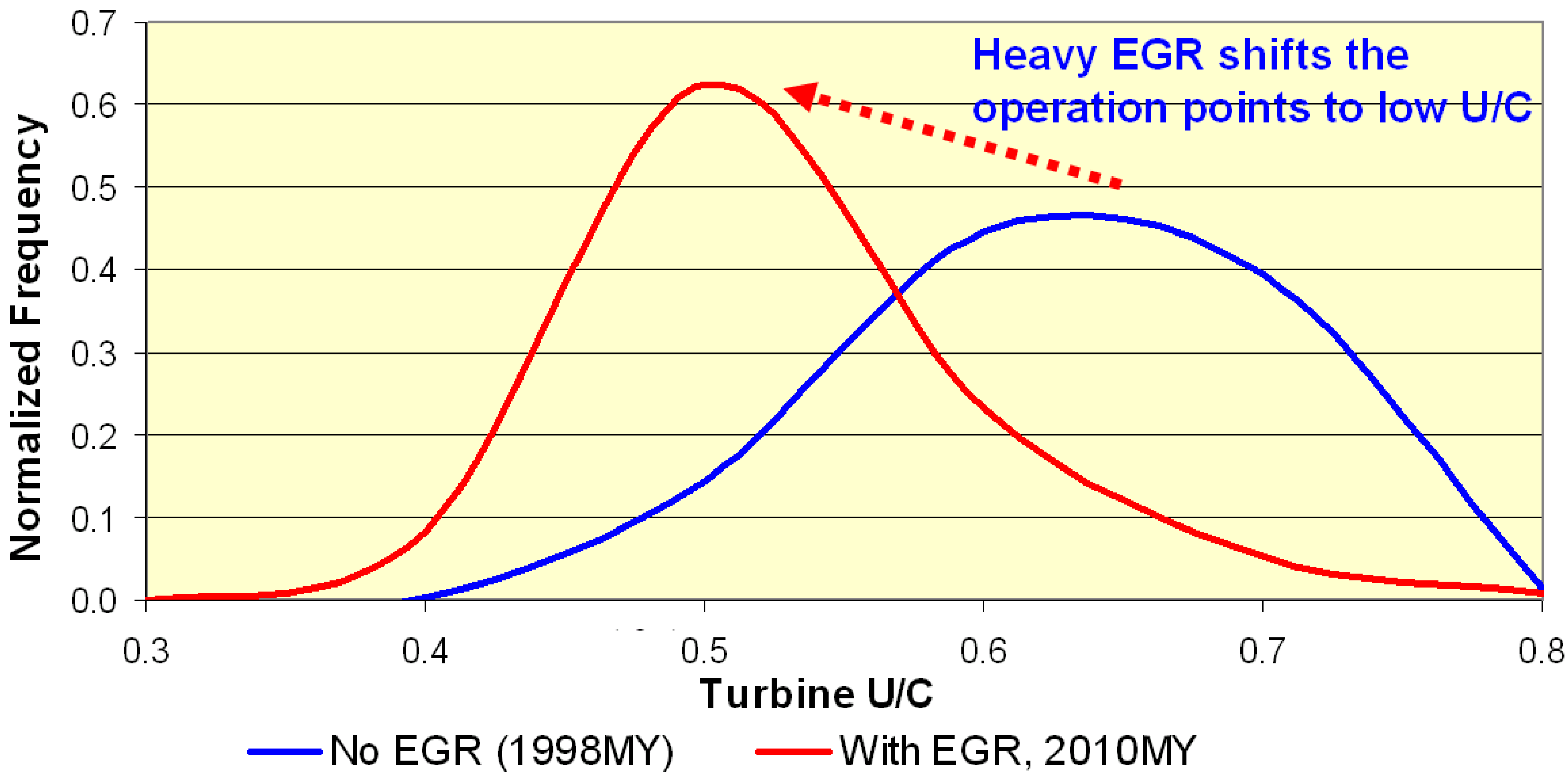
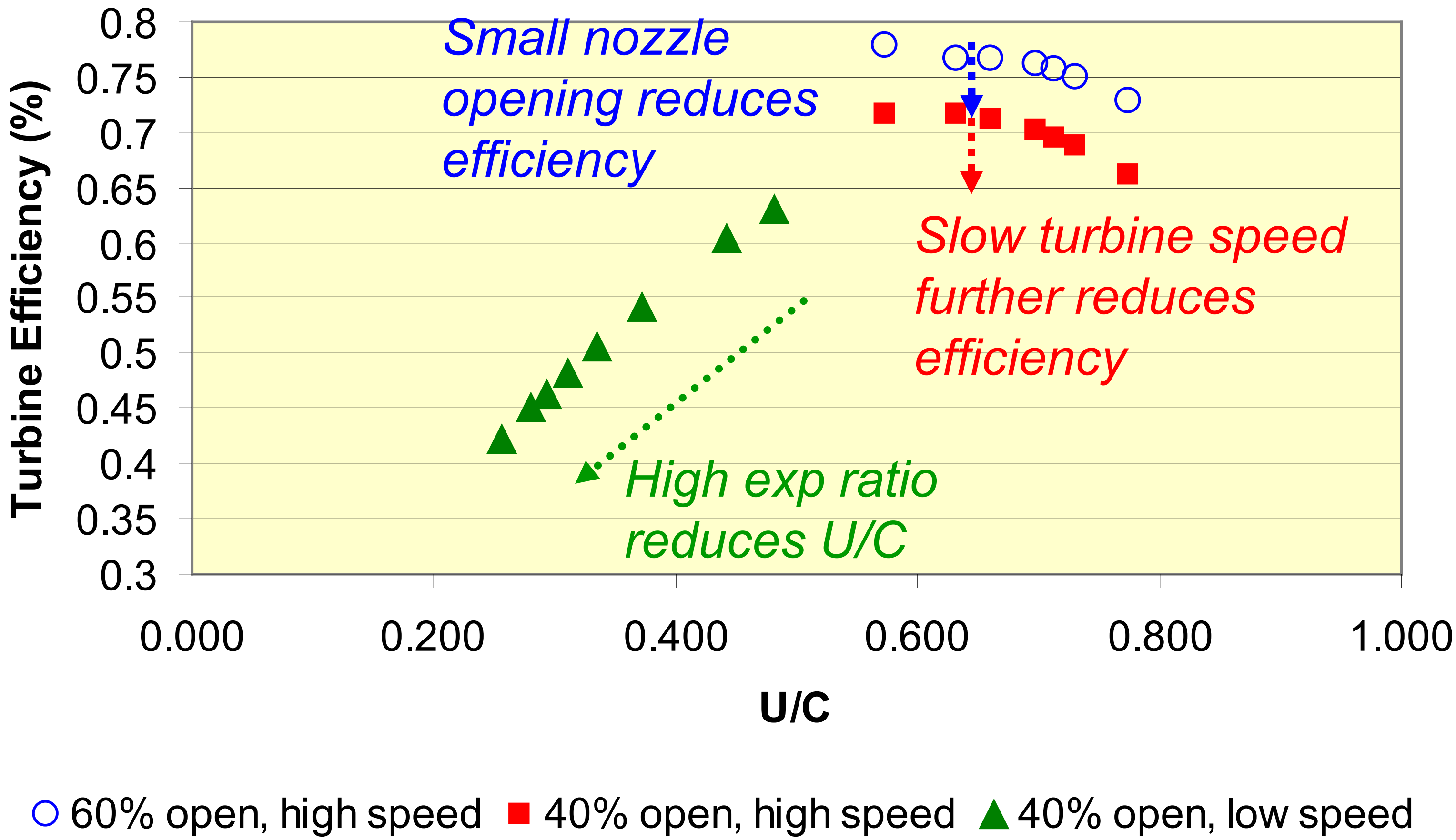
Turbine Speed Ratio (U/C) Distribution over EPA City Cycle



As more EGR is used for NOx reduction, turbine spends more time in low U/C area. Conventional turbine blade, optimized for low/none EGR applications 10-15 years ago, performs well at high U/C but not at low U/C. Therefore future diesel application requires that turbine should have high efficiency in low U/C areas.

Turbine Efficiency vs. U/C

$$\frac{U}{C}=\frac{U}{\sqrt{2C_pT_0\left[1-(\pi_T)^{-0.285}\right]}}$$



Conventional radial flow VGT has low efficiency at small nozzle open positions and low U/C. Heavy EGR, bigger turbo pushes part load turbine operation points into less efficiency areas

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Ford

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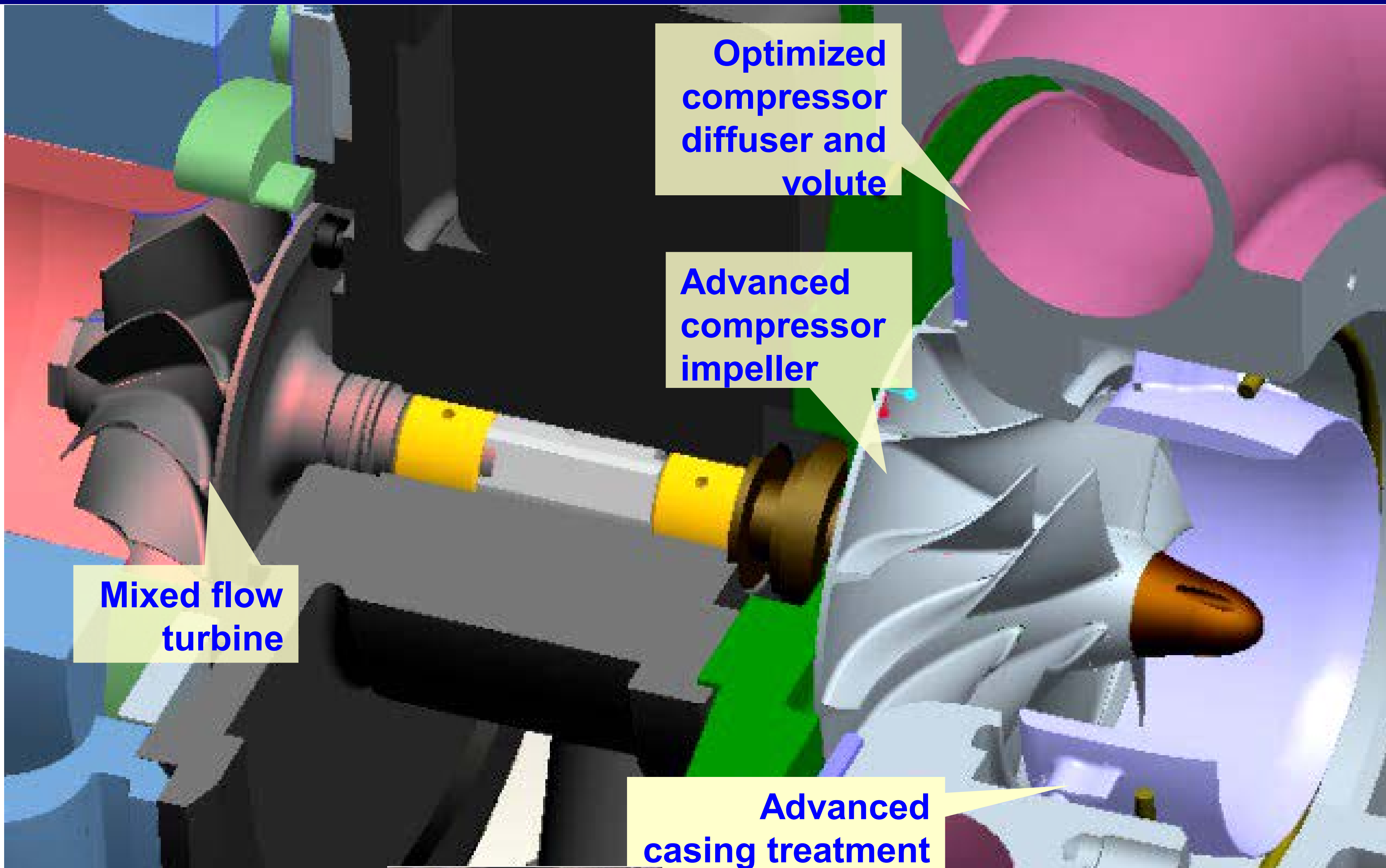
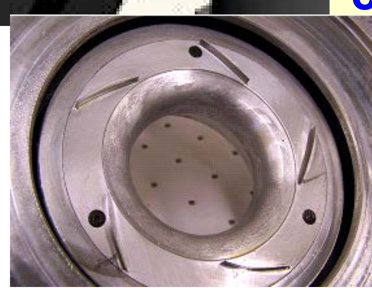
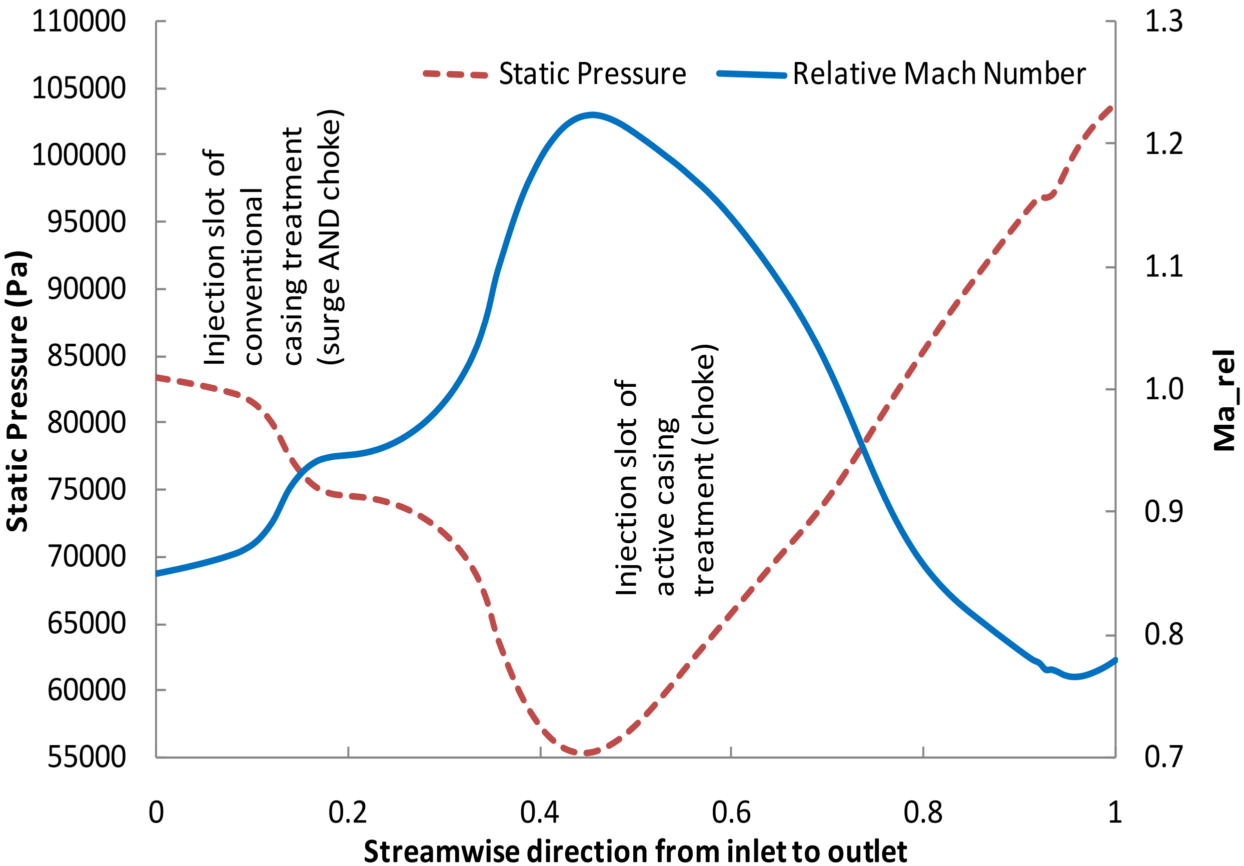
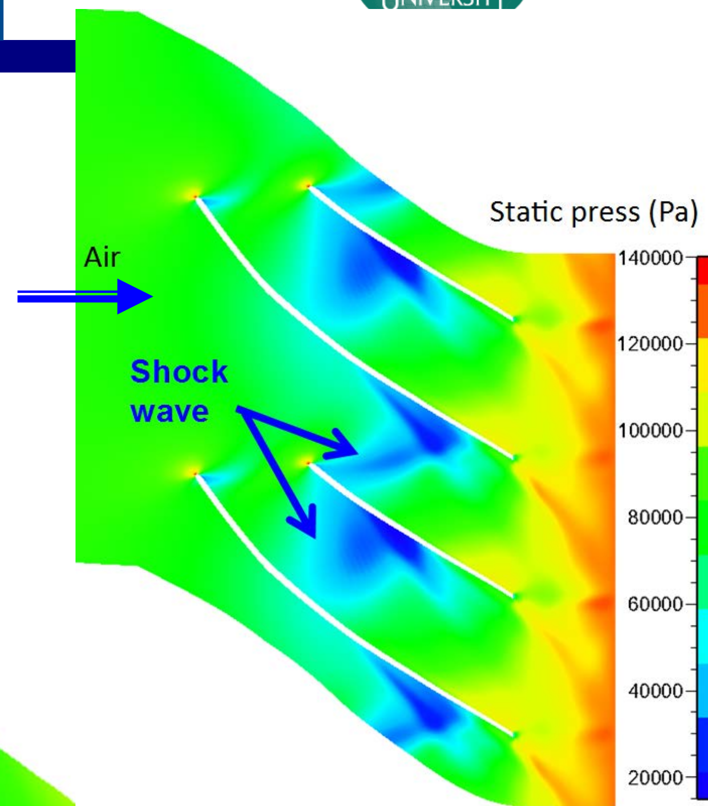
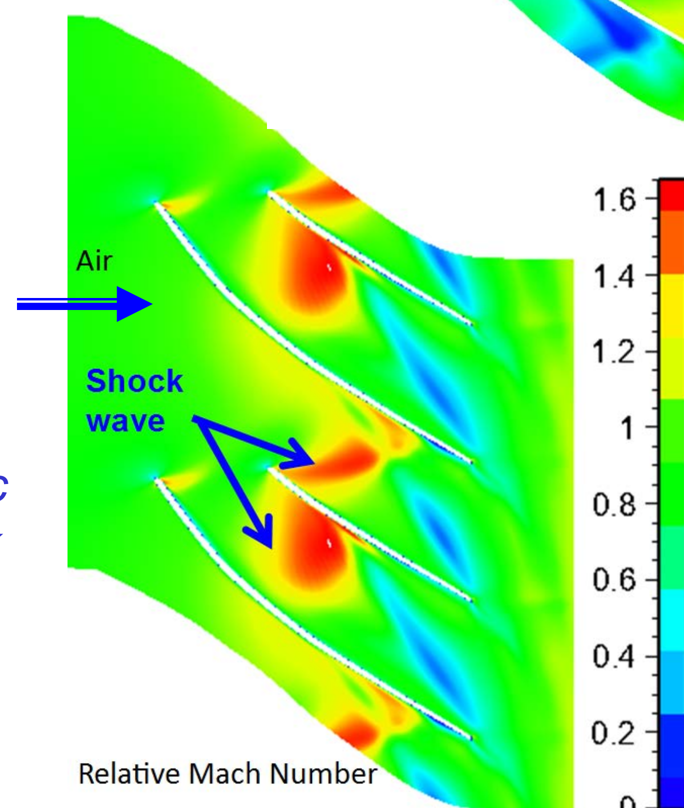






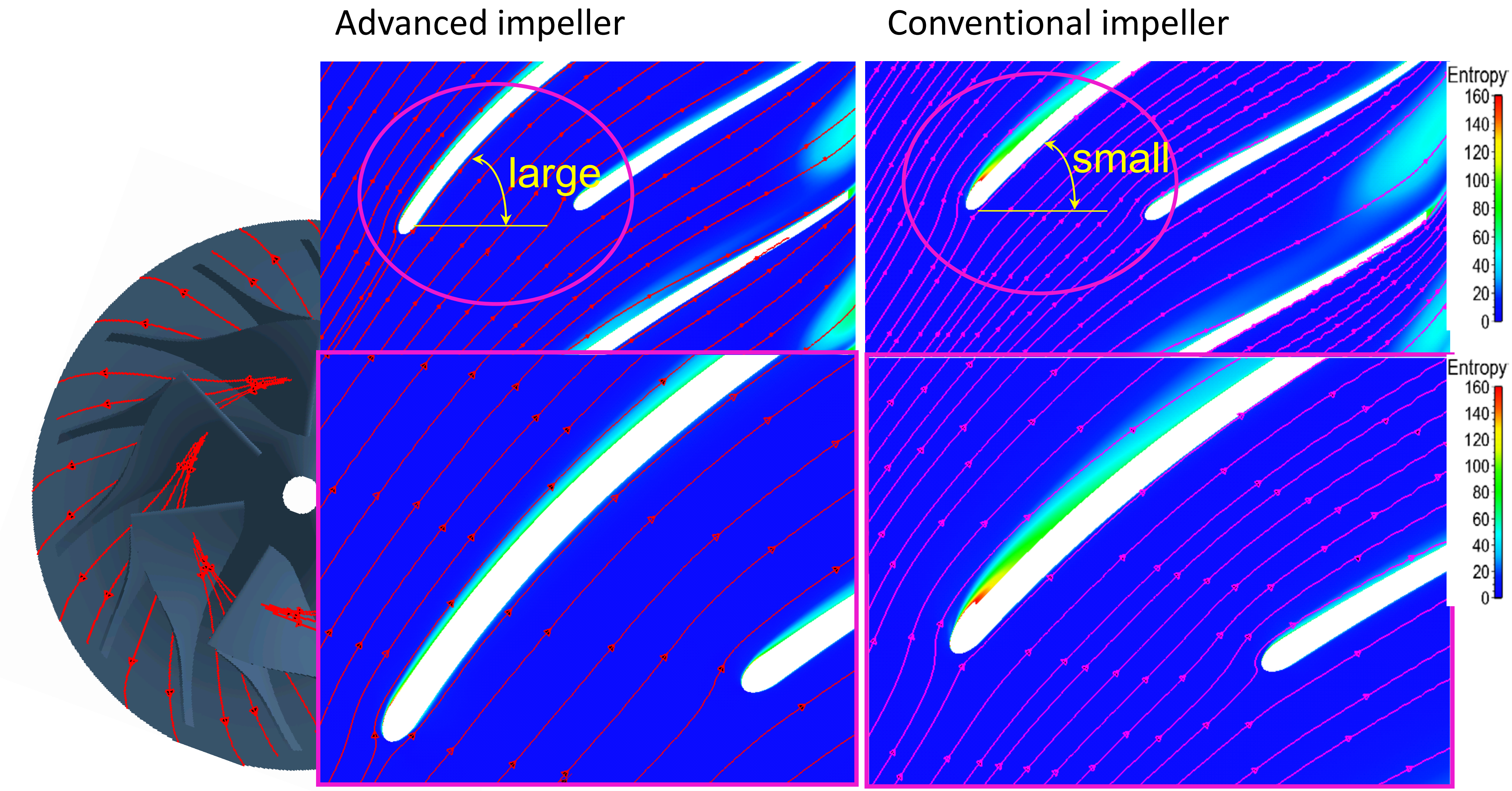




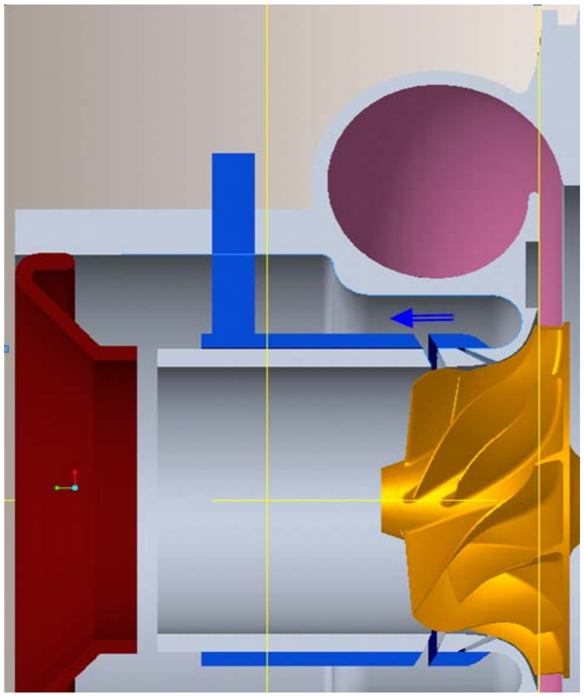
Active casing treatment: a new concept in compressor design:

Advanced impeller design may have the aerodynamic throat located near splitter blades which create shock wave at near choke conditions. This shock wave induced aerodynamic blockage could be utilized…

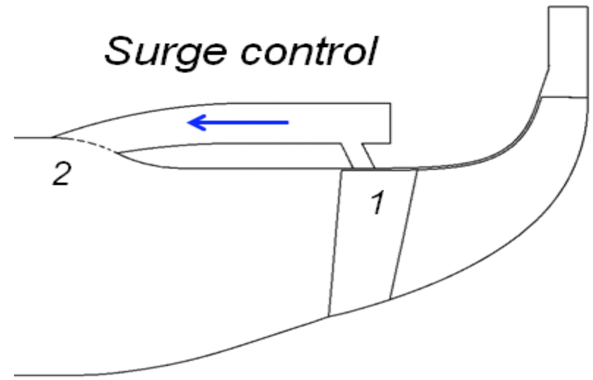
Physics behind compressor efficiency improvement



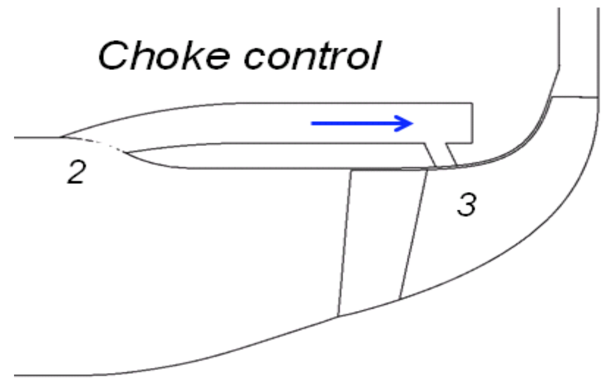
Large beta angle helps improve efficiency but reduces flow capacity



The surge slot "1" can be optimized to improve low end efficiency and surge margin

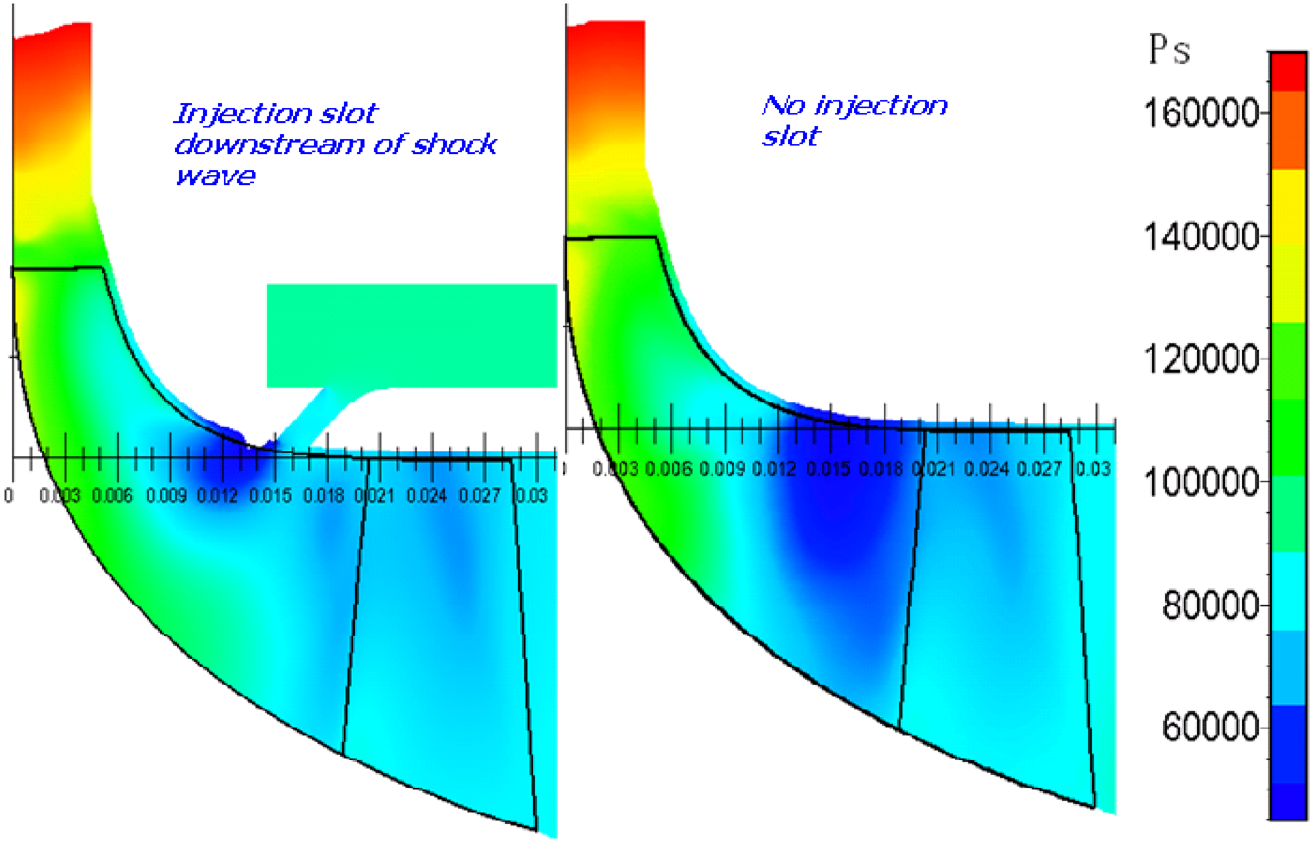


The choke slot "3" can be designed to maximize choke flow capacity

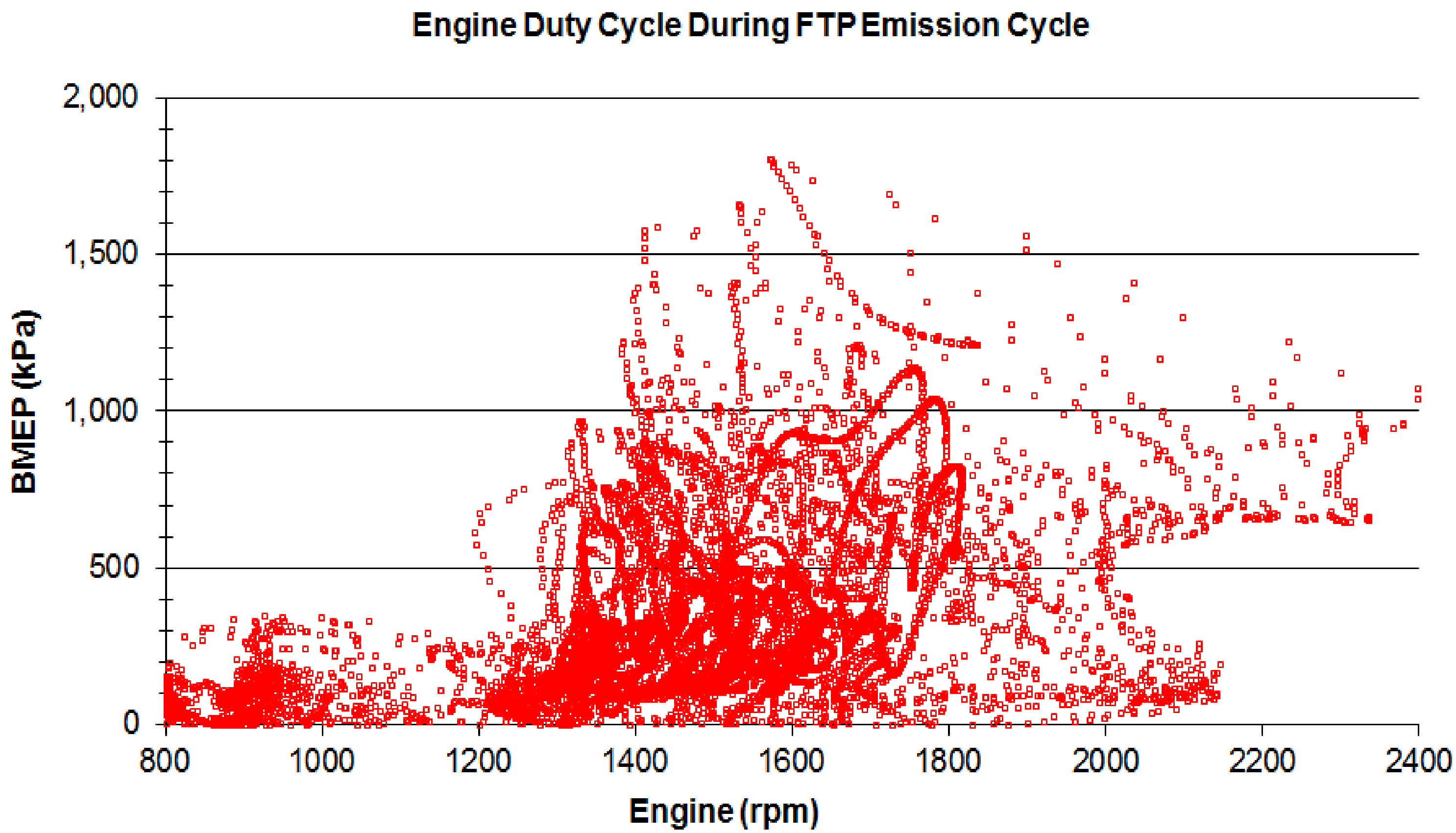


The dual, switchable slots, or ***Active casing treatment,*** can be used to address the surge and low end performance and choke flow capacity separately

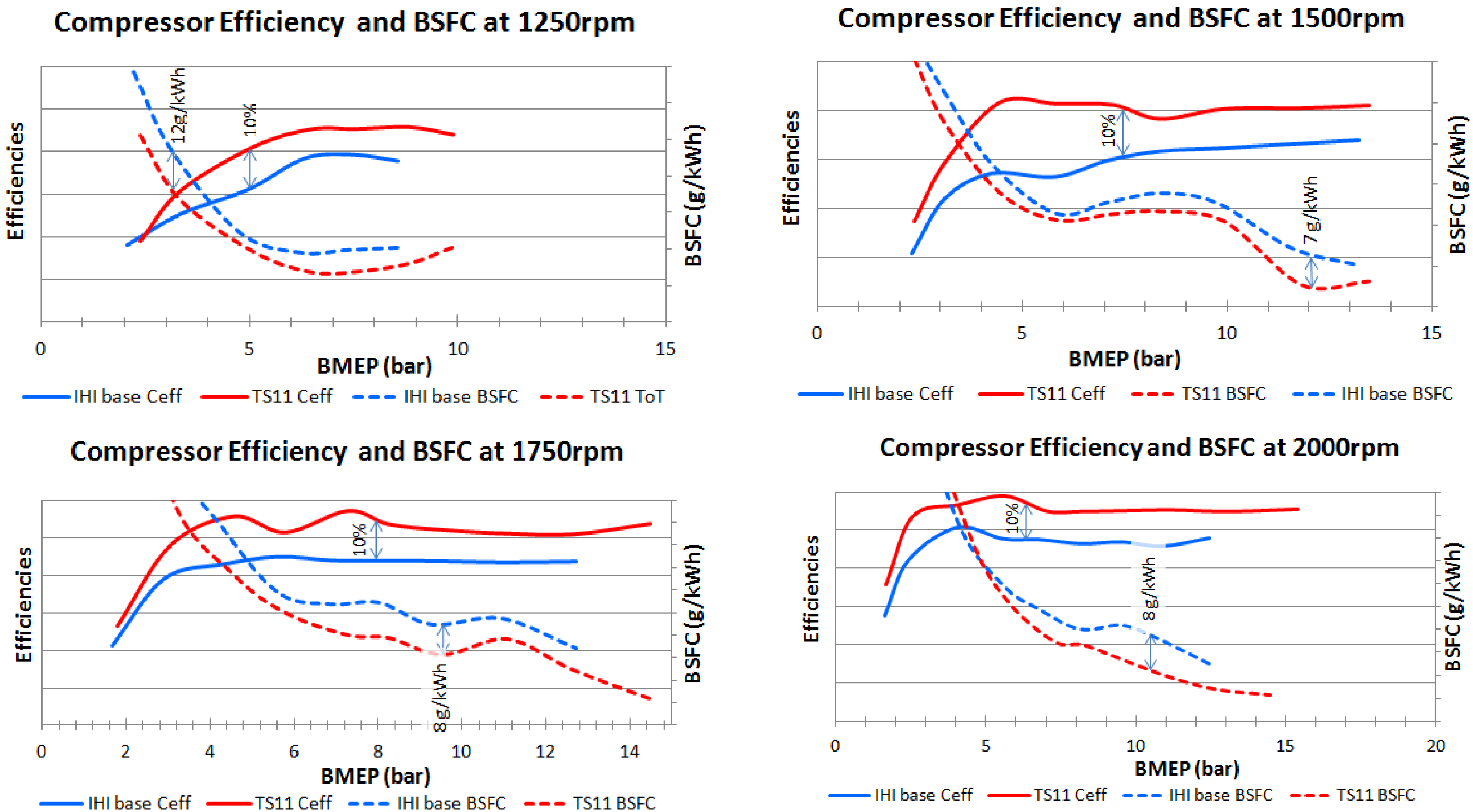
The choke slot utilizes the pressure drop after the shock wave to induce extra air at near choke conditions to extend choke flow capacity



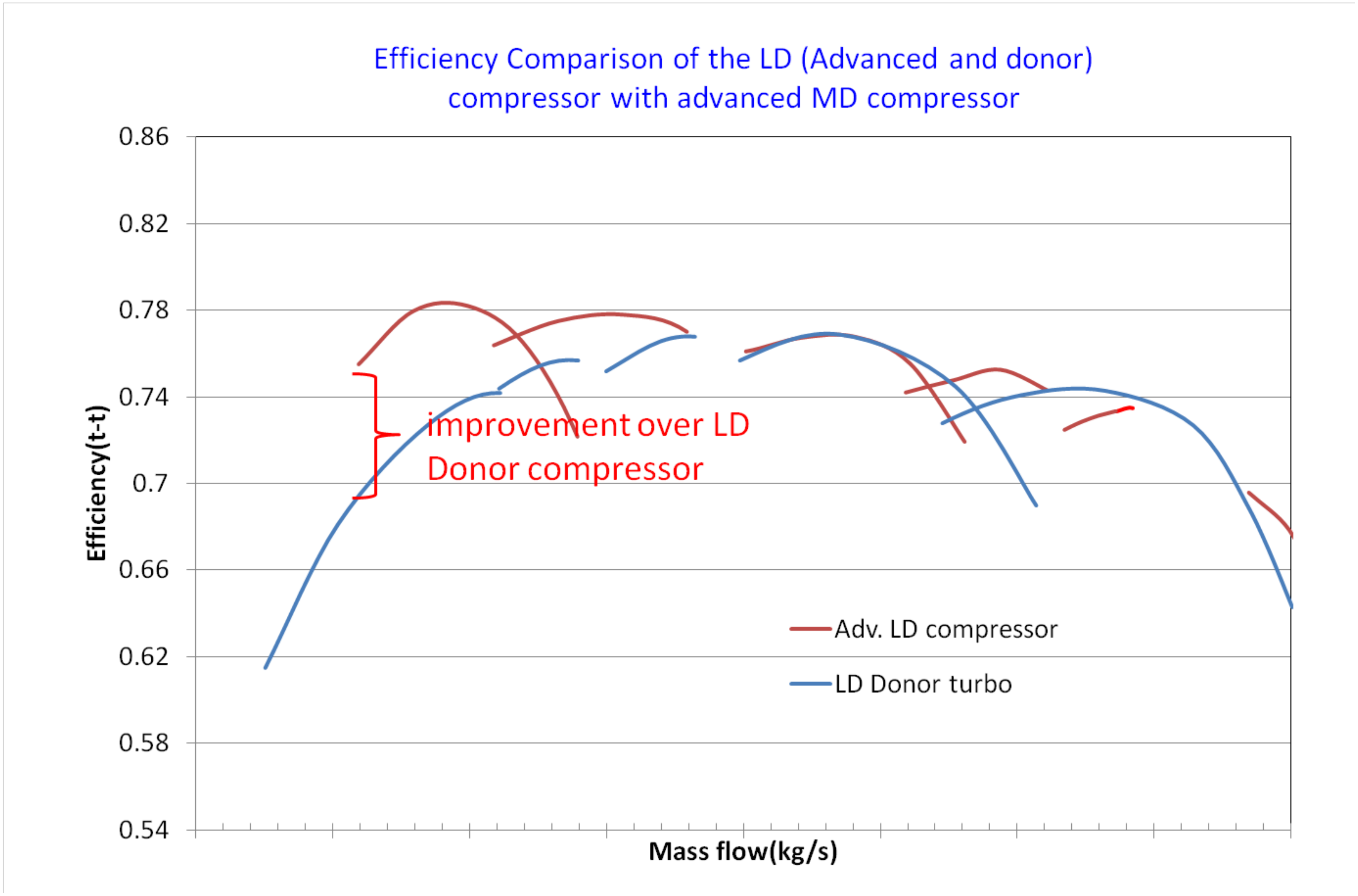
Injection slot after split blade where the aerodynamic throat is located can bypass extra flow thus extend flow capacity



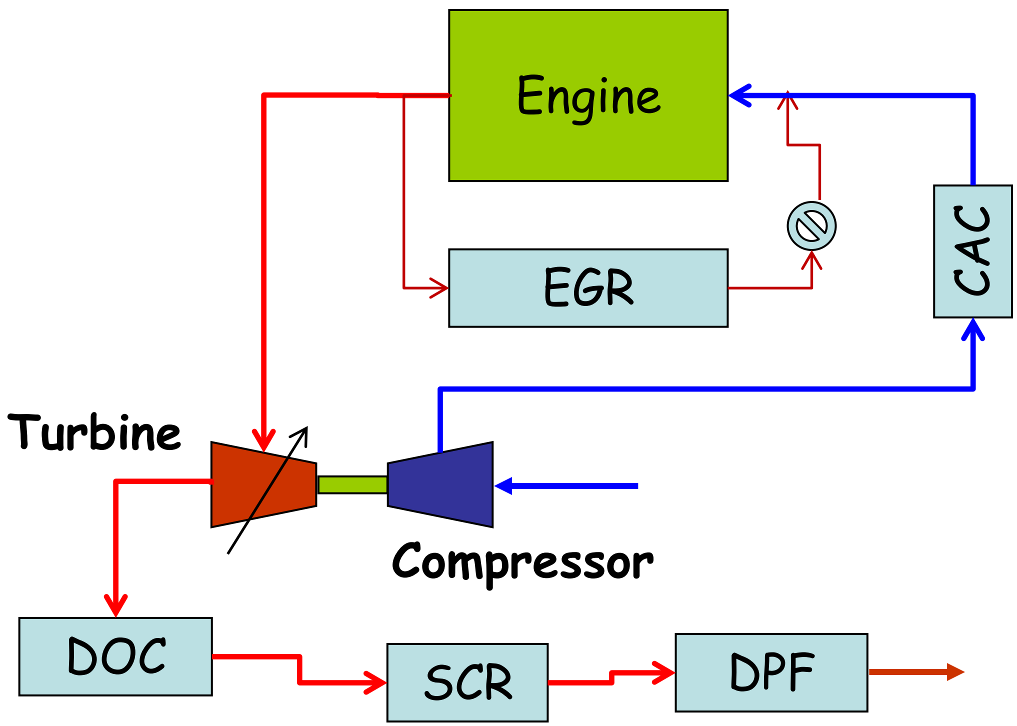
FTP cycle is dominated by light load and medium engine speed thus the turbocharger (or any other engine improvements) should be optimized and evaluated at part load areas



Part load engine test shows that the advanced (TS11) compressor has better efficiency and contributes to better BSFC, which is consistent with FTP transient test



The LD advanced compressor has higher efficiency with wider operation range better than LD donor compressor.



Engine dynamometer test validation is conducted on a production light duty diesel for steady state mapping, transient engine and aftertreatment calibration to demonstrate fuel economy improvement with the advanced turbocharger at Tier2 Bin5 emission level

At Tier2 Bin5 tailpipe emission level, the engine brake thermal efficiency with the newly developed (TS11) turbo shows 3.3% improvement over the base turbo:

	FTP cycle thermal efficiency
IHI Base Turbo	29.55%
TS11 Adv. Turbo	30.52%
Improvement	3.3%

For light duty vehicle application, FTP cycle averaged thermal efficiency is more relevant than single point target!

Conclusions

- *EGR based NOx control pushes operation points into less efficient area on compressor and turbine maps, which has to be addressed with advanced turbocharger technologies*

- *Active casing treatment enables compressor efficiency and surge performance improvement at low mass flow (customer driving cycle) area while gaining flow capacity enhancement with a separate choke slot.*

- *The engine dyno test has demonstrated fuel economy improvement of 3% on FTP cycle at Tier2 Bin5 tail pipe emission level due to design optimization on compressor impeller, active casing treatment and mixed flow turbine*