KULI 7.1
New Features and Benefits

Josef Hager, ECS, Magna Powertrain

Contents

- **KULI base**
  - Internal solver improvements
  - 3D view of cooling system
  - Table and map functions
  - Pack function
  - EGR
  - Turbo charger
- **KULI hvac**
  - Steam circuit
- **KULI advanced**
  - Optimzation
- **KULI drive**
  - Engine model for turbo charger

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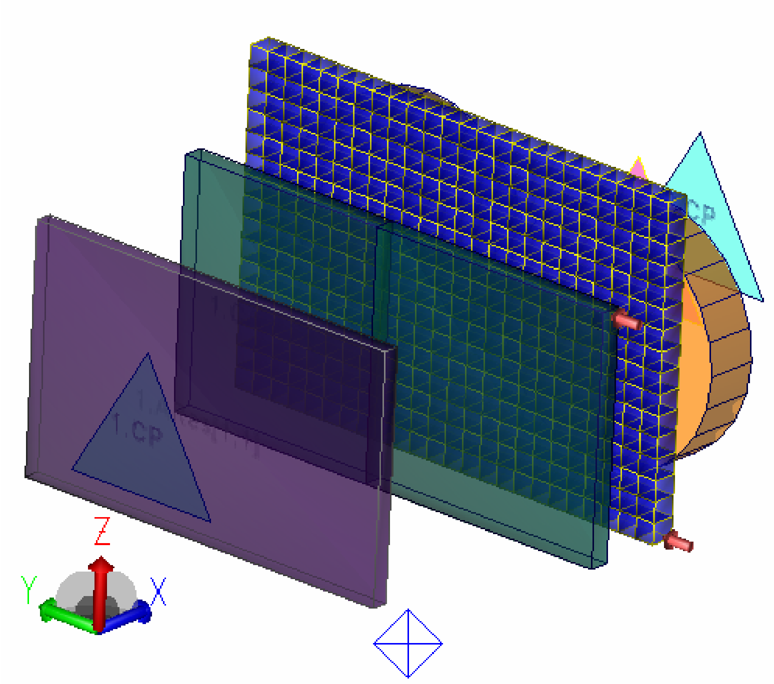
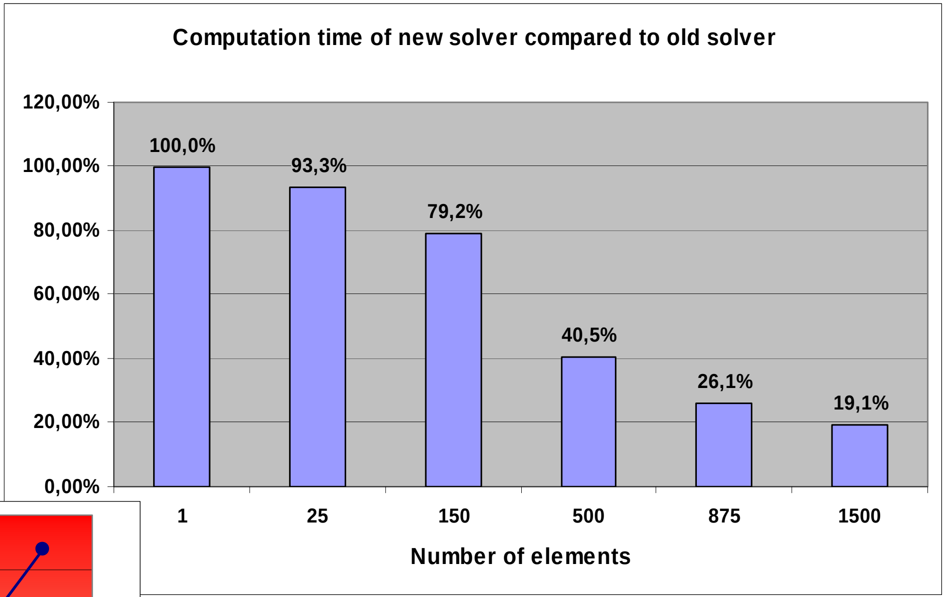
Internal solver improvements

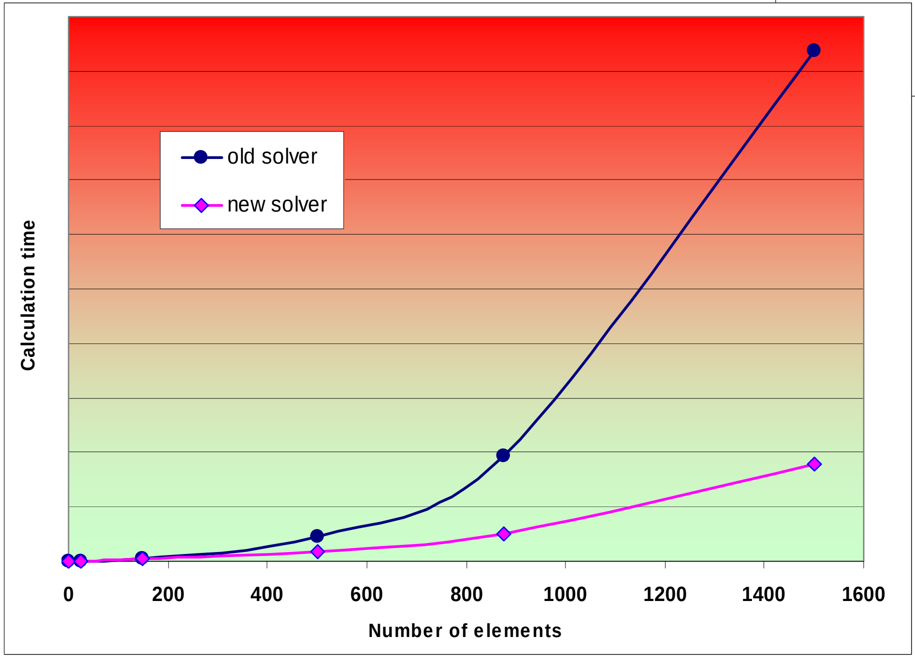
- **Sparse matrix solver implemented for air side network**
- **Particularly effective for systems with many subdivisions**
  - systems with large resistance matrices usually see big improvements
- **Reduction of computation time and memory usage**



Comparison of old and new matrix solver

relative computation times





absolute computation times

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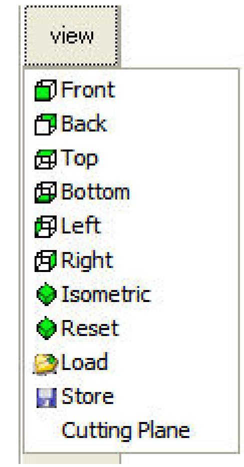
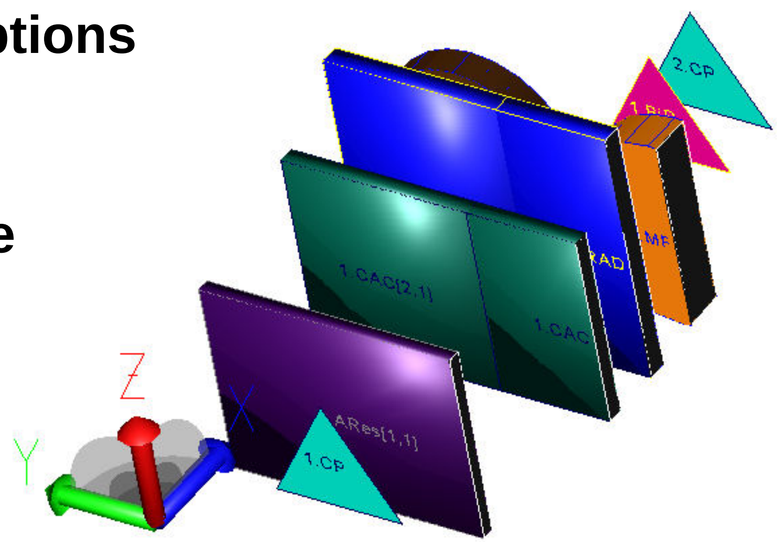
3D View of Cooling System

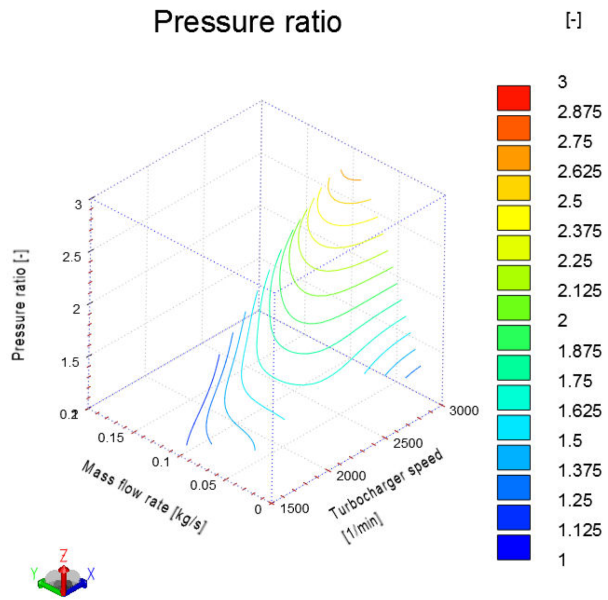
- **Standard views**
  - Front, back, top, bottom, left, right
  - Last view is stored with cooling system data
- **Isometric view**
- **Save view options**
  - Store, load
- **Cutting plane**



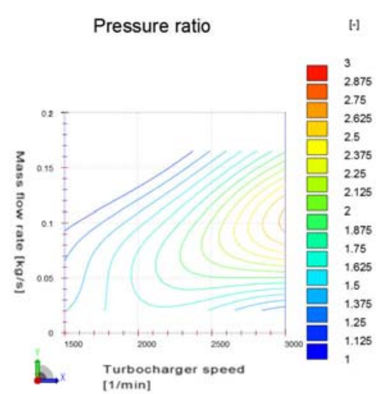


Additional Useful Functions

- **Table and map functions**
  - Iso lines for map view available
  - Up to 7 map-values for up to 7 base-values
  - Functions of characteristic lines and 3-dimensional maps available for n-diemsional map
  - No fully filled in base-value mesh necessary



- **Pack function**
  - Includes media data
  - Includes components for parameter variation
  - Includes CFD-data



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EGR Background

- **Medium: Exhaust gas**
  - N2, O2, H2O, CO2 mixture

- **Air / fuel mixture ratio lambda (λ)**
  - Stoichiometric mixture ratio L_{st} (λ = 1)
  - L_{st}-Diesel = 14,545
  - L_{st}-Gasoline = 14,664

$$\lambda = \frac{m_{air}}{m_{fuel} \cdot L_{st}}$$

- **Exhaust gas circuit**
  - Specify medium exhaust gas
  - Use $\lambda > 10^5$ for air
  - Use λ–source for engine
  - Mixture ratio λ is updated at each branch
  - Actual exhaust gas media data are used for each component in circuit

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Exhaust Gas Turbo Charger Background

Compressor

$$T_{2s} = T_1 \cdot \left(\frac{p_2}{p_1}\right)^{\frac{\kappa_1 - 1}{\kappa_1}}$$

$$T_2 = T_1 + \frac{T_{2s} - T_1}{\eta_{s-i,K}}$$

$$T_2 = T_1 \cdot \left(1 + \frac{\left(\frac{p_2}{p_1}\right)^{\frac{\kappa_1 - 1}{\kappa_1}} - 1}{\eta_{s-i,K}}\right)$$

$$P_K = \dot{m}_K \cdot \frac{1}{\eta_{s-i,K} \cdot \eta_{m,K}} \cdot c_p \cdot T_1 \cdot \left(\left(\frac{p_2}{p_1}\right)^{\frac{\kappa_1 - 1}{\kappa_1}} - 1\right)$$

Turbine

$$T_{4s} = T_3 \cdot \left(\frac{p_4}{p_3}\right)^{\frac{\kappa_3 - 1}{\kappa_3}}$$

$$T_4 = T_3 - \eta_{s-i,T} \cdot (T_3 - T_{4s})$$

$$T_4 = T_3 \cdot \left(1 + \eta_{s-i,T} \cdot \left(\left(\frac{p_4}{p_3}\right)^{\frac{\kappa_3 - 1}{\kappa_3}} - 1\right)\right)$$

$$P_T = \dot{m}_T \cdot \eta_{s-i,T} \cdot \eta_{m,T} \cdot c_p \cdot T_3 \cdot \left(1 - \left(\frac{p_4}{p_3}\right)^{\frac{\kappa_3 - 1}{\kappa_3}}\right)$$

$$P_K = P_T$$

T….temperature
p….pressure
$\dot{m}$….mass flow
κ….exponent
c_p…specific heat capacity
η….efficiency
P….power

Subscripts
1….compressor entry
2….compressor exit
3….turbine entry
4….turbine exit
s…..isentropic
m….mechanical
K….compressor
T…..turbine

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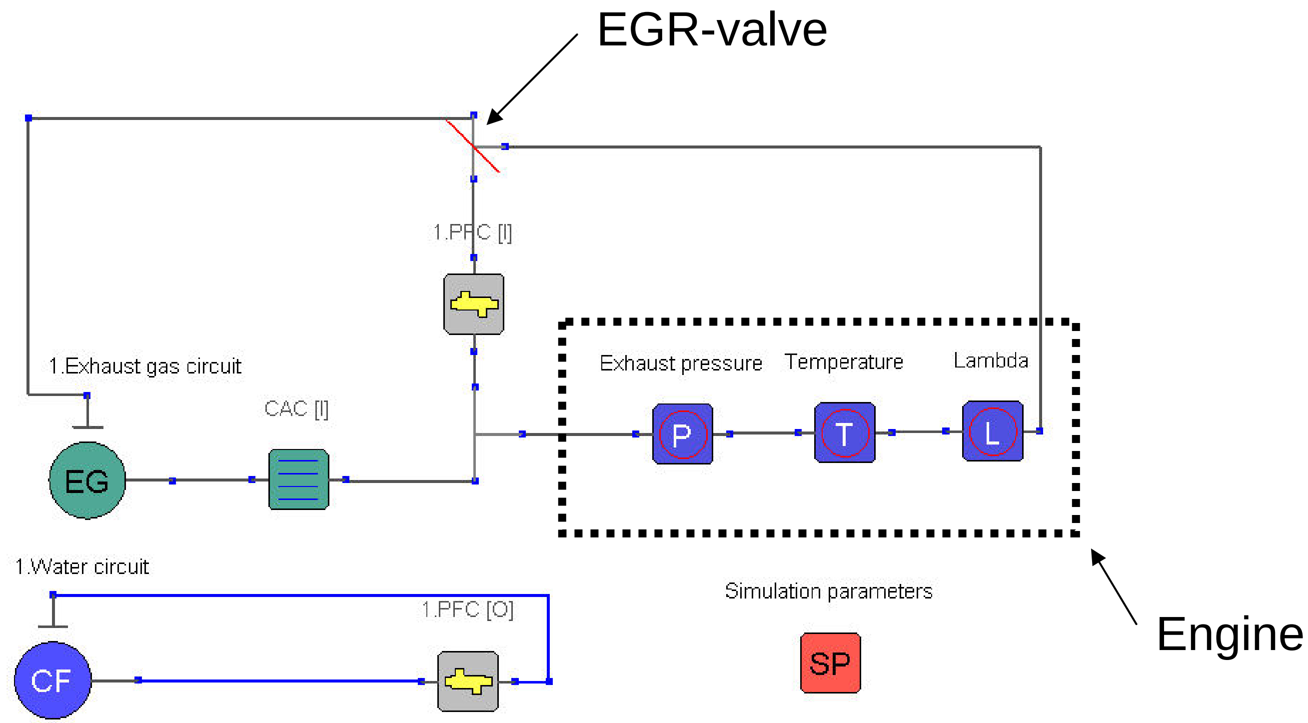
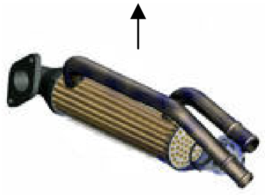
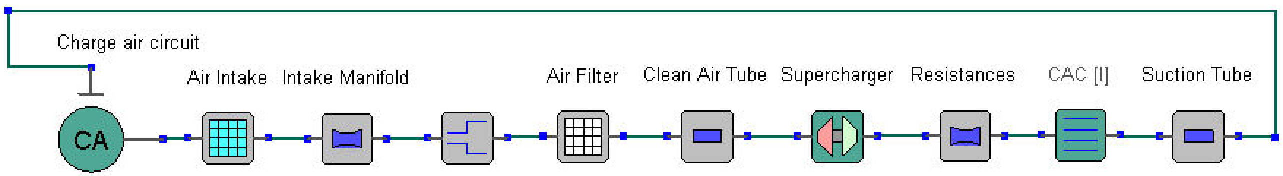
Simulation of an EGR-circuit – engine represented by pressure, temperature and lambda sources



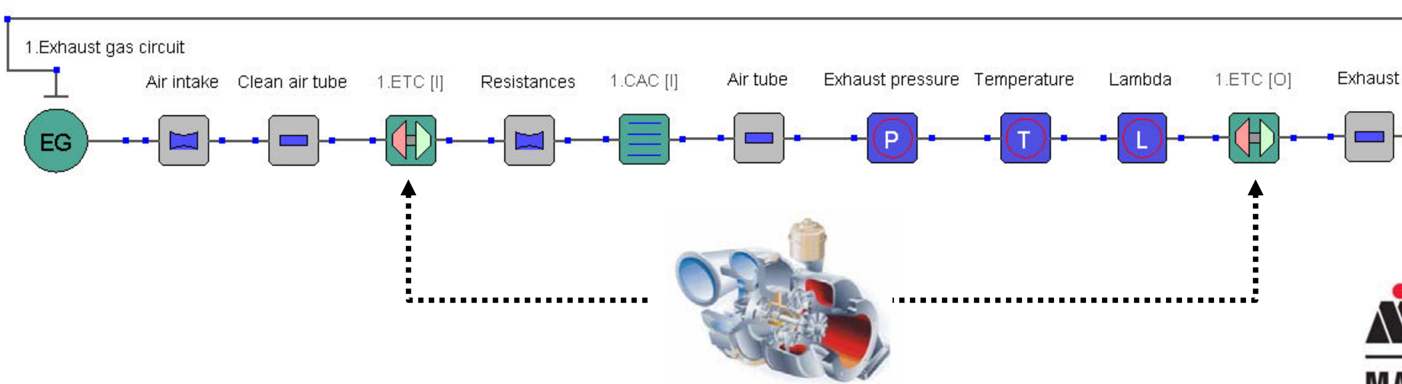


Exhaust Gas Turbo Charger

- **KULI 7.0 – super charger**
  - Charge air side only
  - Linked to specific charger – engine configuration



- **KULI 7.1 – exhaust gas turbo charger**
  - Charge air side and exhaust gas side
  - Turbo charger and engine exchangeable



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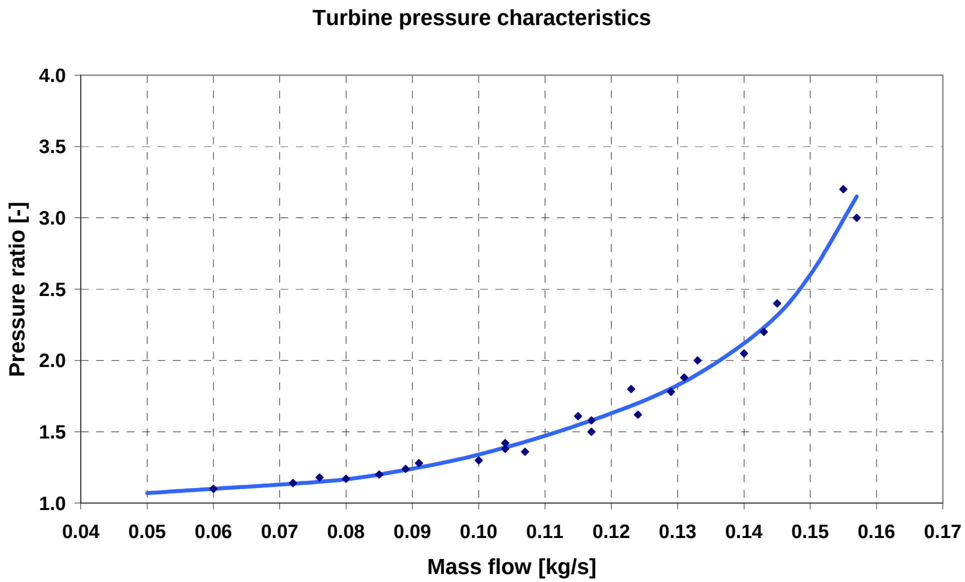
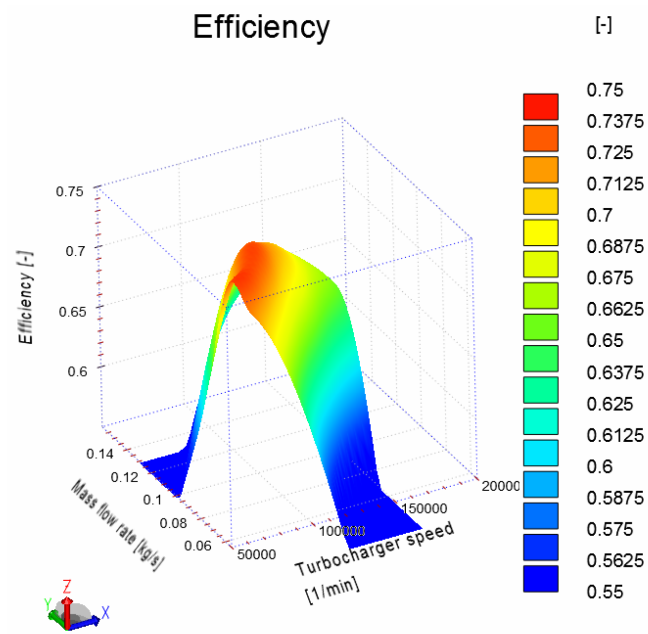
Input Data Turbine

- **Reference data for pressure and temperature**
- **Turbine pressure map**
  - Turbine pressure characteristic is generated from pressure map
- **Turbine isentropic efficiency map**





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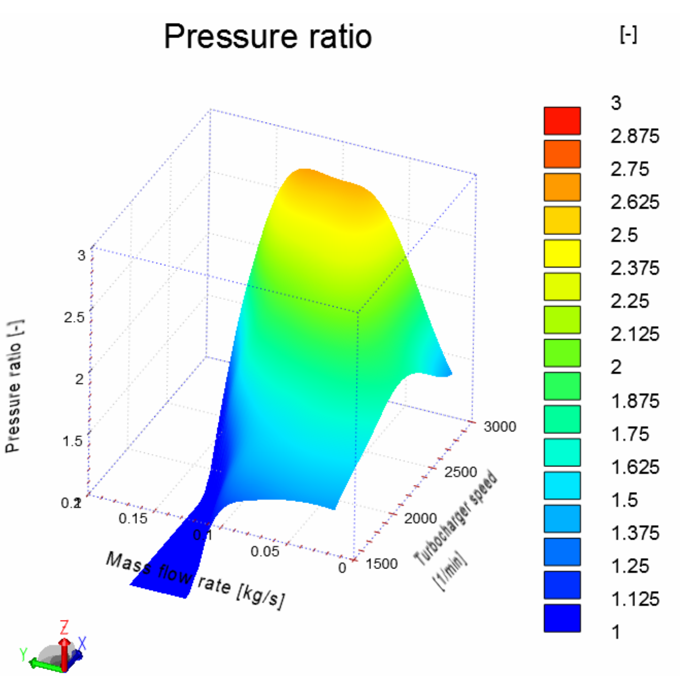
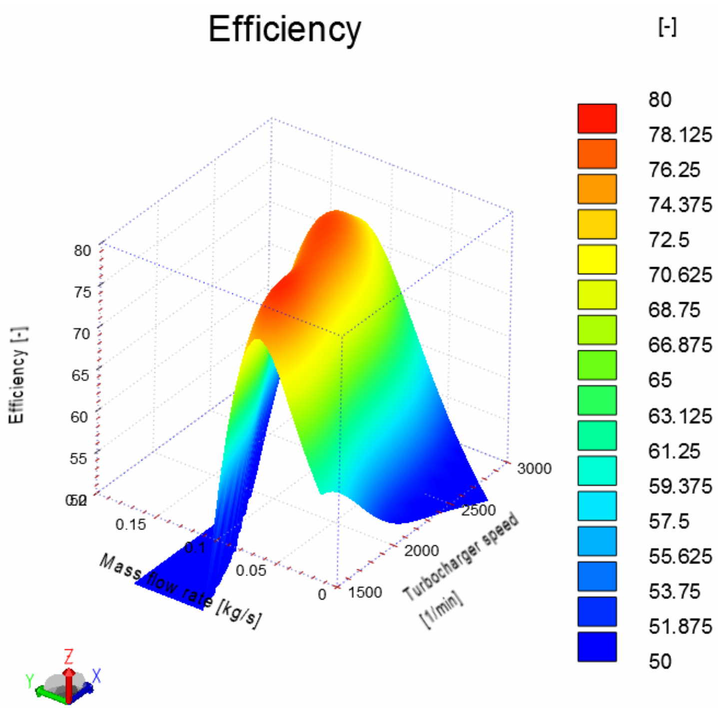
Input Data Compressor

- **Reference data for pressure and temperature**
- **Compressor pressure map**
- **Compressor isentropic efficiency map**





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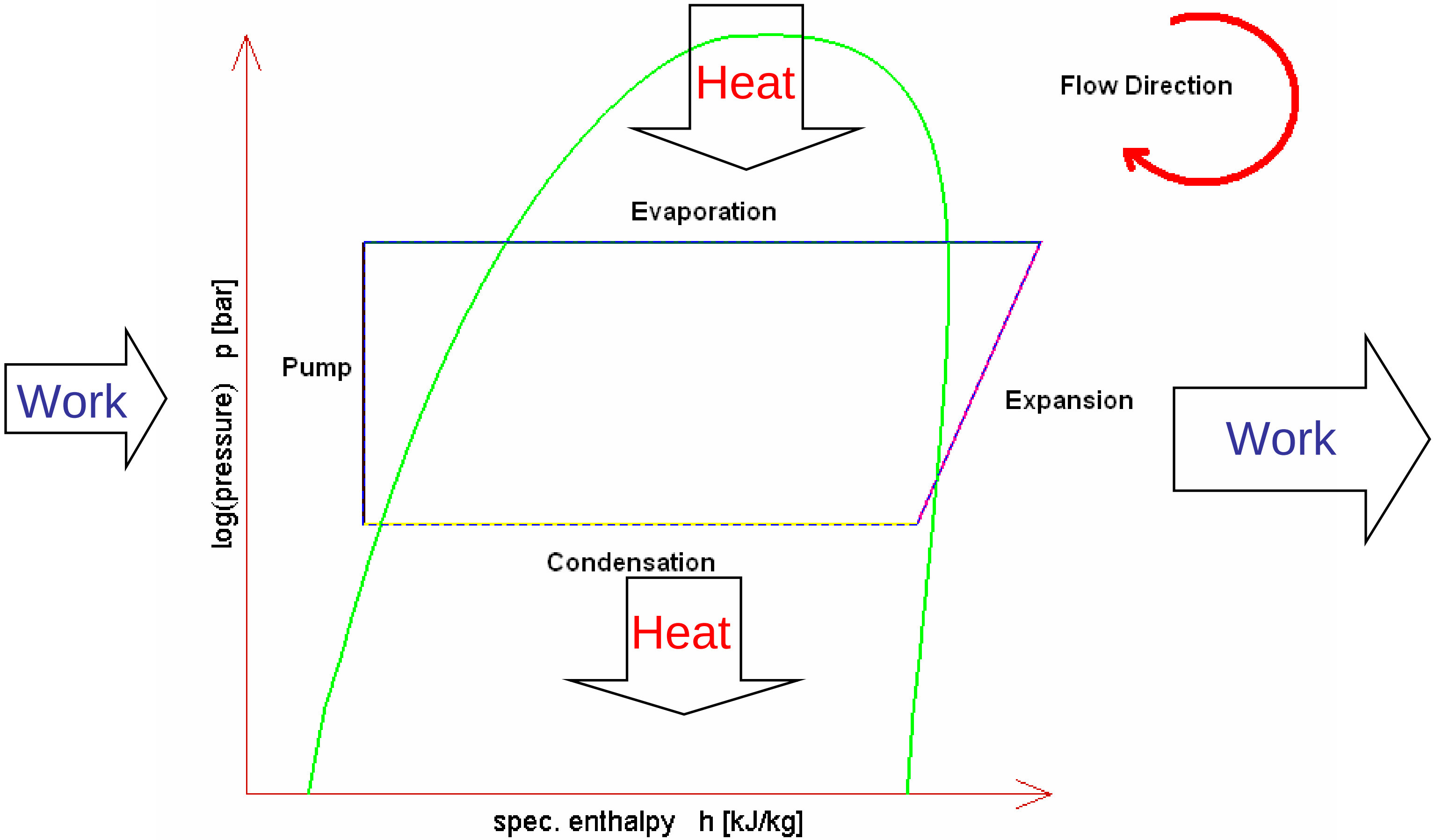
New Feature in KULI hvac – Steam Plant Simulation

- **Steam Plant:**



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New Feature in KULI hvac – Steam Plant Simulation

Why using steam plant simulation in KULI?

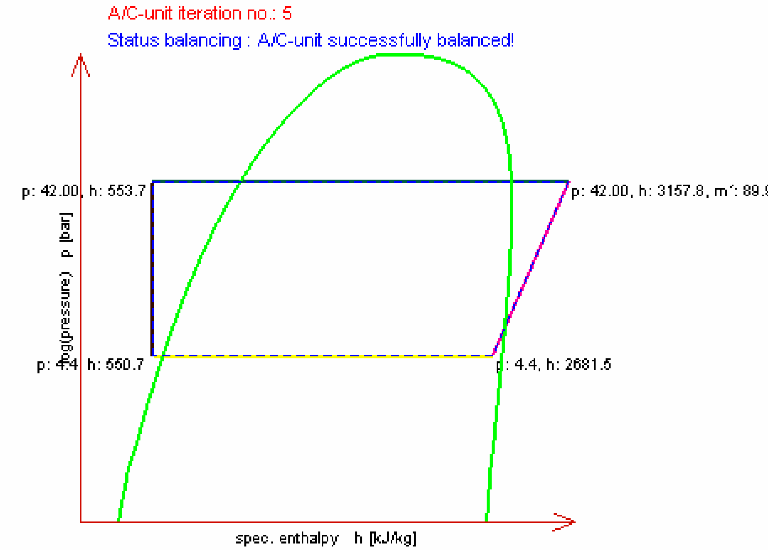
- Demand: Increase the overall efficiency of the vehicle

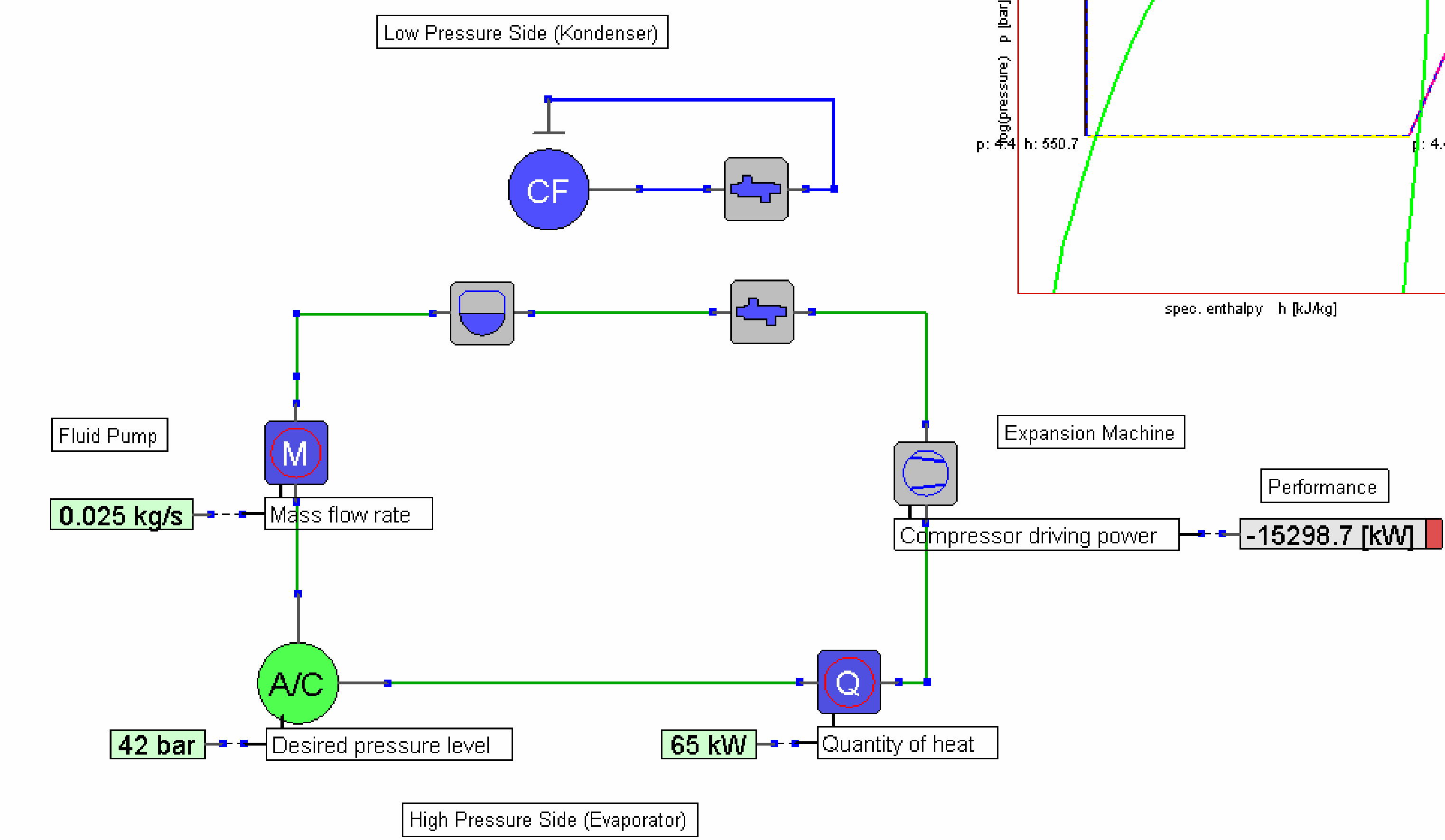
- Trend: Development of Automotive Heat Recuperation Systems

- Automotive Steam Plant: Exhaust gas heat used to achieve mechanical power

New Feature in KULI hvac – Steam Plant Simulation

- **Steam Plant Model in KULI:**





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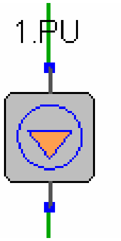
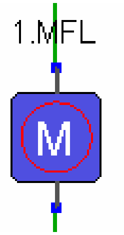
New Feature in KULI hvac – Steam Plant Simulation

How to simulate a steam plant in KULI?

- **Expansion Machine Model: Compressor model is misused!**
  - Compressor characteristics: 

    < 1 !!!

- **Pump: Mass Flow Target** 

  or Fluid Pump 

- **Heat Exchanger: Each HVAC heat exchanger model allowed!**

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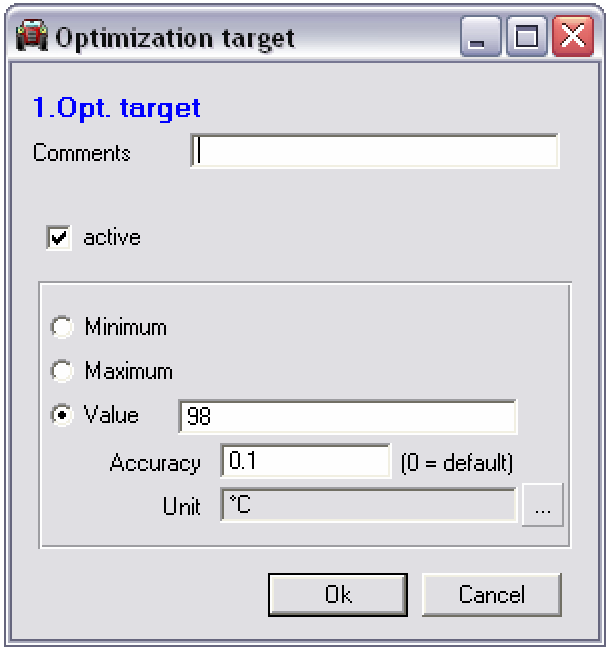
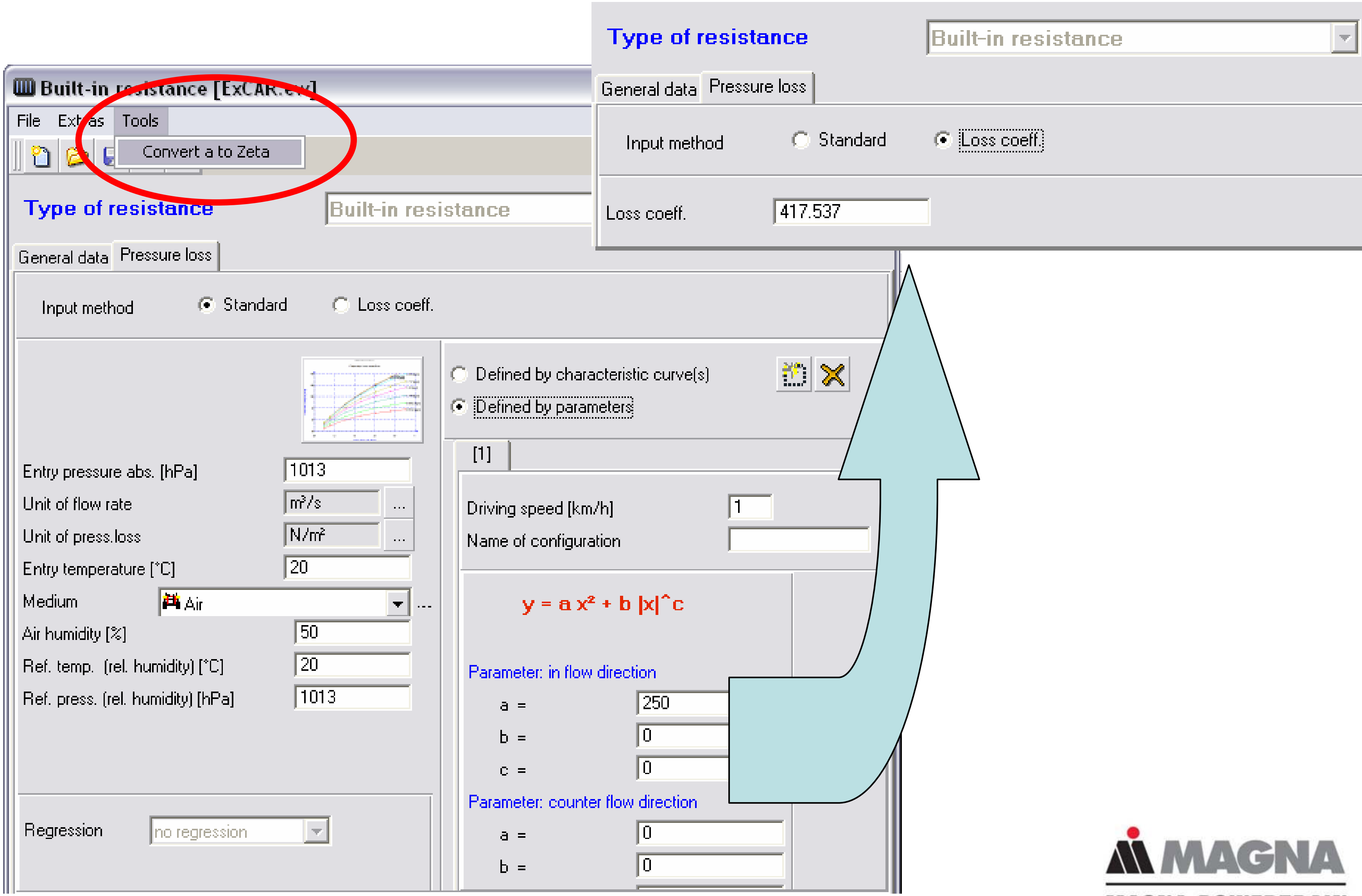
Improvements for Optimization

- **Improvements for 1D optimization regarding speed and dependence on optimization parameter bounds**

- **Optional input of desired optimization accuracy**
  - valid for optimization with single parameter and target



BiR: Conversion of Parameter "a" to Zeta



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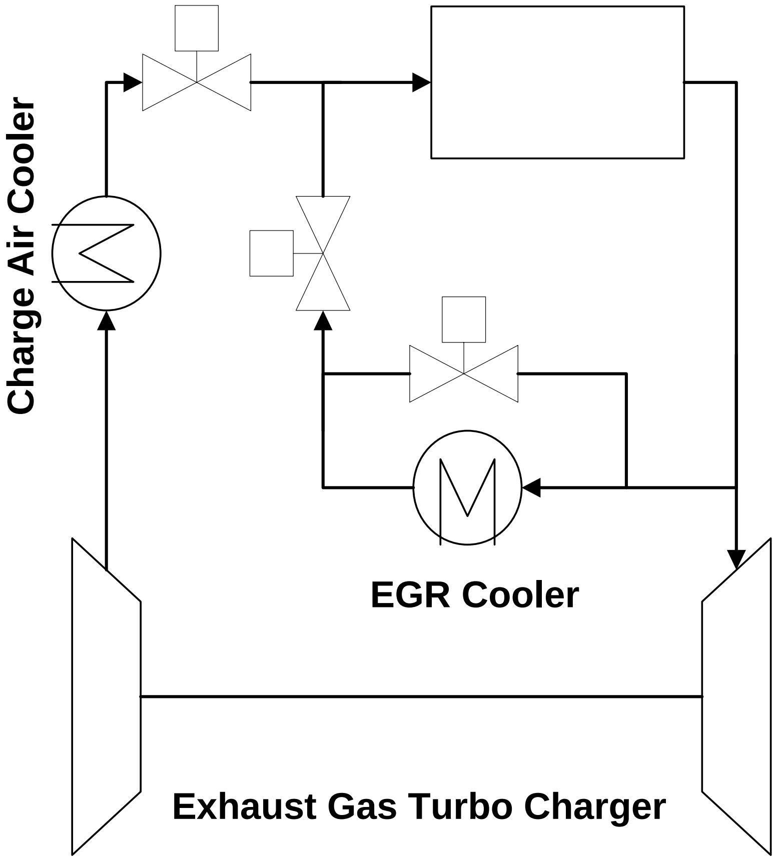
Engine Model for Exhaust Gas Turbo Charger

- **Includable parameters**
  - Charge air cooling
  - EGR mass flow
  - EGR cooling
  - Influence of EGR on cooling system
  - Behavior of turbine and compressor
  - Influence of ambient conditions

- **Exclude parameters**
  - Combustion
  - Gas dynamics



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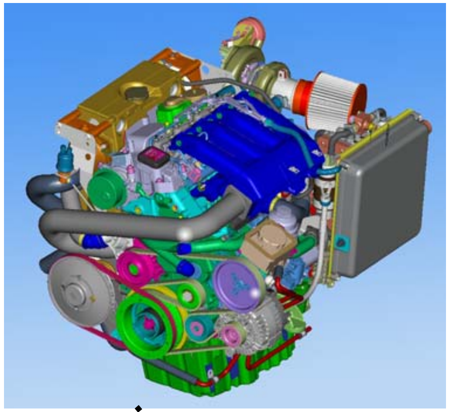
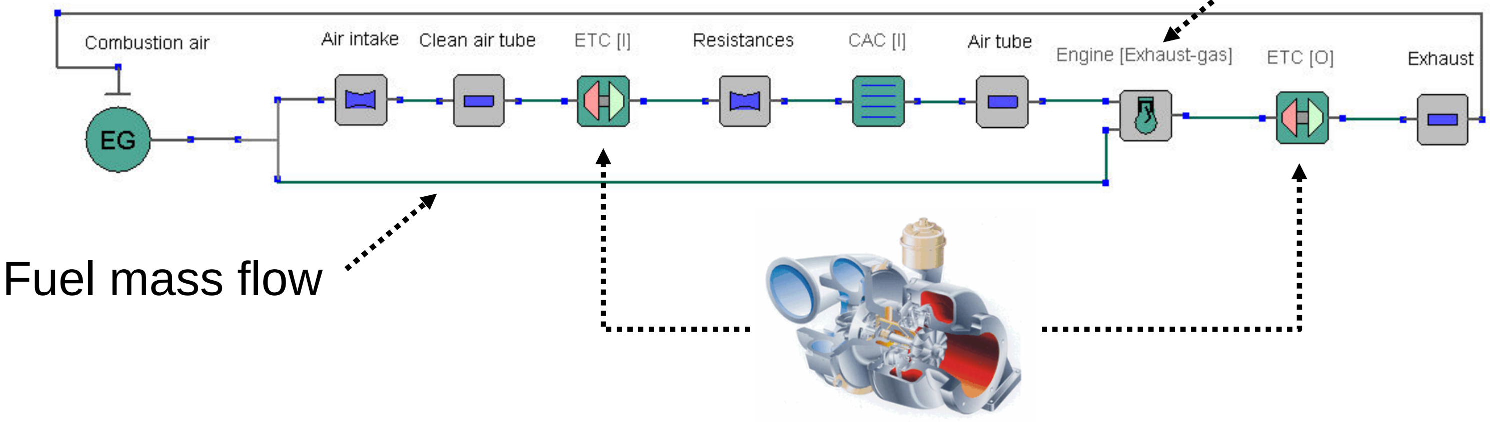
Engine Model for Turbo Charger

- **Exhaust gas turbo charger integrated in engine model**
  - Charge air side and exhaust gas side
  - Turbo charger and engine exchangeable
  - Engine model contains data for charge air and exhaust gas mass flow calculation
  - Data for exhaust gas pressure and exhaust gas temperature specified in engine model





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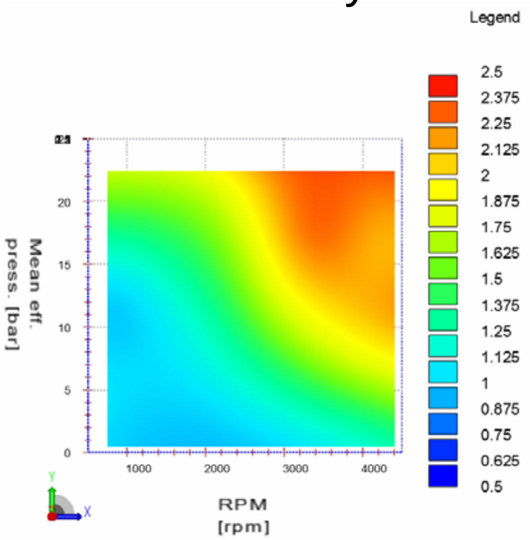
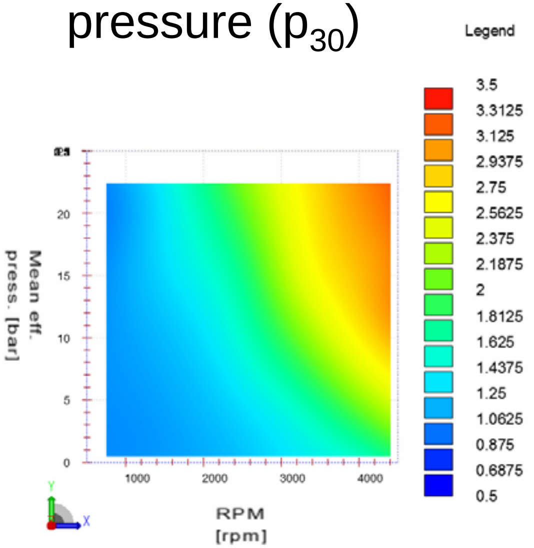
Input Data Engine for Exhaust Gas Turbe Charger

- **Tick “Data for Turbocharger” in engine input data sheet**
- **Add data in „Consumption“ note page**

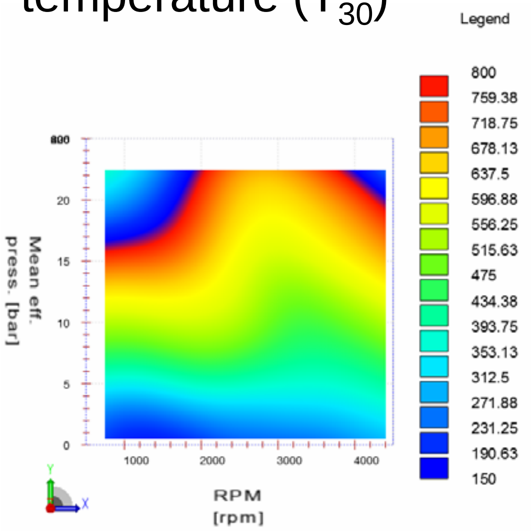
Air efficiency

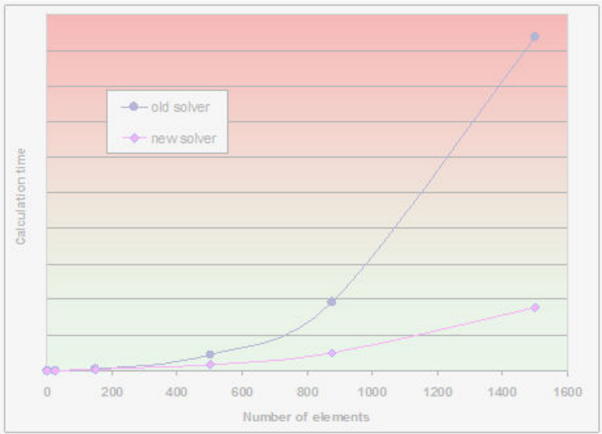


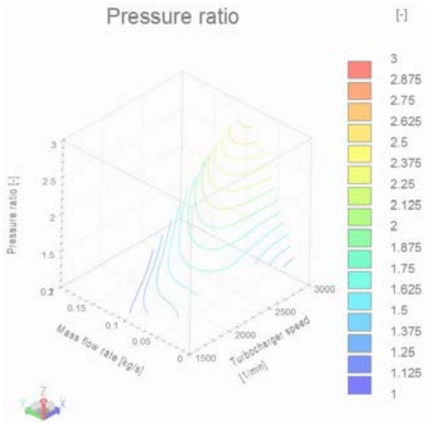
Exhaust gas pressure (p_{30})

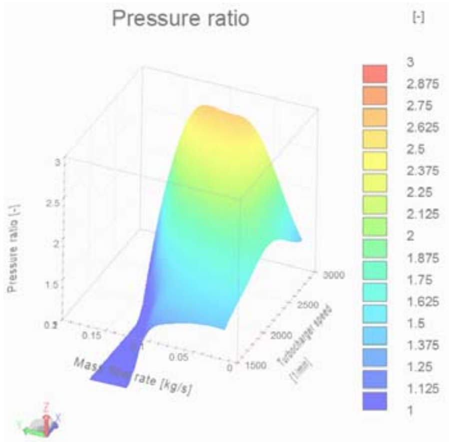


Exhaust gas temperature (T_{30})

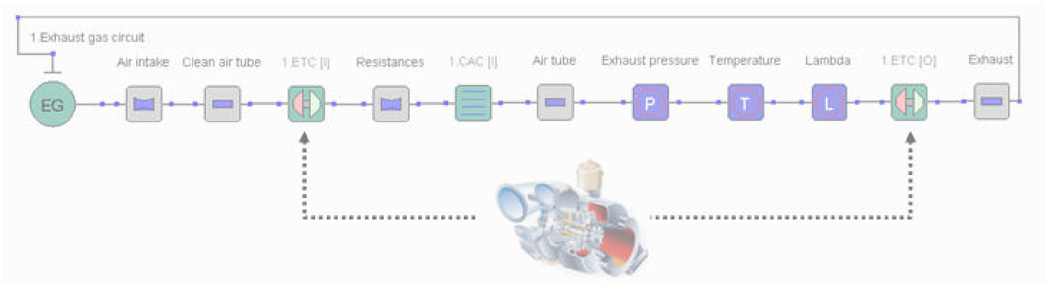


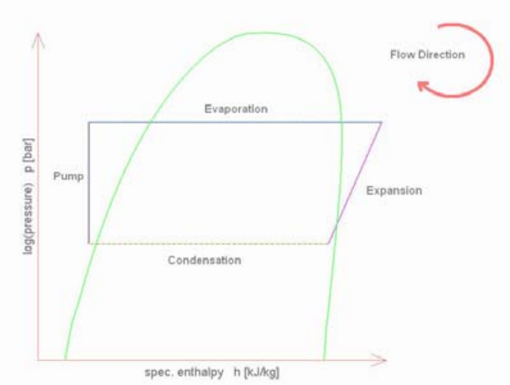






Thank you for your interest!





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