

Development of Integrated Turbocharger and Engine Matching Software

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Let's work together to create Energy Efficient Technologies and a greener world for the future generations!

Plan of Presentation

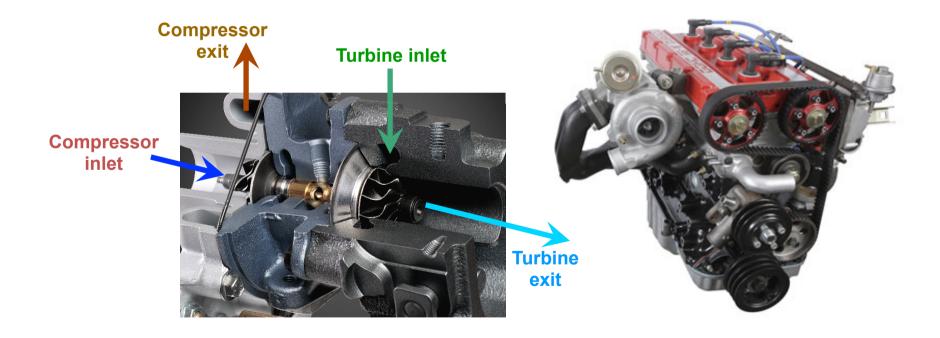


- Need for Turbocharging
- Methods of Turbocharging
- Design Challenges
- AxCHARGER and AXSTREAM for Design of Turbocharger
- Cycles in AxCHARGER
- Case study
- Conclusion

Need for Turbocharging



Turbocharging results in downsizing the engine, and a downsized turbocharged engine allows manufacturers to meet higher fuel economy standards and reduced emissions and yet maintain the power and performance of the larger naturally-aspirated engine it replaces



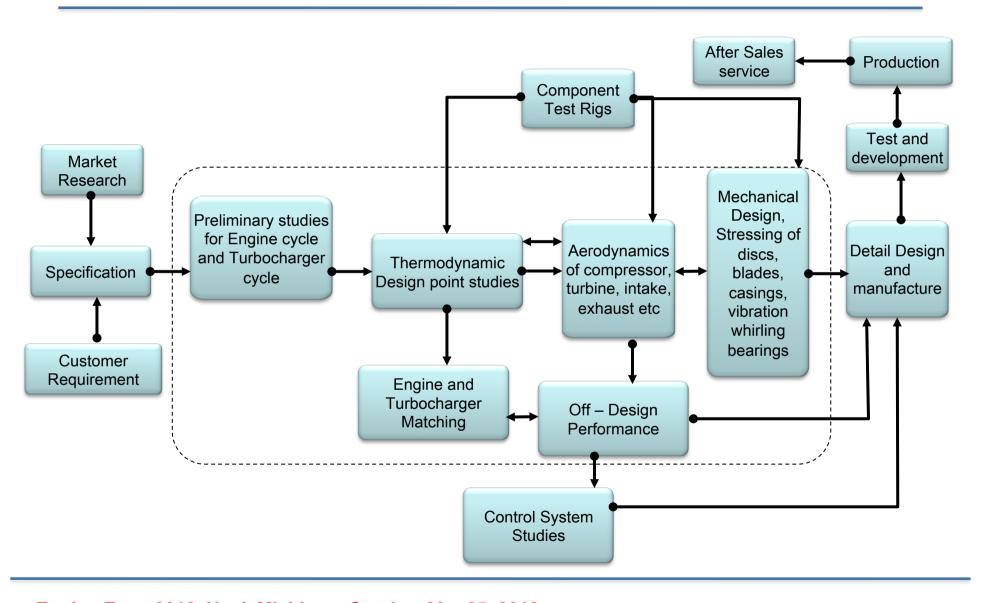
Design Challenges



- The engine is a positive displacement device whereas the turbocharger is an aerodynamic turbomachinery
- These two machines have distinctly different flow characteristics, and properly sizing a turbocharger for an engine is rather complicated process
- The turbochargers performance is so radically affected by the engine and manifold designs; that improper matching can be a disaster not only on the turbo but also on engine performance
- In general, the process of matching an engine and the turbocharger is accomplished based on prior experience instead of using a reliable and robust calculation methodology which is tedious and time-inefficient
- Modeling the engine and turbocharger as an engineering system is the most efficient way, but lacks proper tools.
- SoftInWay Inc. has developed AxCHARGER™ which integrated with AxSTREAM™ provides the most efficient solutions for matching turbo with engine.

Typical Design Process for Turbocharger

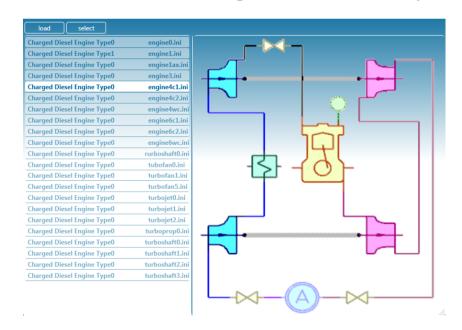




AxCharger – Key Features



- Can model many combinations of engine and turbocharger / supercharger
- Few inputs required to generate the boundary conditions for designing the turbocharger
- Generates the engine performance map for different operating speeds
- All data can be viewed and reviewed by user
- Direct data export to AxSTREAM to design turbine / compressor

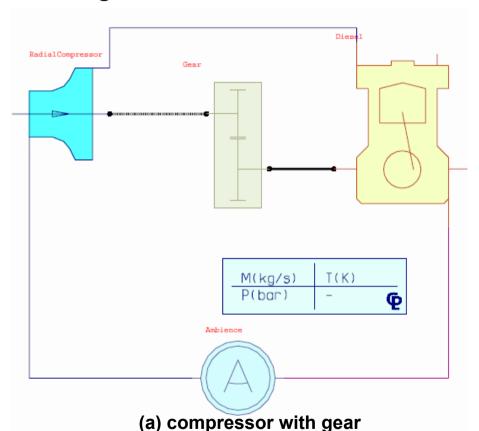


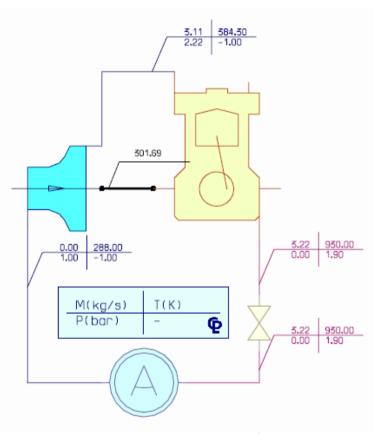
AxCharger – Cycle Configurations



Various configurations of supercharging or turbocharging can be employed

AxCharger



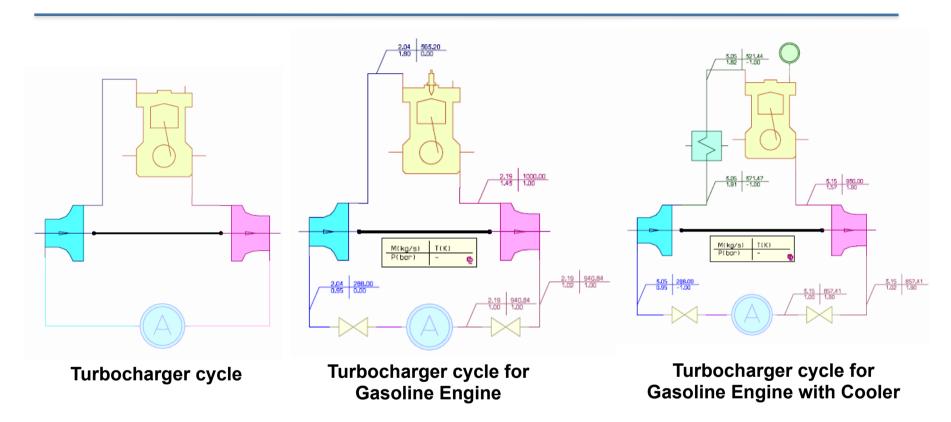


(b) coupled to crankshaft

Supercharging Cycle in AxCharger

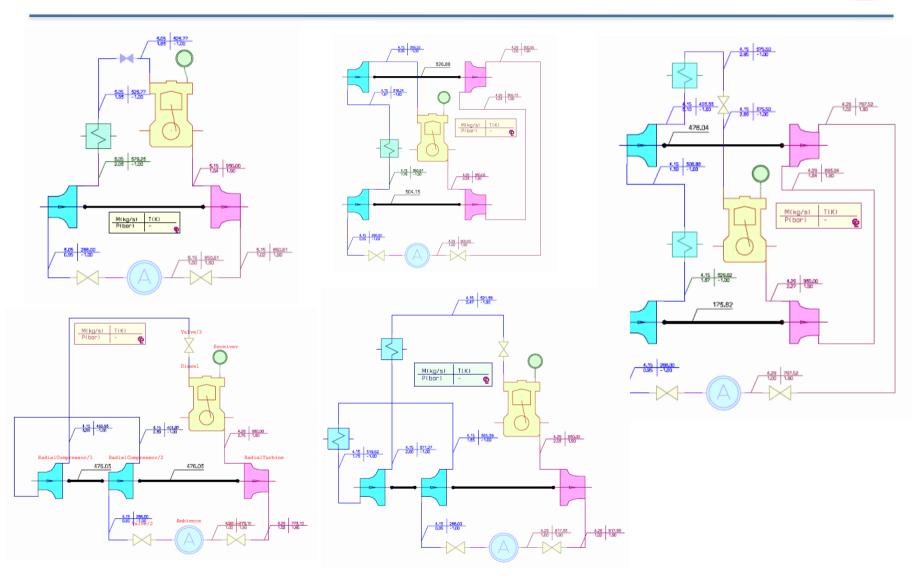
AxCharger – Cycle Configurations





AxCharger – Cycle Configurations





AxCharger Inputs / Output

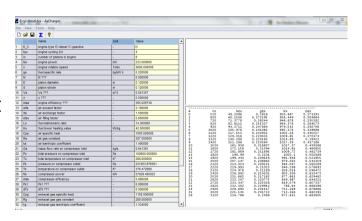


Inputs

- Engine Information
 - Type of Engine (Diesel / Gasoline), 2 Stroke or 4 stroke, Number of pistons in engine, Engine power, engine rotation speed, fuel specific rate, engine size (stroke length and piston diameter)
- Turbocharger Compressor
 - Pressure and temperature at compressor inlet
 - Temperature at compressor inlet
 - Efficiency of compressor
- Turbocharger Turbine
 - Pressure and temperature at compressor inlet
 - Temperature at compressor inlet
 - Efficiency of turbine

Outputs

Boundary conditions for compressor and turbine



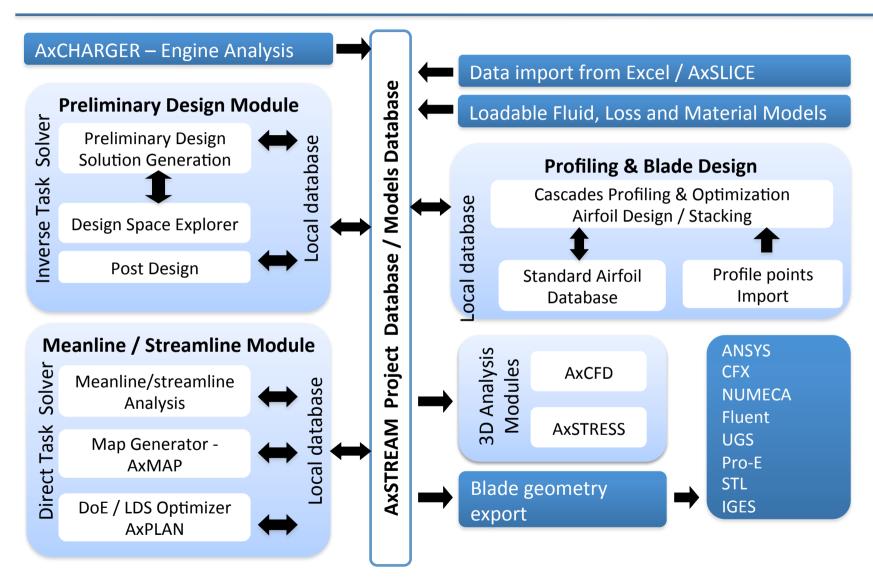
Design Process for Turbine/Compressor



- 1. Generate an optimal flow path that satisfies the design point performance for compressor and turbine (indepedently)
- 2. Streamline calculations and off-design performance analysis for both turbine and compressor
- 3. Blade profiling and mechanical design for both turbine and compressor
- 4. Performance matching for both compressor and turbine
- 5. CAD Modeling of full turbine and compressor
- 6. Structural and fluid flow analysis for verifying the designed compressor meets the required performance
- 7. Design of auxiliary systems, lubrication system, control system etc...
- 8. Detailed design for manufacture and prototype testing
- 9. Matching performance with engine

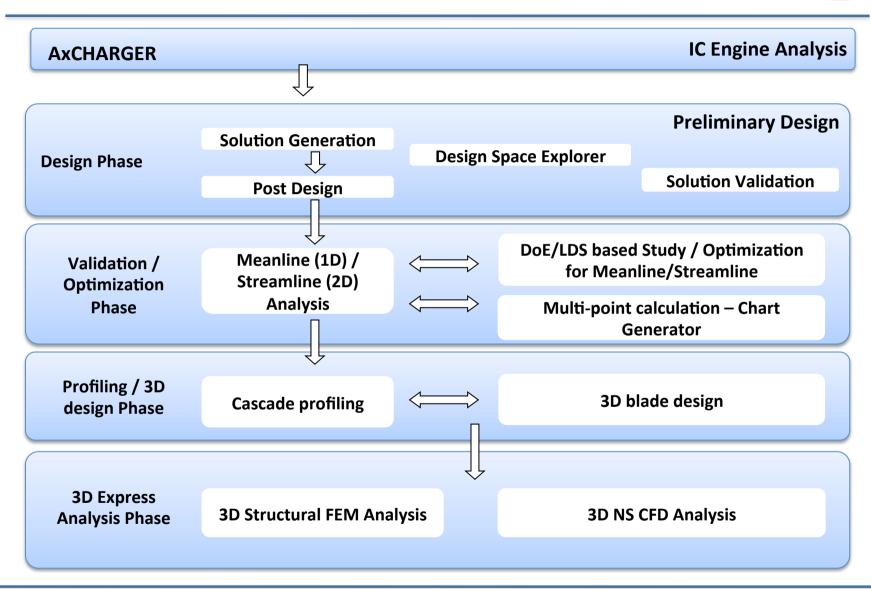
AxSTREAM™ Architecture





Design Process for Compressor/Turbine

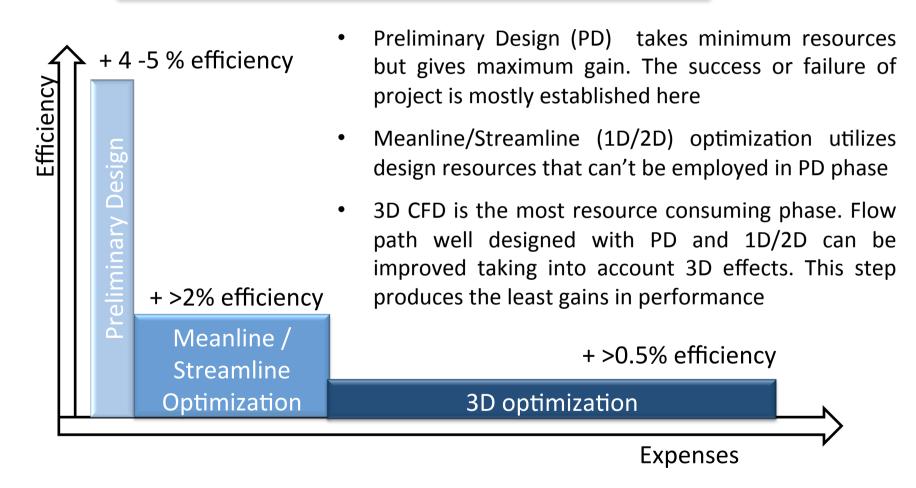




AxCharger Inputs / Output



Design Process Phases: Efficiency vs. Expenses



AxSTREAM™ – Turbocharger Design



Key features for Turbocharger design

- Can model both turbine and compressor from scratch
- Boundary conditions directly imported from AxCharger
- Only diameter limits to be specified to get the complete design of Turbine or Compressor
- Generates more than a thousand design for given input in less than a minute
- Different designs can be explored and reviewed to select the best geometry
- Complete performance map can be generated for both turbine and compressor and matched to meet the turbocharger operating conditions
- 3D geometry generated can be exported to manufacturing
- The data from AxSTREAM and AxCharger can be compared to ensure proper matching of the engine with the turbocharger all in a single integrated user friendly GUI

Case Study – Diesel Engine Turbocharging 🥨

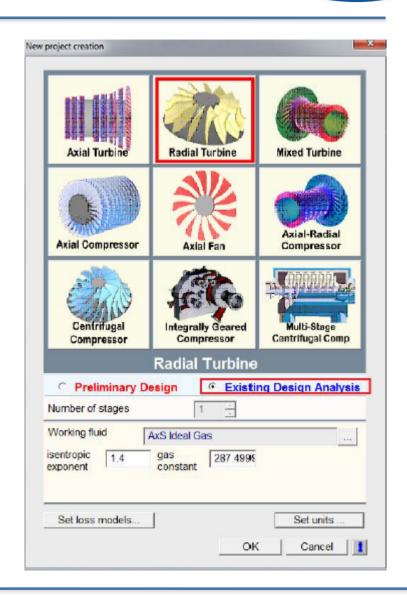


Engine Specifications

- Type of Engine 8 Cylinder 4 stroke
 Diesel Engine,
- Engine Speed 2600 rpm
- Fuel Specific Rate 0.22 kg/kWh
- Bore/Stroke 0.12m / 0.12m

Turbocharger Requirement

- Boost Pressure 2.4
- Efficiency max
- Operating Range As per engine operating speed
- Turbocharger speed 40K 50K

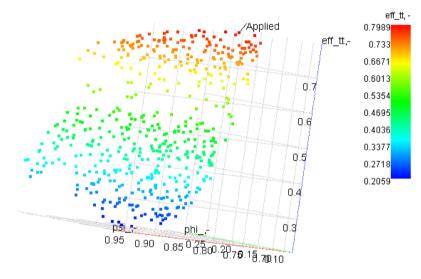


Case Study – Diesel Engine Turbocharging



Specification for Turbocharger - Output from AxCharger

- Compressor (Design Point)
 - Mass flow rate 0.58 kg/s
 - Inlet Pressure 100 kPa
 - Outlet Pressure 243.8 kPa
 - Inlet Temperature 15 C
- Turbine (Design Point)
 - Mass Flow Rate 0.655 kg/s
 - Inlet Pressure 176.9 kPa
 - Inlet Temperature 656.5 C

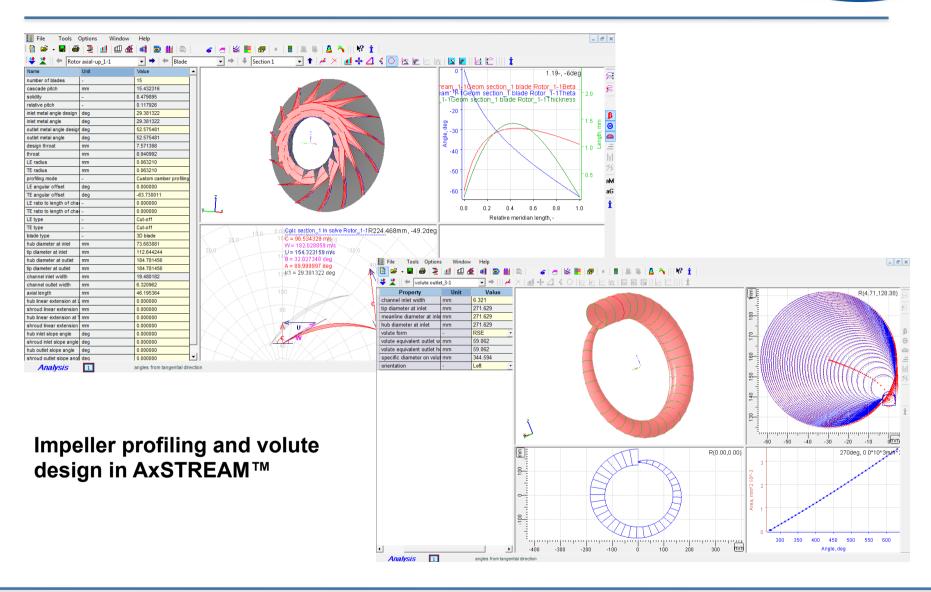


Different designs for Compressor

Speed – 40k rpm selected for both turbine and compressor

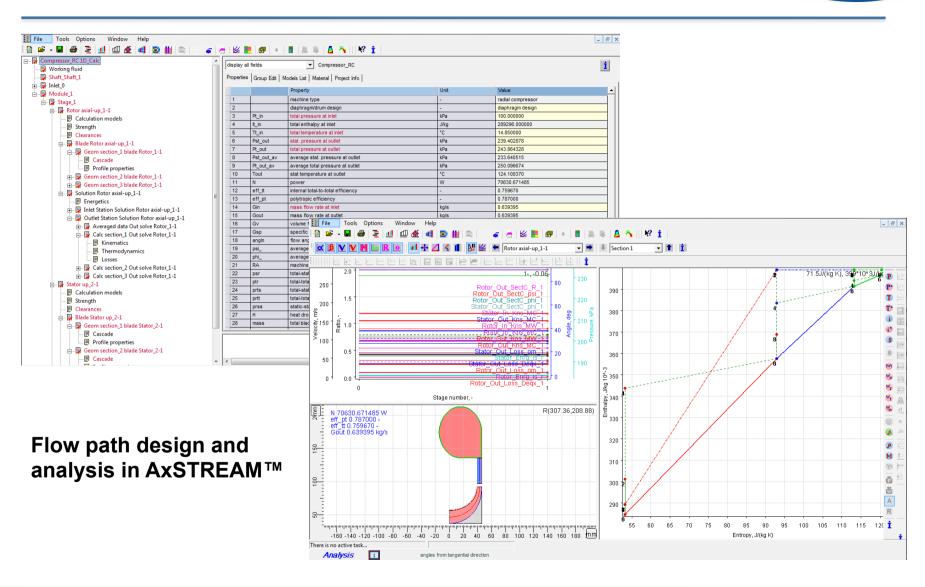
Case Study - Diesel Engine Turbocharging (Softlin Wall)





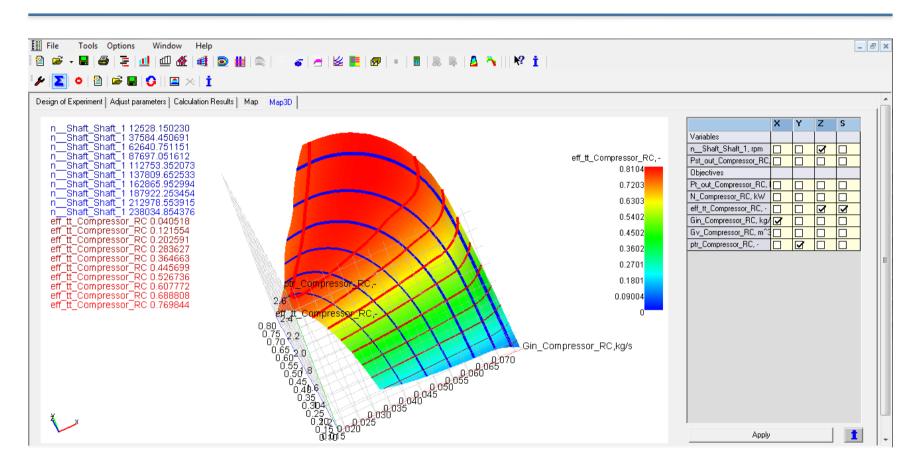
Case Study - Diesel Engine Turbocharging (Softlin Way)





Case Study – Diesel Engine Turbocharging (Softling)

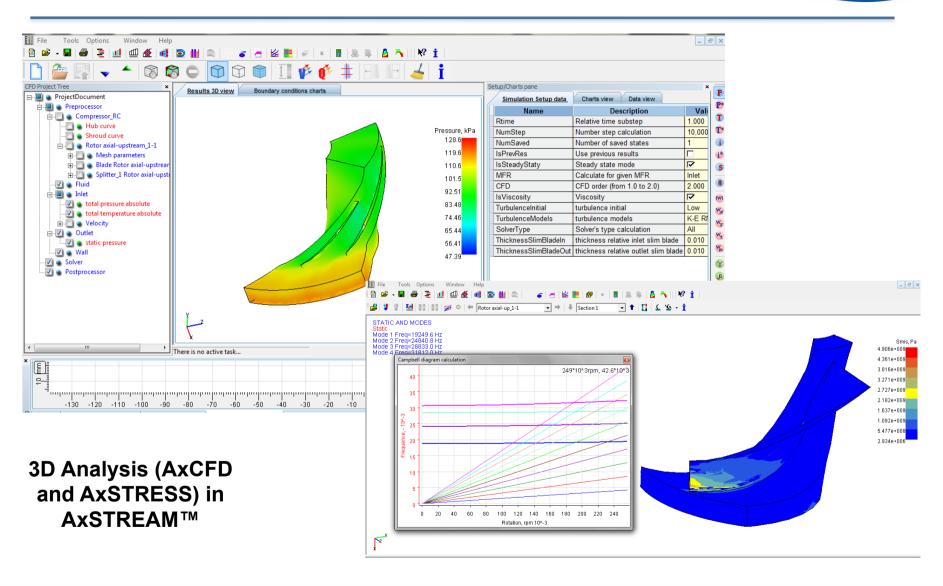




3D - Performance map in AxSTREAM™

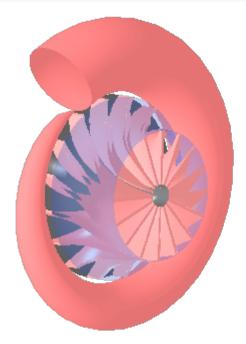
Case Study – Diesel Engine Turbocharging (Softla Wa)



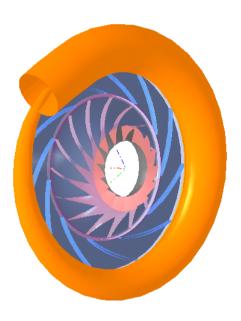


Case Study – Diesel Engine Turbocharging





Designed Radial turbine with inlet volute and impeller

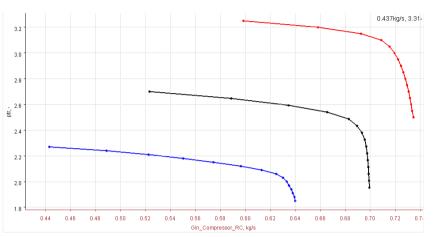


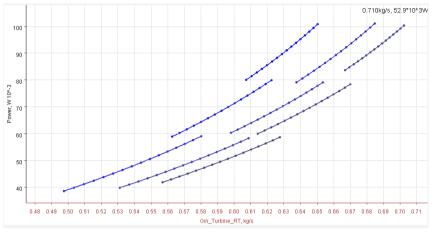
Designed Compressor with impeller, diffuser and volute

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	Centrifugal Compressor		Radial Turbine	
	AxCHarger Spec	As Designed	AxCHarger Spec	As Designed
Power [kW]	70.5	70.6	70.5	77
MFR [kg/s]	0.641	0.639	0.656	0.664
Efficiency (TT)	-	0.76	-	0.895

Case Study – Diesel Engine Turbocharging







Compressor Performance Map

0.459kg/s, 99.2*10*3W
95
90
85
75
76
60
65
60
45
40
0.44
0.45
0.48
0.50
0.52
0.54
0.56
0.58
0.60
0.62
0.64
0.66
0.68
0.70
0.72
0.74

Turbine Performance Map

Turbine and Compressor
Performance Map combined for
matching

Conclusion



- An integrated tool for designing engine and turbocharger as an integrated system has been developed
- A case study is presented which demonstrates the capability of the developed tool to design a turbocharger to meet the entire operational range of the engine with few inputs
- The turbine and compressor is designed individually from specifications obtained from AxCHARGER and performance map generated to match the turbine and compressor
- The ability of the tool to individually design and match the components provides opportunity for the manufacture to mix and match different turbines and compressor to meet the operational range of the engine.
- The developed tool can model different engine and turbocharger configurations
- The integrated approach reduces the time to market and provides the best performance of the turbo with the engine
- Software suite for designing engine and turbocharger as an integrated system has been developed



Thanks for your time