GT-POWER 7.5新模板应用

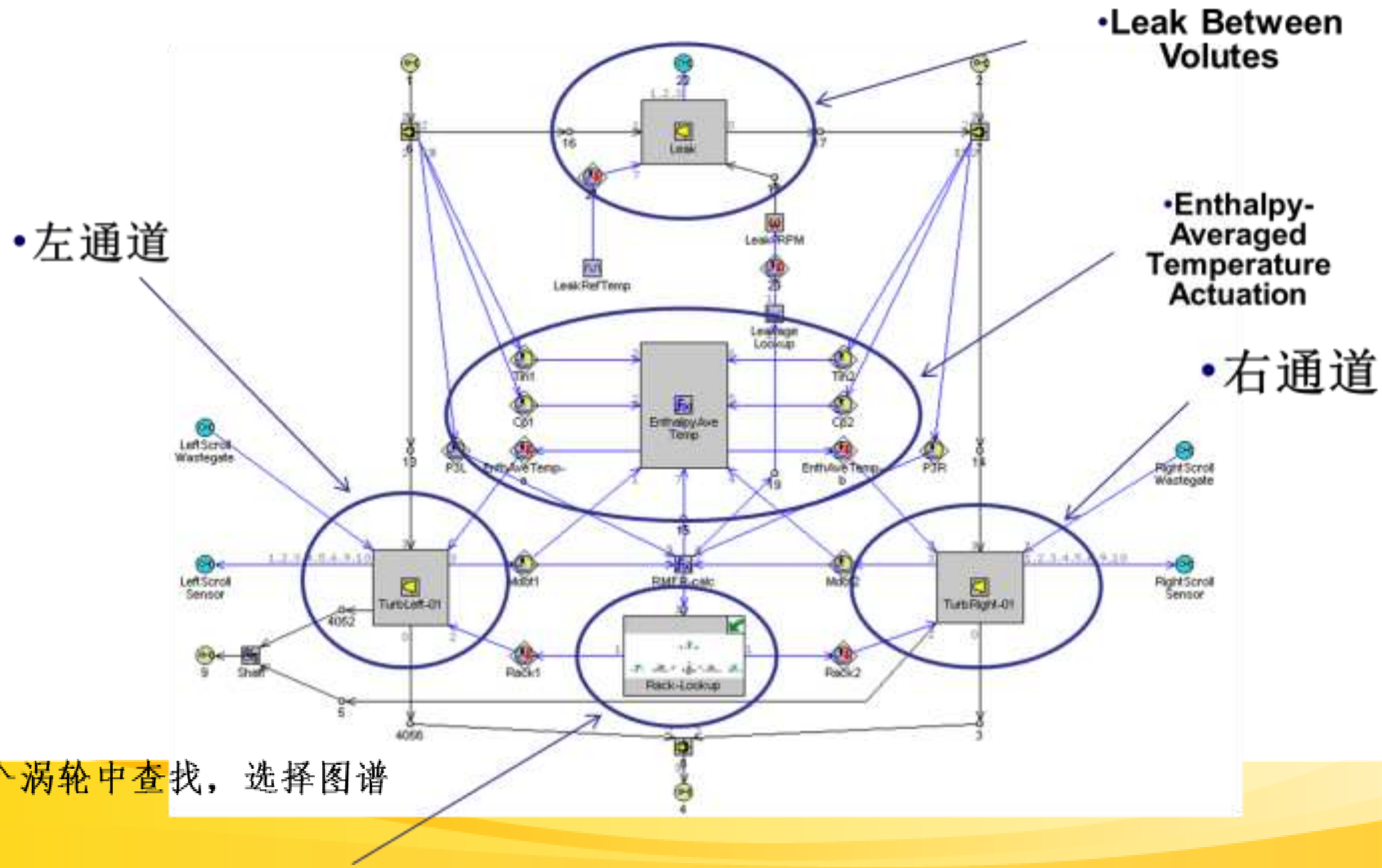
所属:IDAJ Team

内容

- 增压器方面应用
- 预测燃烧模型
- 配气机构耦合应用
- FRM转化工具
- 高级优化功能

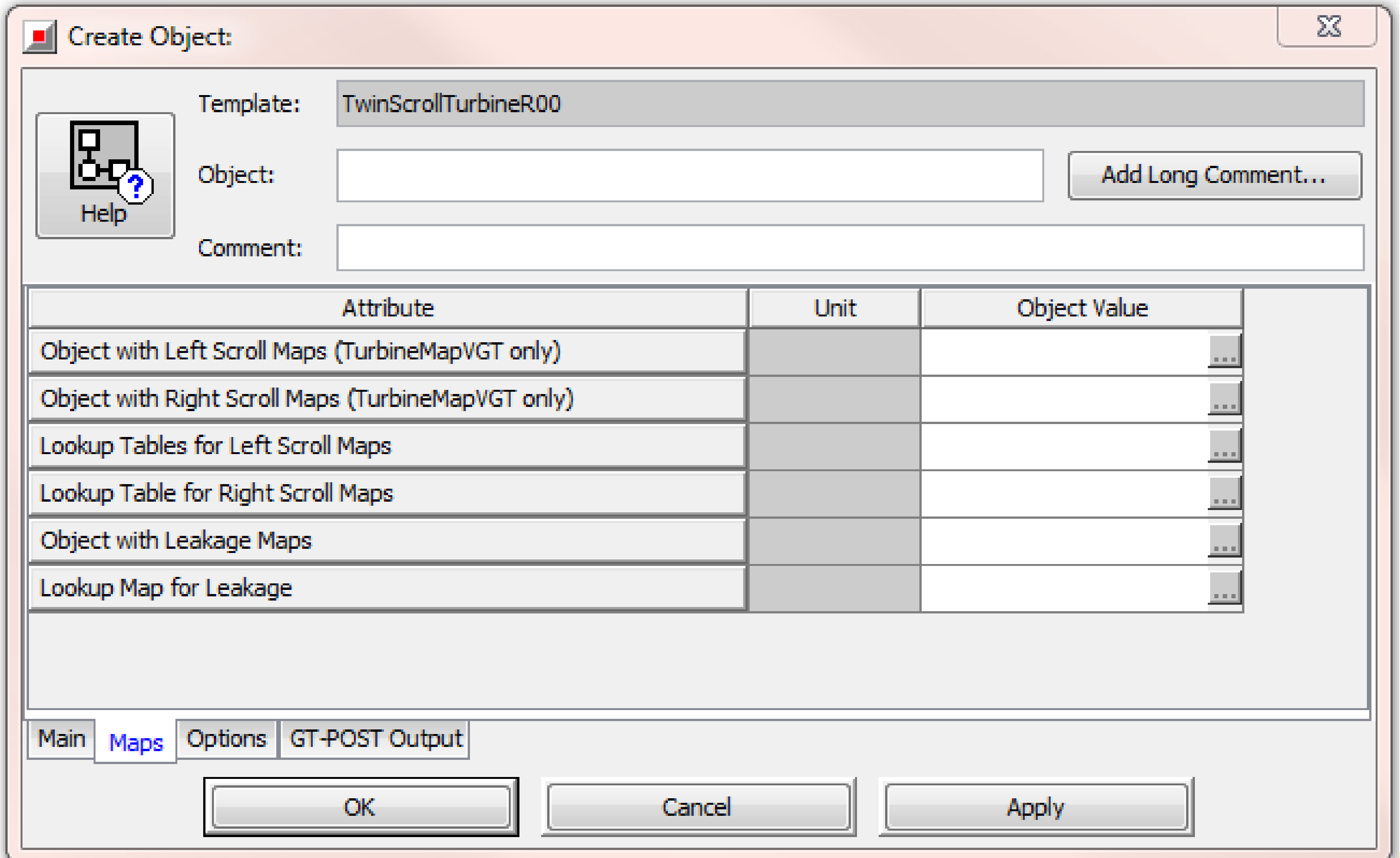
涡轮增压器 -双通道涡轮

- 组合模板创建的 双通道涡轮
- GTI根据FVV的项目要求创建
  - 原模型（测试版本）符合项目要求



•在每个涡轮中查找，选择图谱

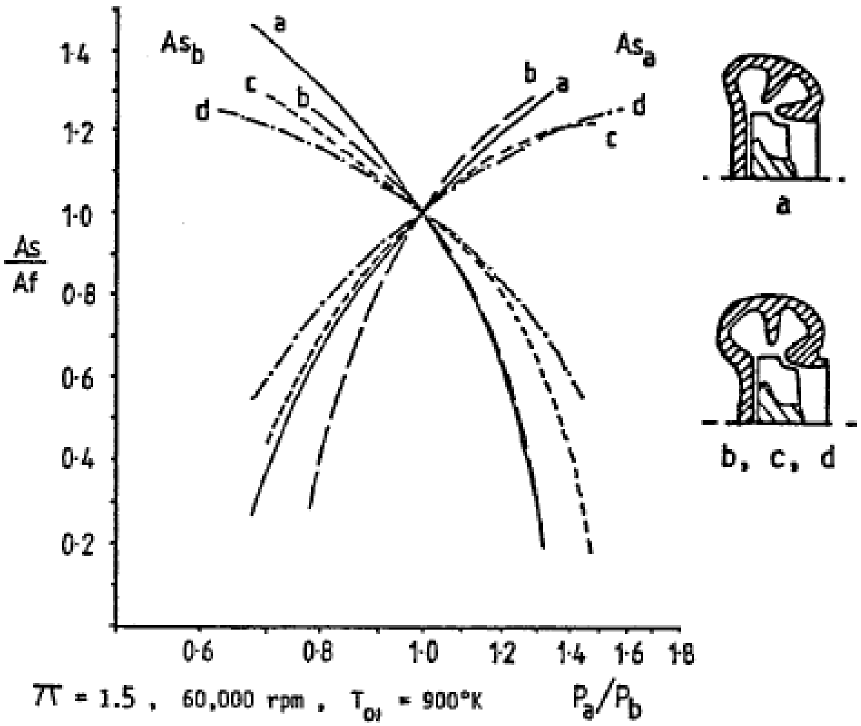
双通道涡轮模板



Create Object:
Help
Template:
TwinScrollTurbineR00
Object:
Add Long Comment...
Comment:
Attribute
Unit
Object Value
Object with Left Scroll Maps (TurbineMapVGT only)
Object with Right Scroll Maps (TurbineMapVGT only)
Lookup Tables for Left Scroll Maps
Lookup Table for Right Scroll Maps
Object with Leakage Maps
Lookup Map for Leakage
Main
Maps
Options
GT-POST Output
OK
Cancel
Apply

带有控制的双涡轮部件方法：理论介绍

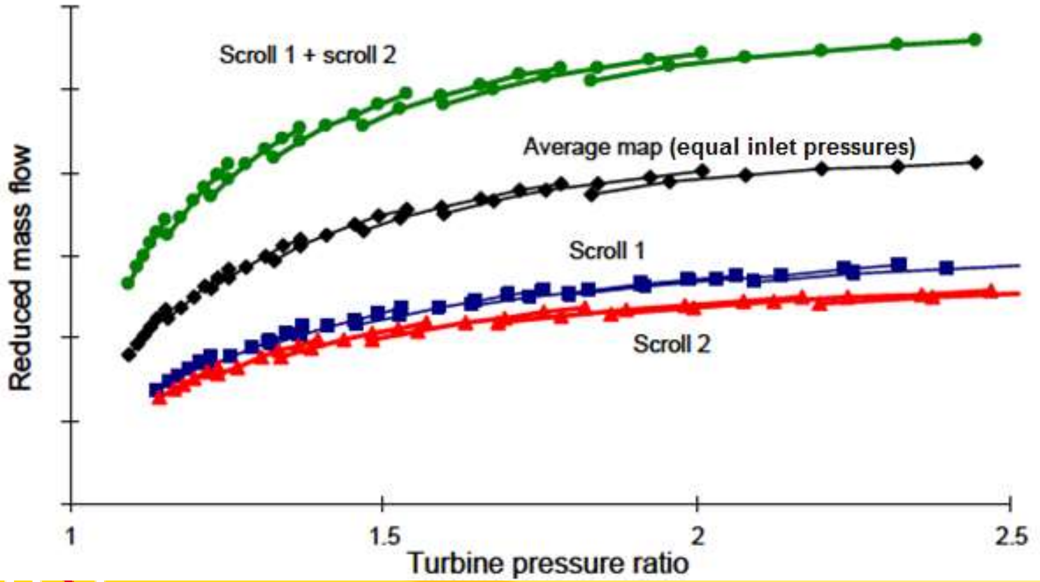
- 众多研究者发现：当入口压比不是1时，入口的有效面积会变大
- 在循环波动中，气缸产生的交变的压力脉动 会导致入口压力的不平衡，也就会导致更大的流量
- 更高的流量实现通过改变质量流量系数来实现，质量流量系数是入口压比的函数



•From ‘Fundamentals of Turbocharging’ by N. Baines

多MAP方法:背景介绍

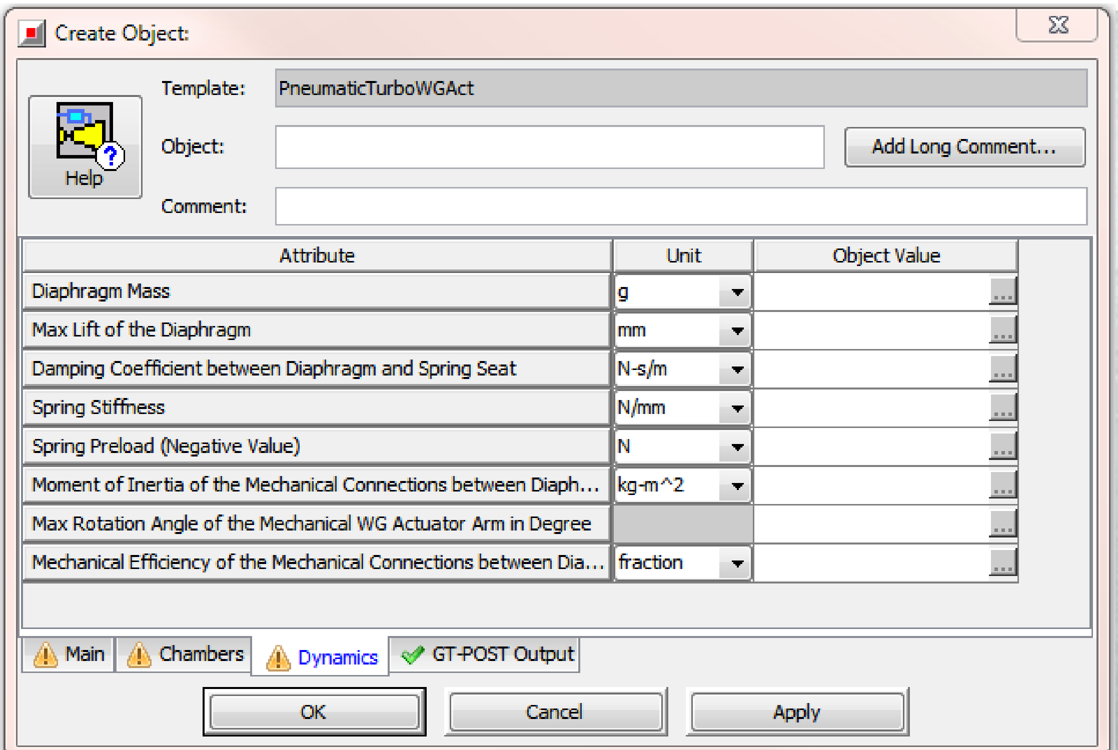
- 对于双入口的涡轮，测量3个或更多的MAP图变得越来越普遍
- 一个map是：相等的压力测试
- 其它的map图：允许一个入口流入，而另外一个入口不允许流入
- 下图可以显著的看出，单入口的流量比双入口流量的½要多

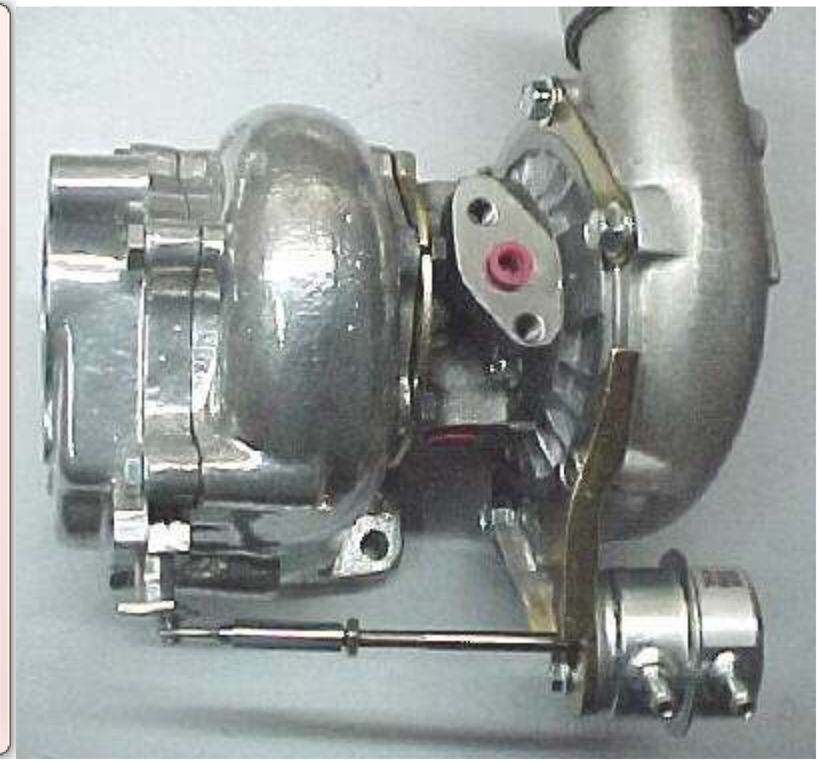


- **Image from 'Charging System for a High Performance SI-Engine – Technology and Methods' by Drangel, et al., Aufladetechnische Konferenz 2007.**

废气旁通阀模板及控制

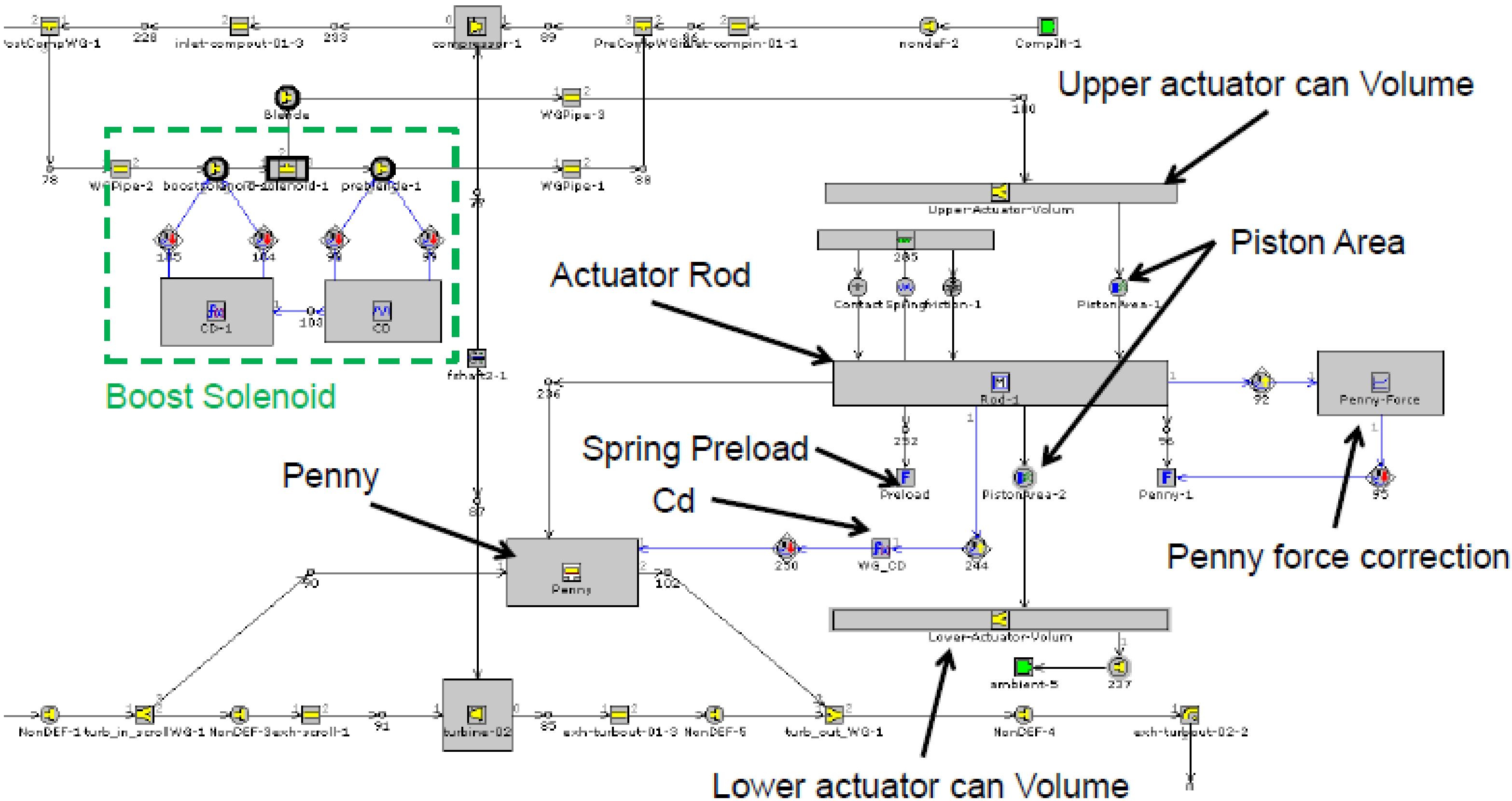
- 气动的废气旁通阀
  - 直观、易用的气动阀





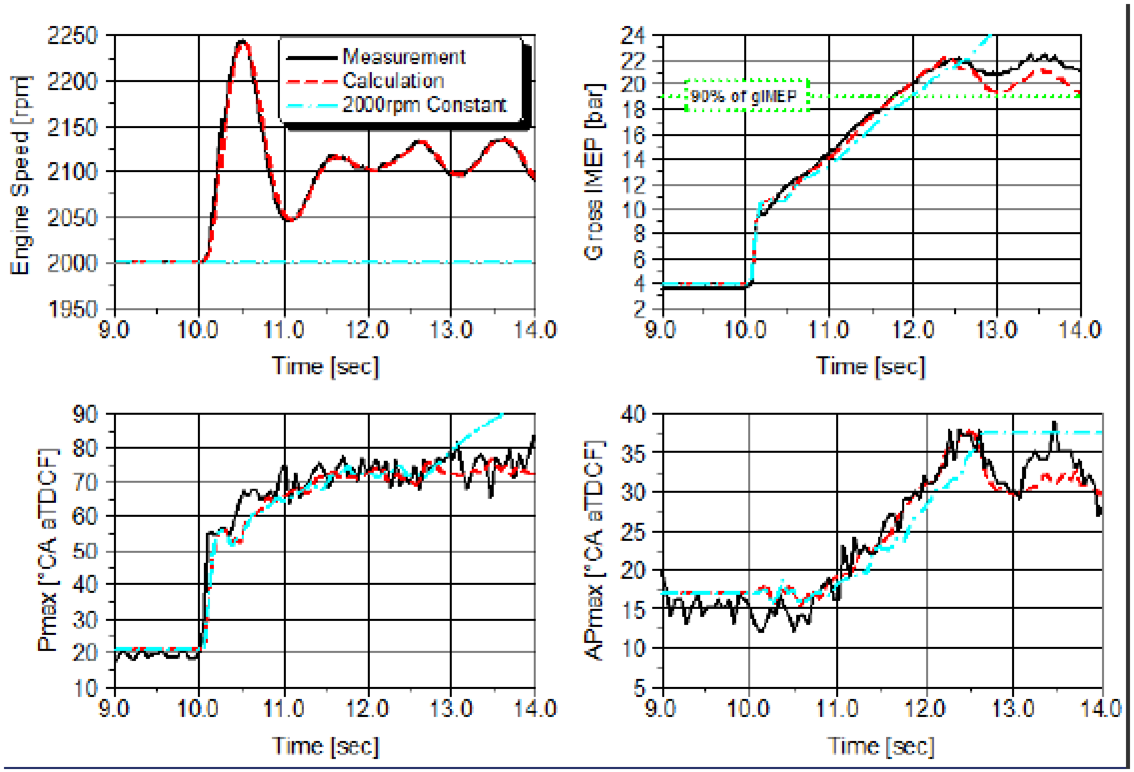
废气旁通阀模板及控制

■ 模板结构



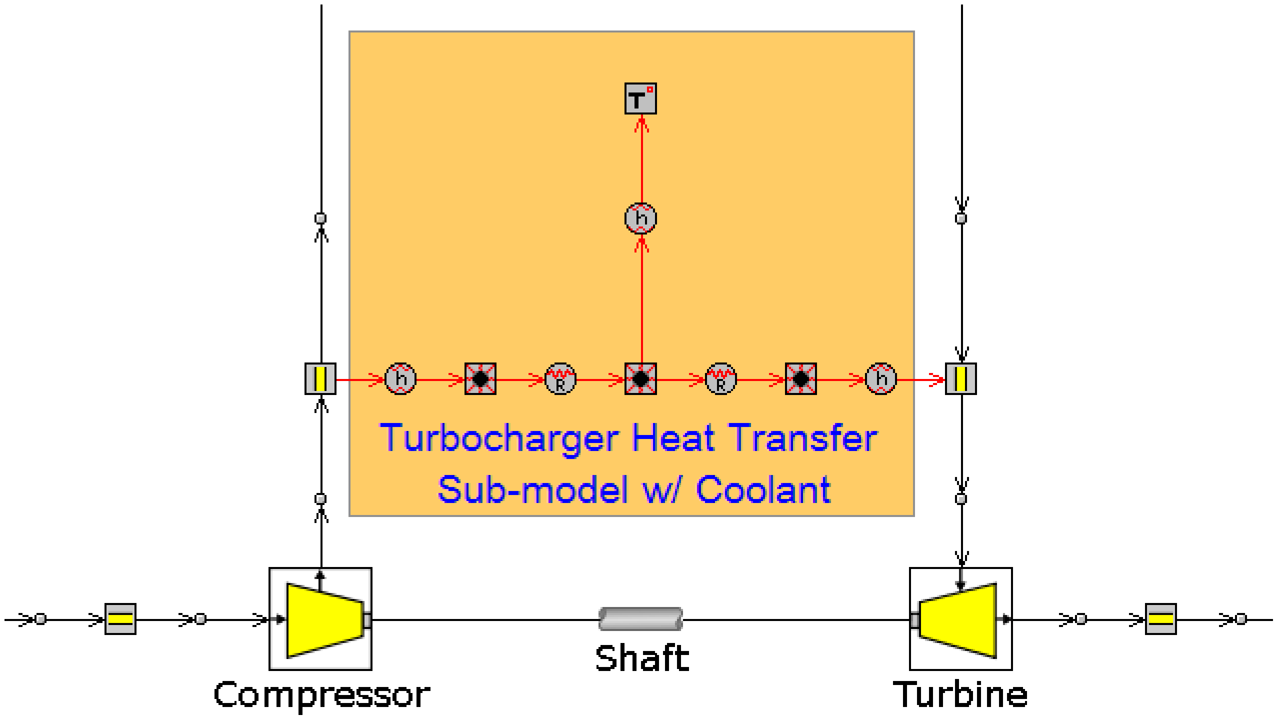
废气旁通阀的响应过程

- 废气旁通阀的响应过程
  - 2000rpm,动态响度应



涡轮增压器中的传热分析

- 简化的热传递路径可以用热的库板进行搭建

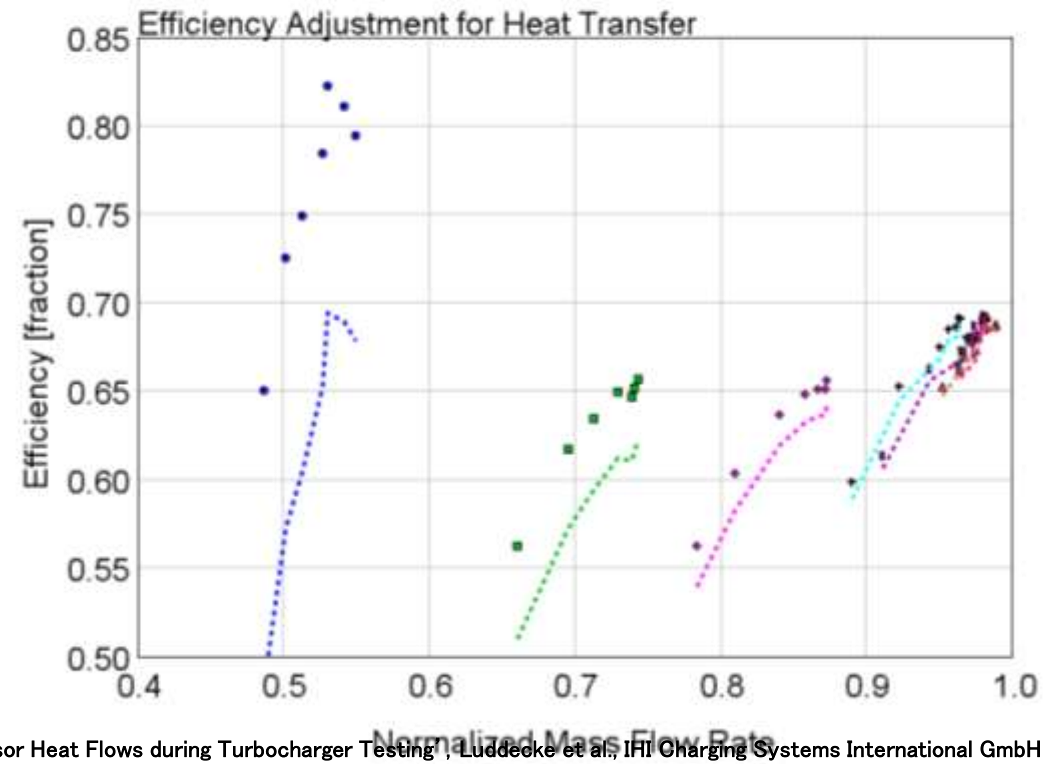


- 专门的部件将很快发布
  - 带有水冷的增压器(主要用于SI发动机)
  - 不带水冷的增压器（主要用于柴油机)

涡轮增压中的传热分析

- 有两个属性使得在涡轮增压器中的考虑传热变得简单
  - v7.5新的特性：Map的前处理过程中能修正传热对效率的影响
  - 热的模板能体现从涡轮传递到压气机的热量传递

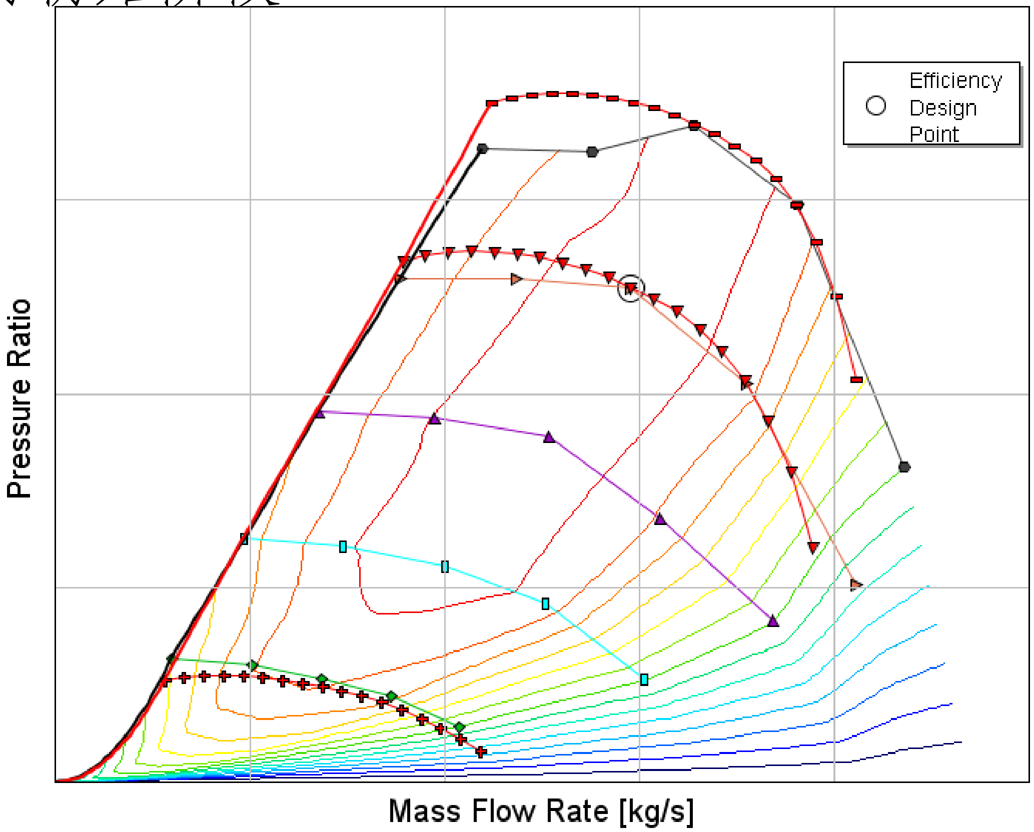
- **Map修正**
  - 参数化的温度和热阻属性的添加或移除可以考虑热能对效率的影响



·Ref: ‘On Wide Mapping of a Mixed Flow Turbine with regard to Compressor Heat Flows during Turbocharger Testing’, Luddecke et al., IHI Charging Systems International GmbH

参数化的压气机MAP

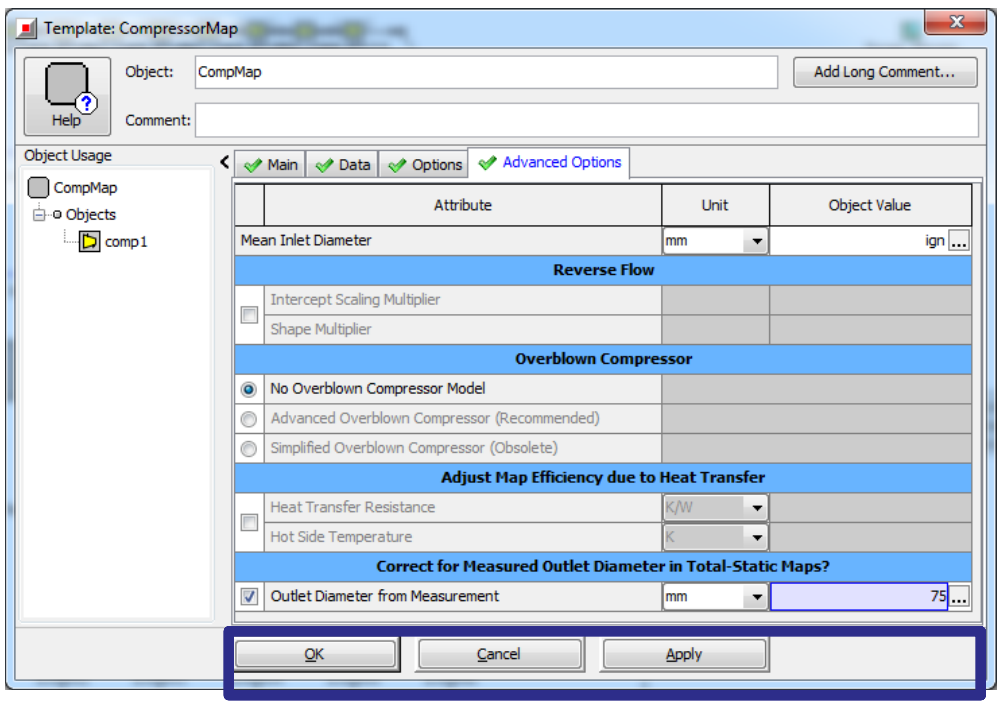
- 根据少量的基本几何尺寸的，基于物理特性去修正与预测压气MAP图
- 应用于尺寸分析在设计的初始阶段
- 需输入的参数：
  - 叶轮直径
  - 设计点信息：
    - Mass Flow Rate
    - Pressure Ratio
    - Compressor Speed
    - Isentropic Efficiency
- 模板：
  - CompressorMapParam



•Ref: Casey, M. and Robinson, C., “A Method to Estimate the Performance Map of a Centrifugal Compressor Stage”, Proceedings of the ASME Turbo Expo 2011, ASME paper GT2011-45502..

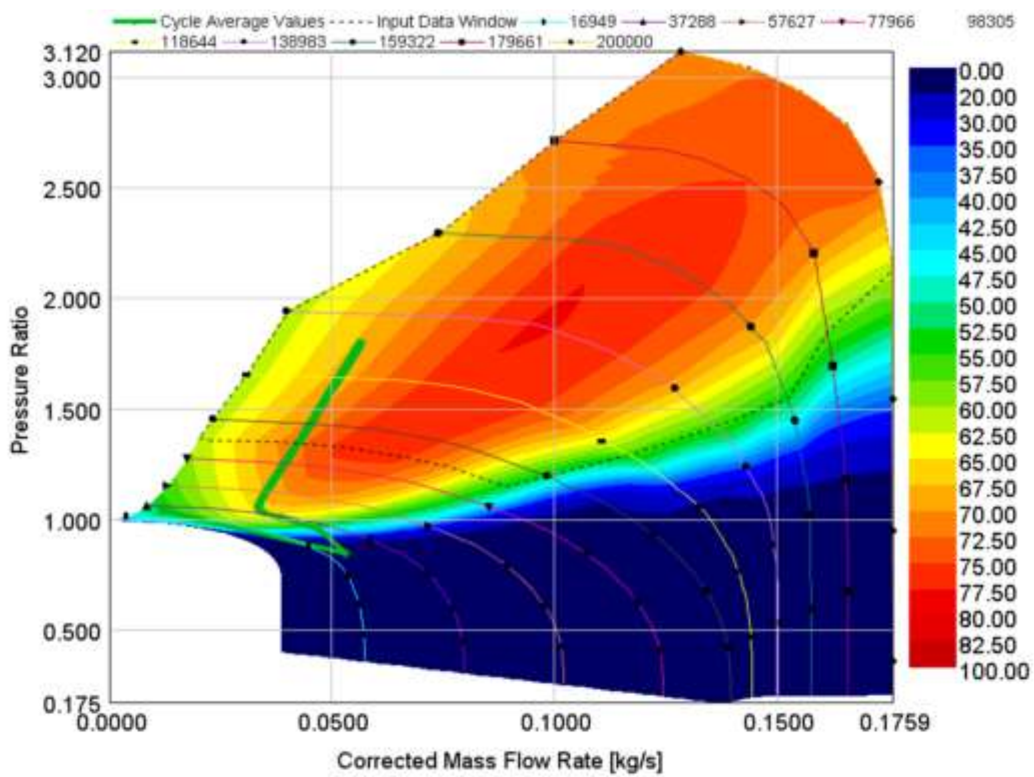
PR 修正Turbocharger 的Map

- <u>问题</u>：涡轮机的MAP是由total-to-static压比+ 发动机尾管的直径与测试设备的直径不一定相同= 造成误差
- <u>新特性</u>：当直径不一样时，MAP图的修正自动完成。当输入‘Outlet Diameter from Measurement’属性时会考虑



Turbo 模拟

- 质量流量允许在RPM & PR<1在压气机的过流状态下



- 应用：使涡能断开时，在两级和顺序增压系统时

•* M V Casey, M Schlegel: Estimation of the performance of turbocharger compressors at extremely low pressure ratios 2010.

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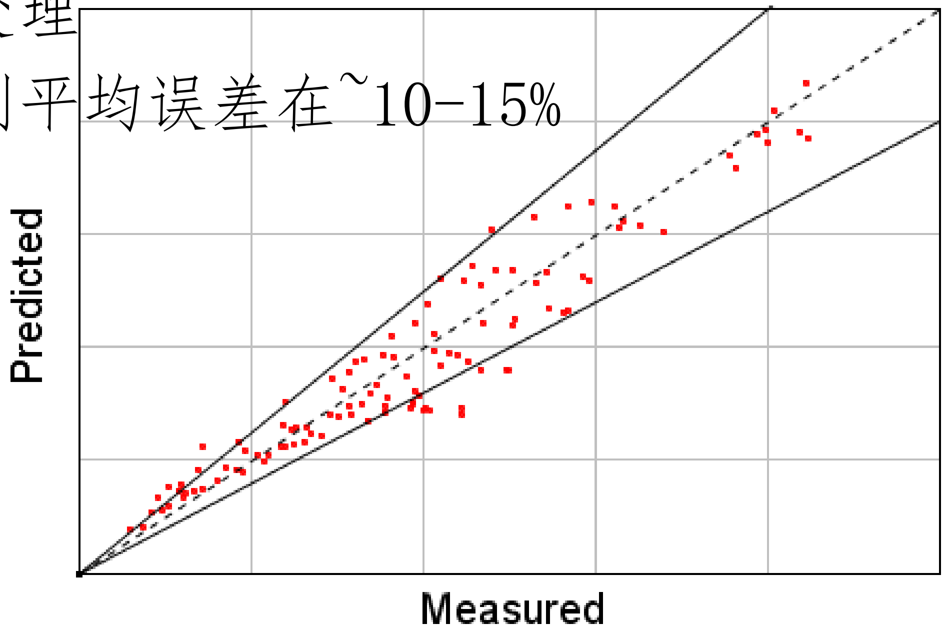
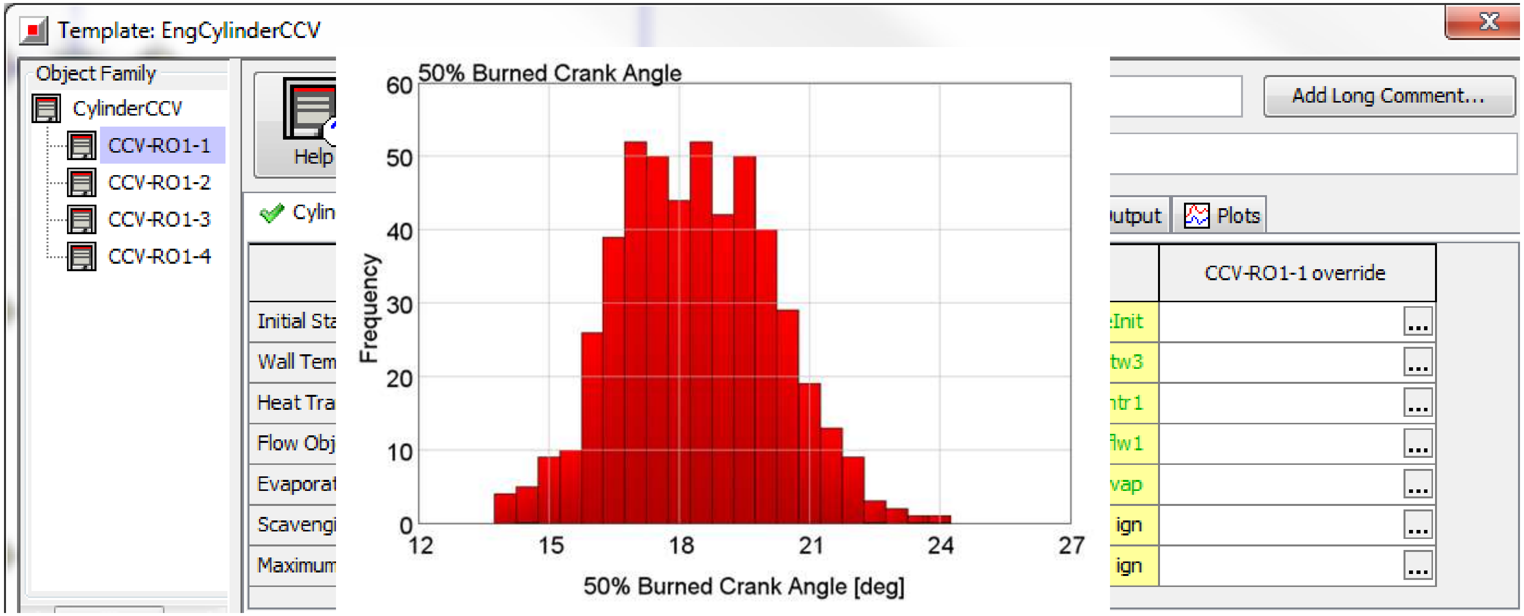
柴油机预测燃烧模型（DIPulse）

- v75中的DIPLUS模型
  - 相对于转速有更准确的燃烧率预测
    - 提升了湍流混合模型
  - 提高了Nox排放预测精度
    - 对已燃区域进行分层处理
    - 绝大部份发动机能达到平均误差在~10-15%



SI预测燃烧模型（SITurb）

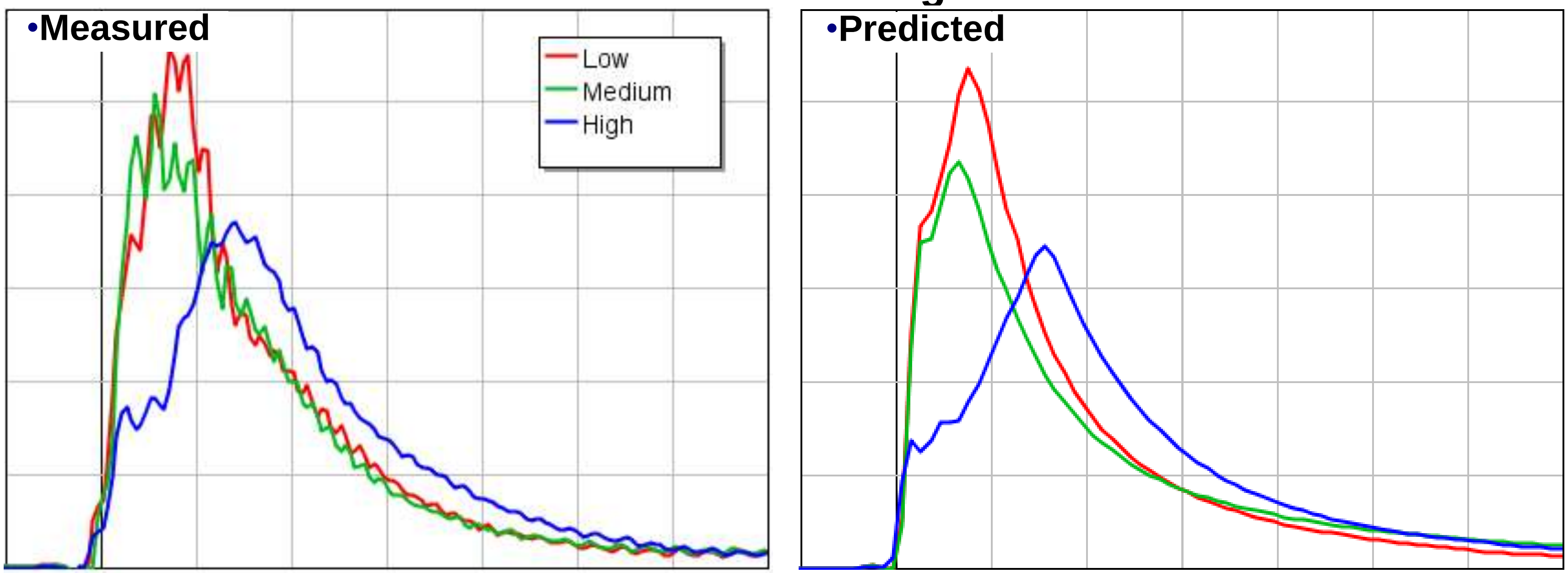
- v75中的SITurb模型
  - 在高残余废气比例时，能更准确的预测燃烧率
    - 提高升了层流火焰速度修正项
- 对于SI燃烧模型算例体现cycle-to-cycle变动(CCV)
  - 新的部件演示如何实现CCV模拟



双燃料的预测燃烧模型

- 对于柴油/天然气的发动机，两者的组份可以从0-100% 任意变化

•Burn rates at three levels of gas substitution



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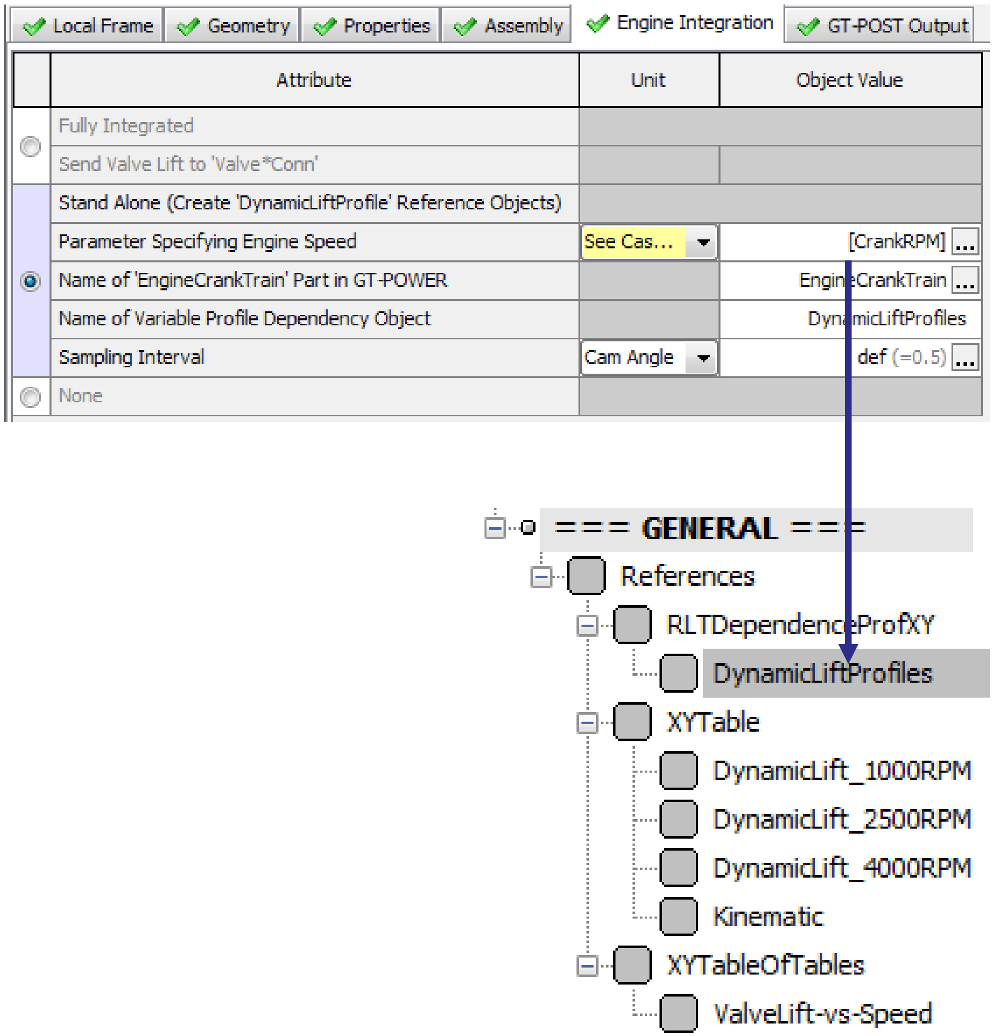
对于发动机的流程自动化处理（对于发动机只是一个组件）

- 当配气构完全耦合时，并不需要准确捕捉发动机性能，GT-SUITE提供自动化的流程
- PoppetValve数据输出特性能自动型线的动态曲线MAP图（如：vs. speed）
- 动力学升程曲线能一步导入到GT-POWER发动机模型中



对于发动机的流程自动化处理-只用于分析

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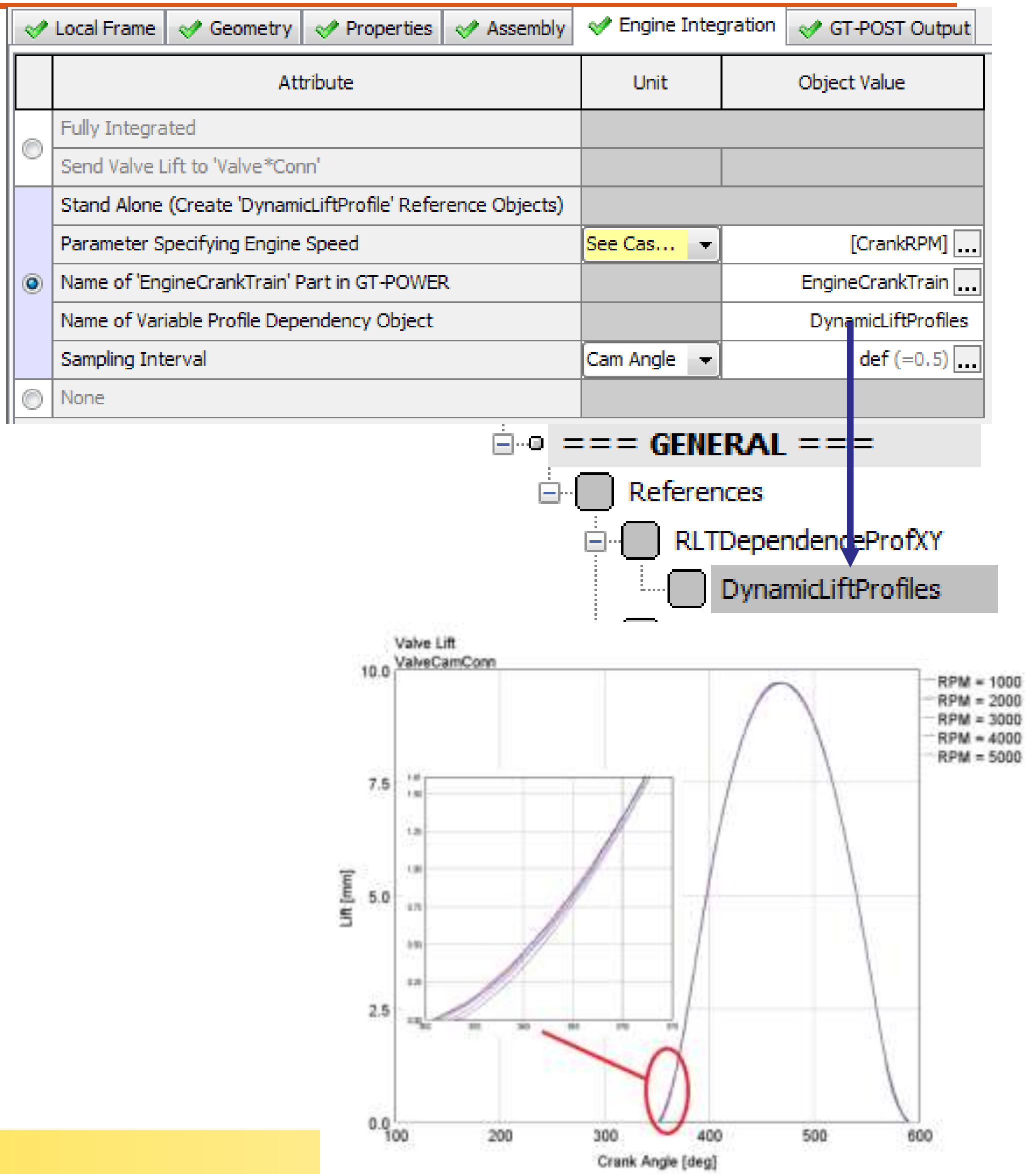

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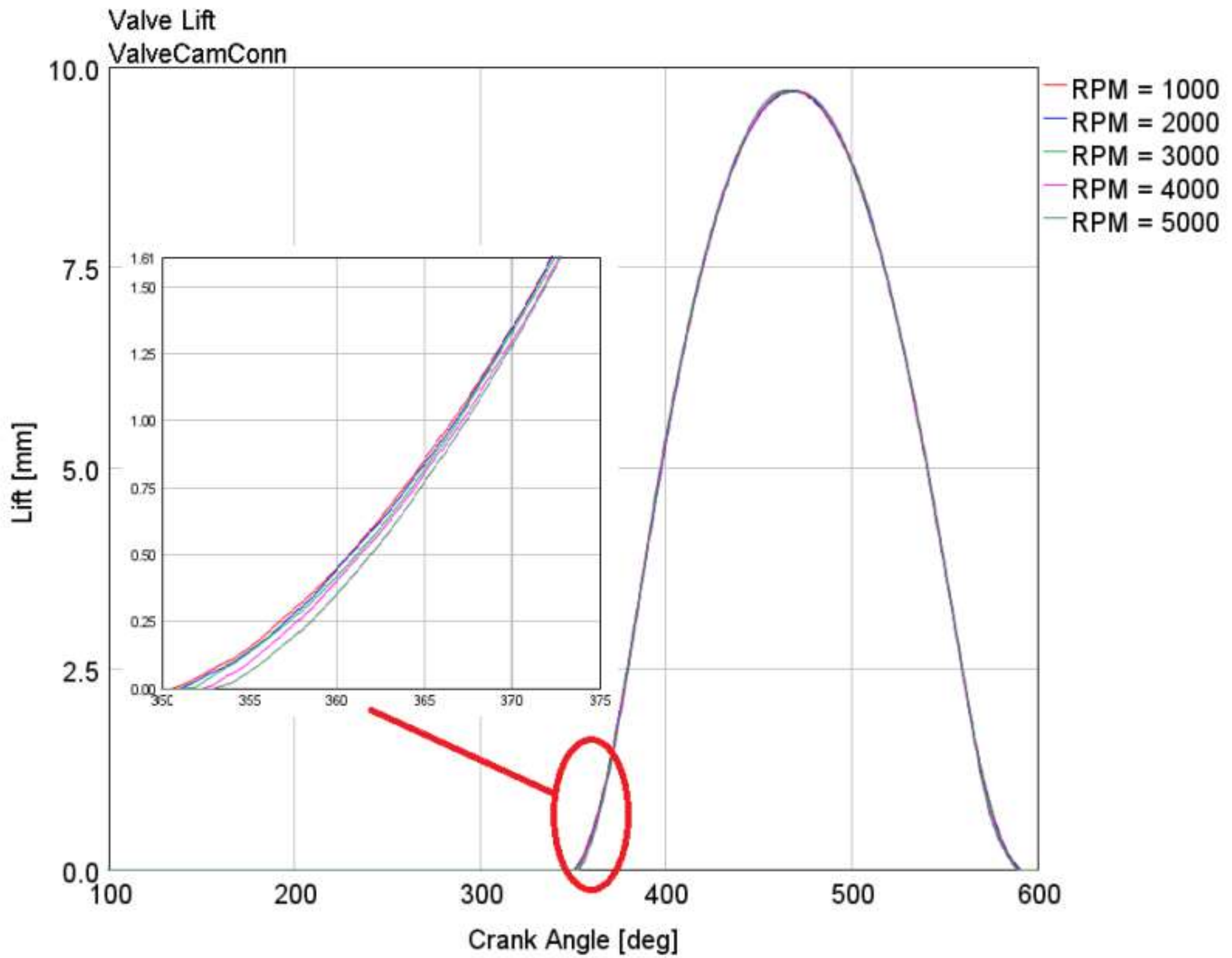
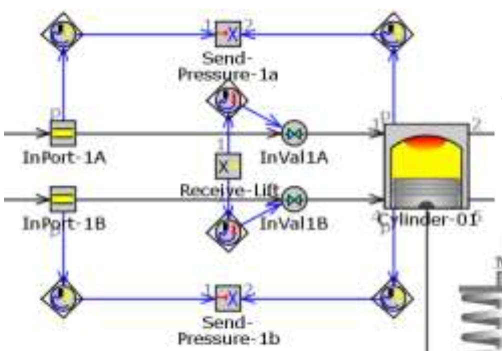
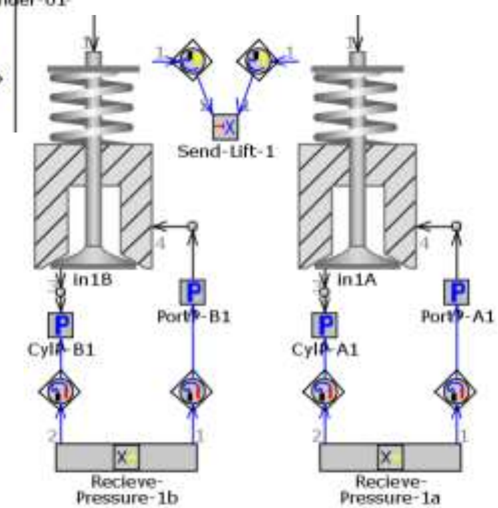


发动机-配气机构模型联接

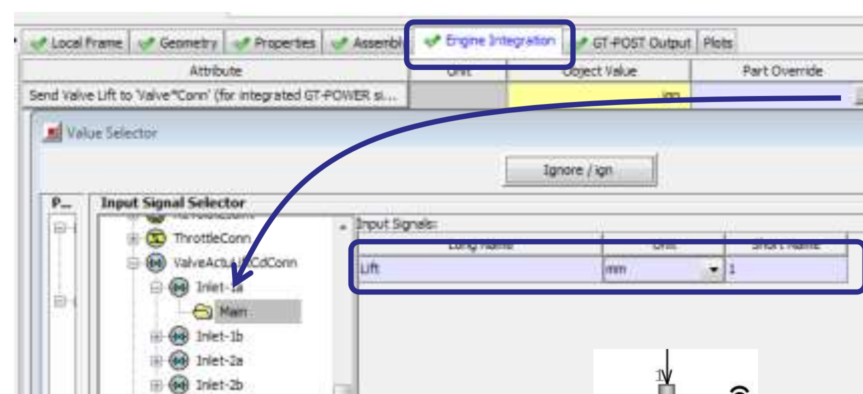
- 模板PoppetValve中的单一属性，兼容性各种Valve*连接
- 自动接收阀门上游/下游的压力信号
- 自动发送阀门升程

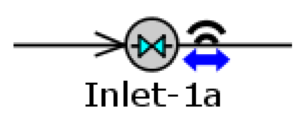


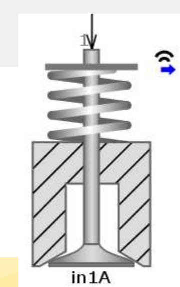
Before



After







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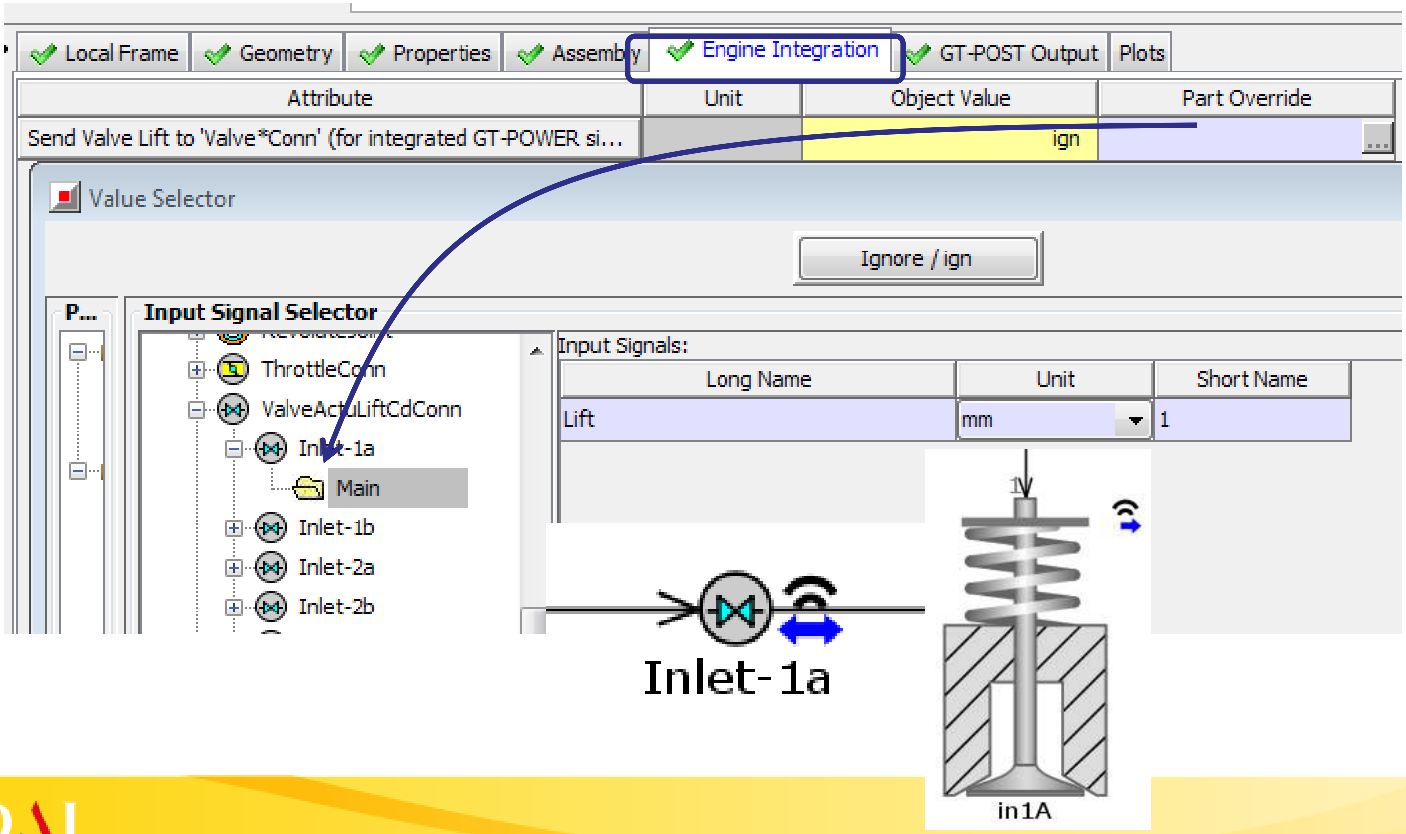
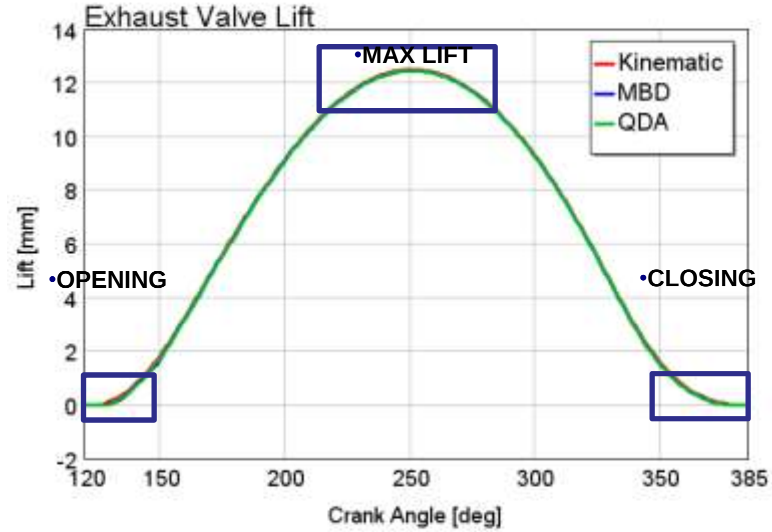
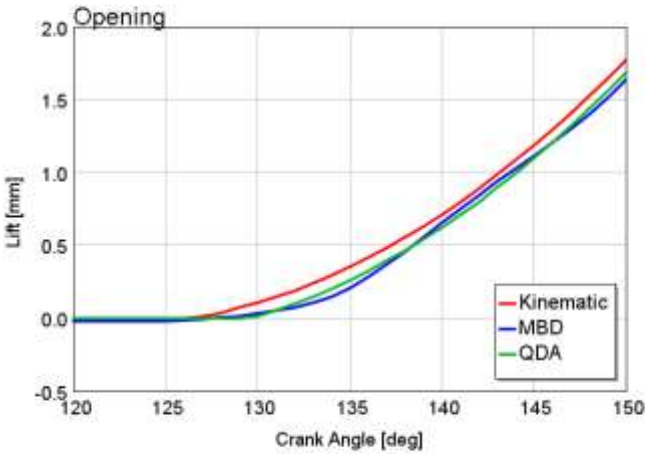


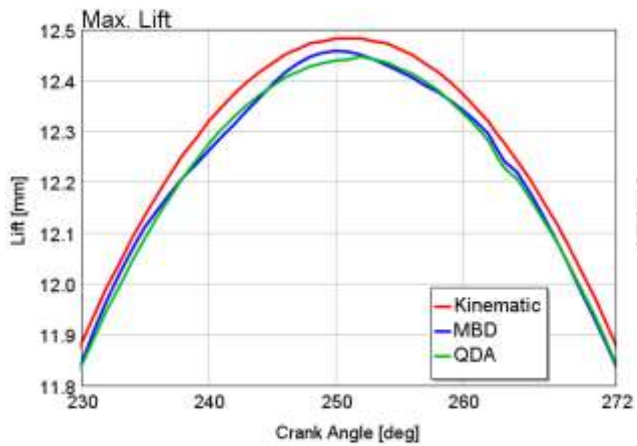
准动力学分析(QDA)

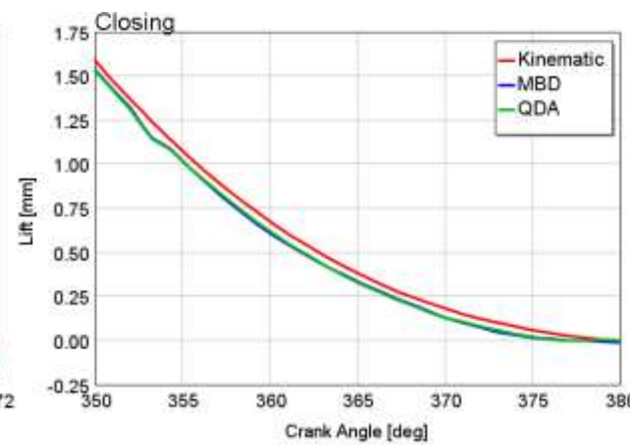
阀门升程预测

- QDA 通过**MBD分析**多重考虑配气机构变形去预测相关分析，把配气机构集成成一个等效的集总系统.
- QDA 只是不考虑二阶运动对高频动力学的影响





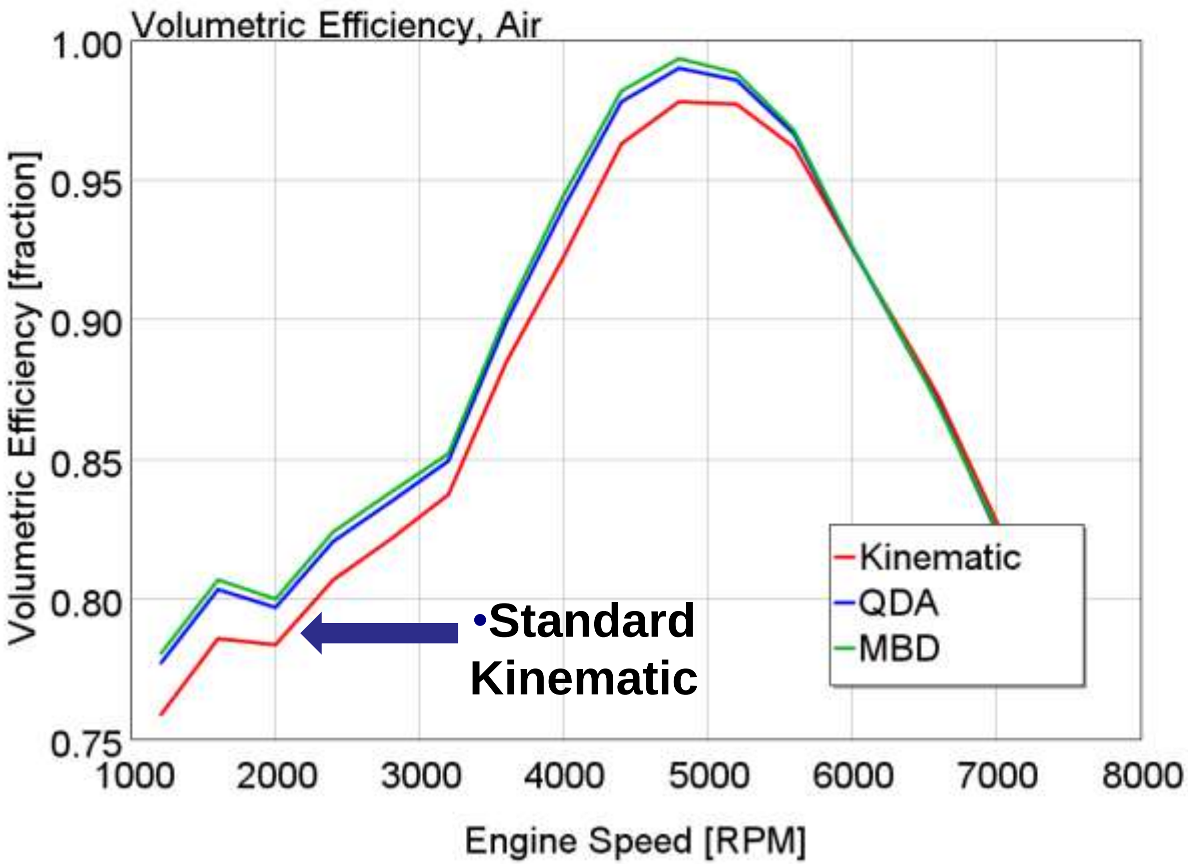




*Differences are due to consideration and treatment of dynamic deformations only. Effect of lash accounted for in all curves

Volumetric Efficiency对比

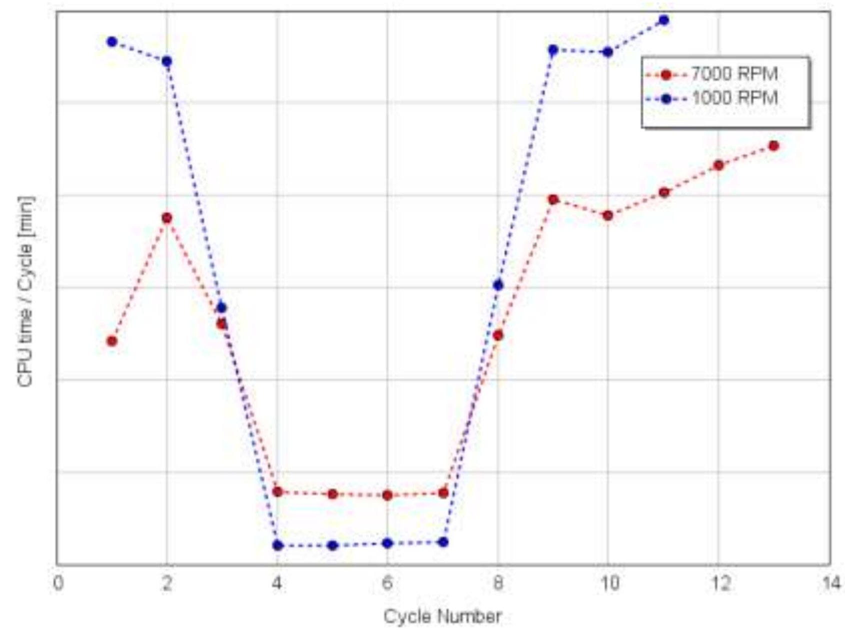
- QDA求解与Full-MBD一致性很好(两者都是 engine+valvetrain)
- 运行时间比全多体动力学快5-10x倍



配气机构求解的循环忽略

- 通过多体动力求解不激活来加速耦合模型
  - 只需操作CamAnalysis简单按钮实现
- 随后的升程可以与Kinematic，Quasi-Dynamic或 Dynamic保持一致

Attribute	Unit	Object Value
Camshaft Analysis Option		Rigid
Valvetrain Branches Analysis Option		
Dynamic Entire Duration		
Quasi-Dynamic Entire Duration		
Dynamic Cycle Skipping		
Solution Schedule (1=Enabled; 0=Disabled)		on-off-on
Valve Lift for Disabled Cycles		Previous-Cycle
Dynamic Lift Delay after Enabling		2
List of Additional Disabled Parts		ign
Quasi-Dynamic Cycle Skipping		



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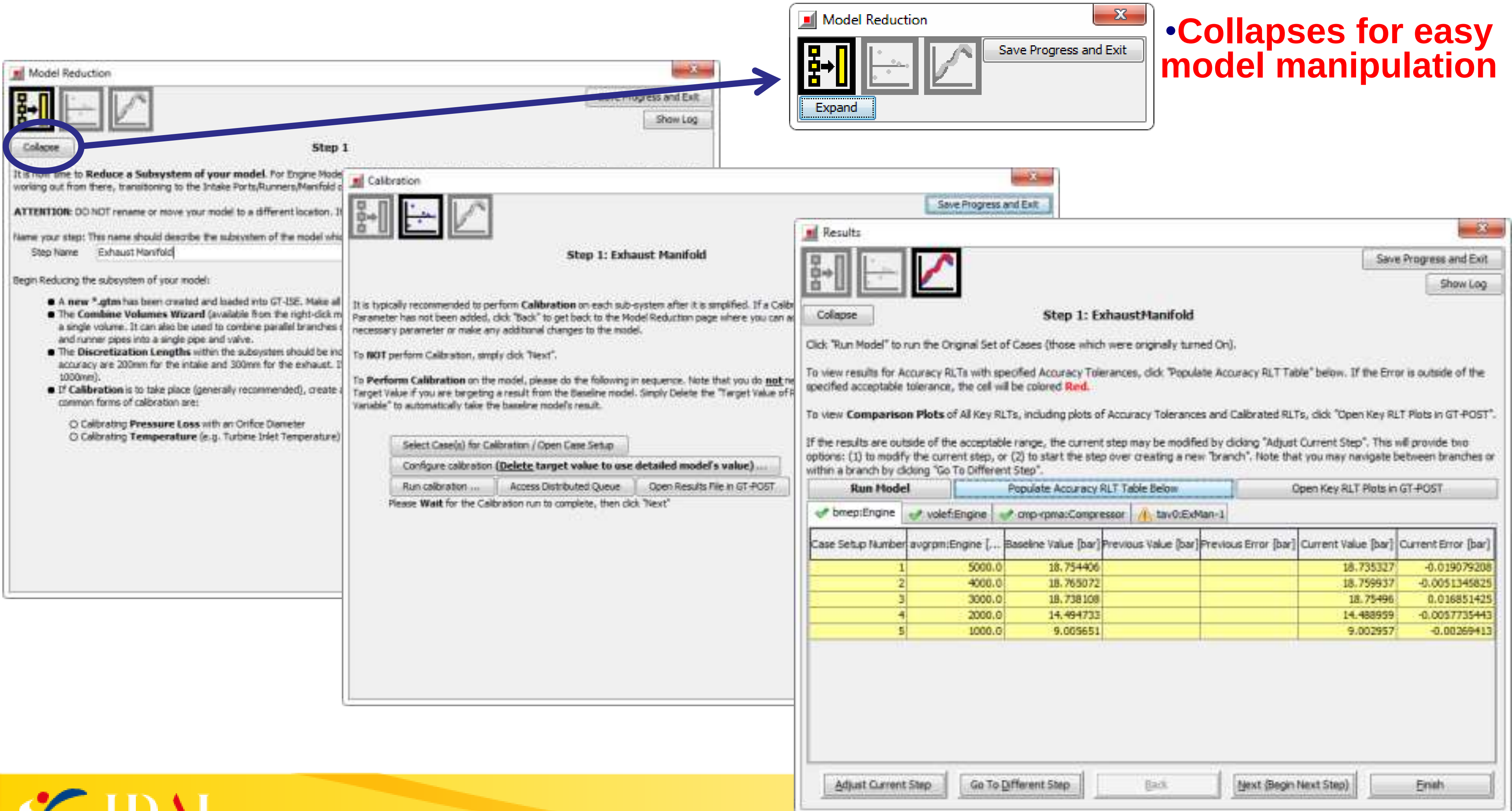
FRM模型转换工具

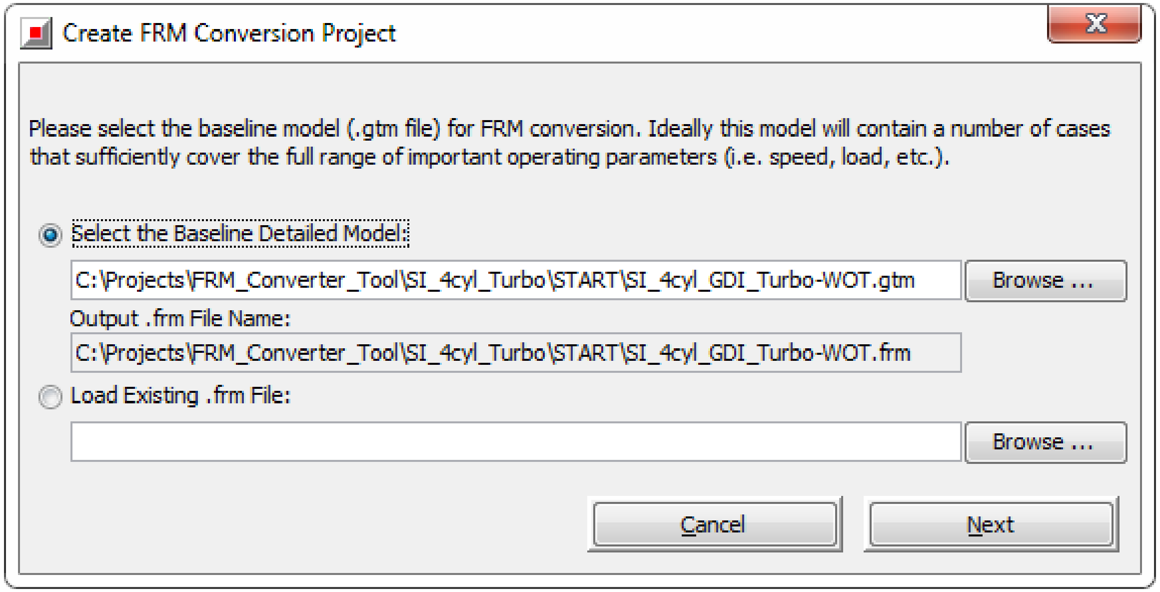
- FRM转化工具可以从开始到最终全程跟踪转换过程



- **Collapses for easy model manipulation**

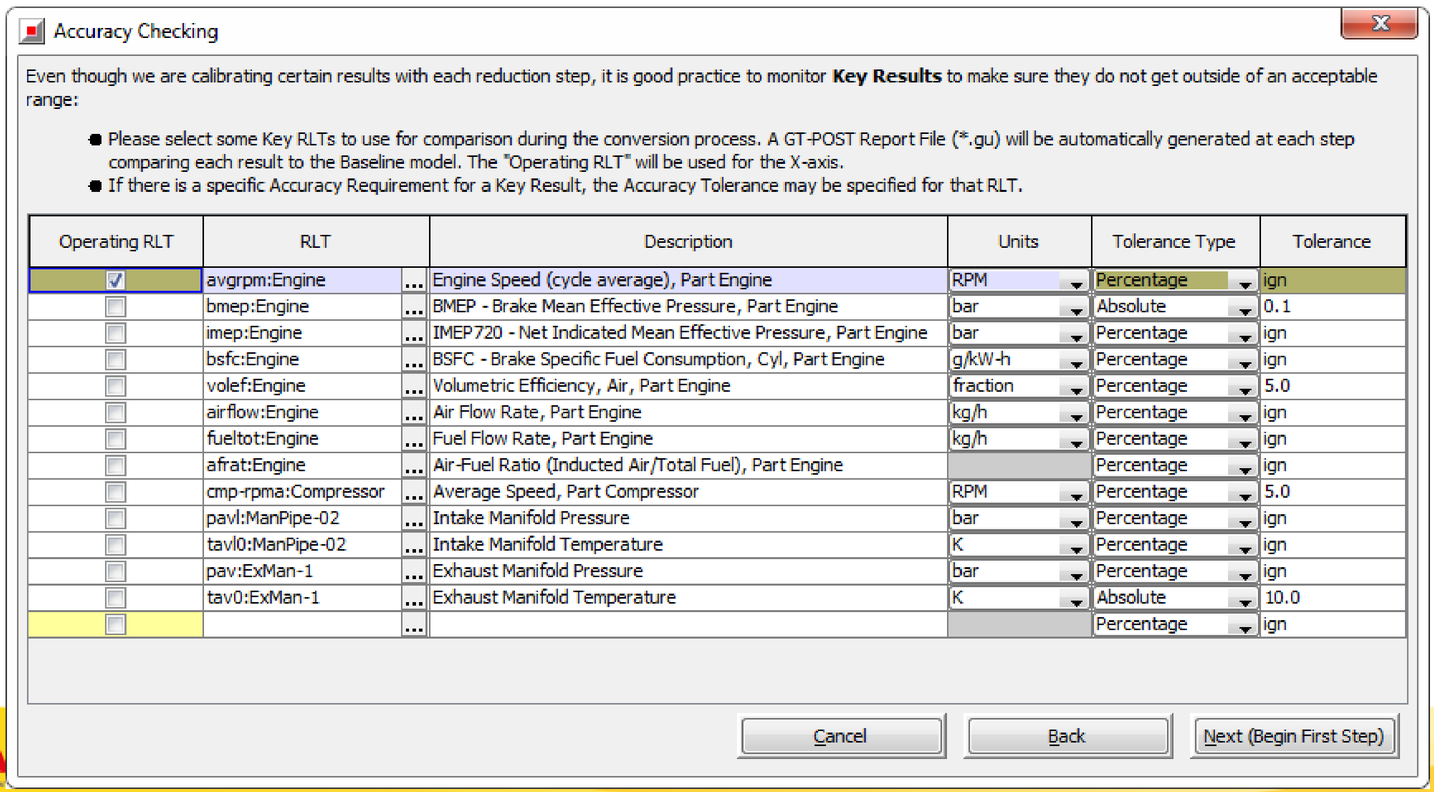
FRM转换工具

- 转换过程的信息何存在 *.frm文件中， 这个文件可以在任意时间保存、重载， 以确认转换过程是否合理，以便后续继续



FRM转换工具

- 关键的RLT结果（由用户选择）能在每一次转化过程中进行对比与确认，以保证转换准确性
- 可自定义输入RLT可接受误差范围，当超出范围时，提出警告以提醒用户



Accuracy Checking

Even though we are calibrating certain results with each reduction step, it is good practice to monitor **Key Results** to make sure they do not get outside of an acceptable range:

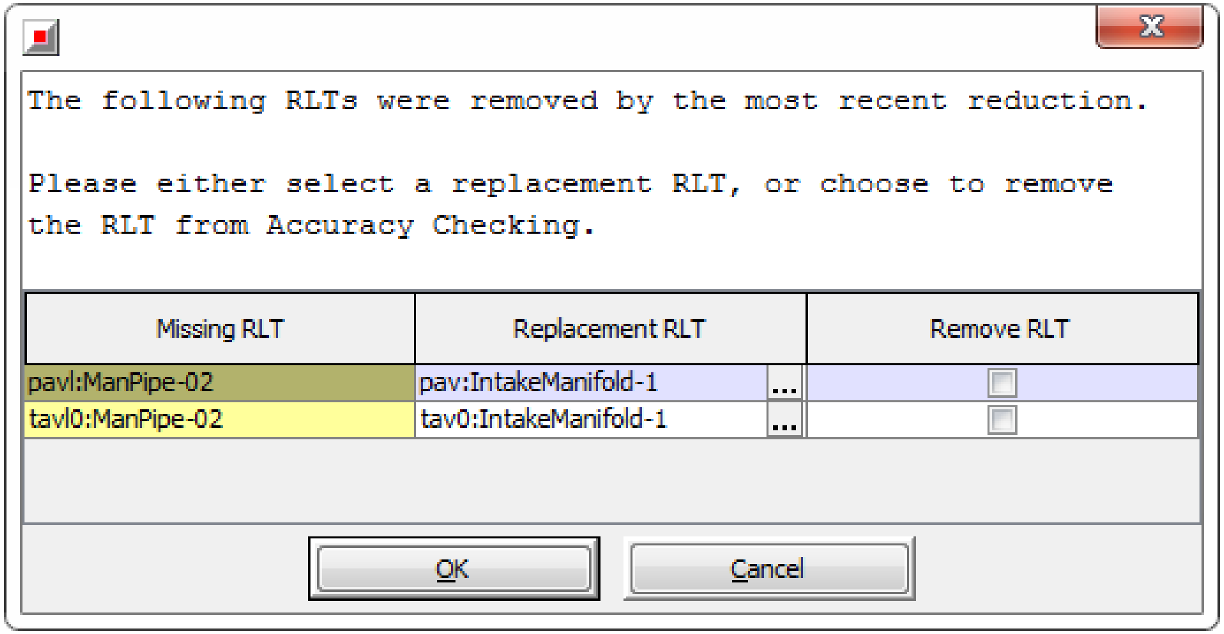
- Please select some Key RLTs to use for comparison during the conversion process. A GT-POST Report File (*.gu) will be automatically generated at each step comparing each result to the Baseline model. The "Operating RLT" will be used for the X-axis.
- If there is a specific Accuracy Requirement for a Key Result, the Accuracy Tolerance may be specified for that RLT.

Operating RLT	RLT	Description	Units	Tolerance Type	Tolerance
☑	avgrpm:Engine	Engine Speed (cycle average), Part Engine	RPM	Percentage	ign
☐	bmep:Engine	BMEP - Brake Mean Effective Pressure, Part Engine	bar	Absolute	0.1
☐	imep:Engine	IMEP720 - Net Indicated Mean Effective Pressure, Part Engine	bar	Percentage	ign
☐	bsfc:Engine	BSFC - Brake Specific Fuel Consumption, Cyl, Part Engine	g/kW-h	Percentage	ign
☐	volef:Engine	Volumetric Efficiency, Air, Part Engine	fraction	Percentage	5.0
☐	airflow:Engine	Air Flow Rate, Part Engine	kg/h	Percentage	ign
☐	fueltot:Engine	Fuel Flow Rate, Part Engine	kg/h	Percentage	ign
☐	afrat:Engine	Air-Fuel Ratio (Inducted Air/Total Fuel), Part Engine		Percentage	ign
☐	cmp-rpma:Compressor	Average Speed, Part Compressor	RPM	Percentage	5.0
☐	pavl:ManPipe-02	Intake Manifold Pressure	bar	Percentage	ign
☐	tavl0:ManPipe-02	Intake Manifold Temperature	K	Percentage	ign
☐	pav:ExMan-1	Exhaust Manifold Pressure	bar	Percentage	ign
☐	tav0:ExMan-1	Exhaust Manifold Temperature	K	Absolute	10.0
☐				Percentage	ign

Cancel | Back | Next (Begin First Step)

FRM转换工具

- 在当前转换步骤中，某重的的RLT 被移除了，用户可以选择另一RLT去替换，使得结果对比仍然可行
  - 举例：用一个单一容积的FlowSplit替代详细、离散化的进气歧管>> 进气歧管内的压力/温度仍然需要进行监测



FRM转换工具

- 整个转换过程一直可以监控，并可以任何时刻进行确认

Summary

☐ Show Inactive Steps

Step #	Active	Step Name	Optimization Objective	Optimization Algorithm Method	RLT Variable to be Optimize	Target Value of RLT Variable
Step 0	☑	Original Model	-	-	-	-
Step 1	☑	Exhaust_Manifold	Target	Brent-method	trb-tia:Turbine	1097.3434
Step 2	☑	Exhaust_Pipes	Target	Brent-method	trb-poa:Turbine	1.4365817
Step 3	☑	Intake_Manifold	Target	Brent-method	pavr:Throttle_Out	2.1189222
Step 4	☑	Compressor_Out	Target	Brent-method	cmp-poa:Compressor	2.2777095
Step 5	☑	Intake_Pipes	Target	Brent-method	cmp-pia:Compressor	0.9341944
Step 6	☑	**Cyl_Time_Step**	-	-	-	-

- …

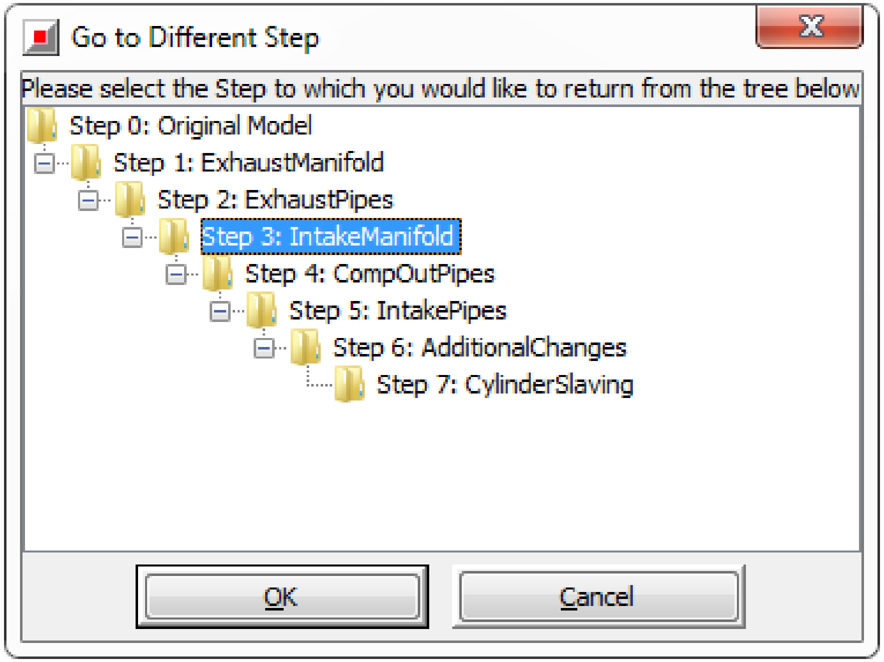
- When calibration is to be performed, the Target Value is <u>automatically</u> taken from the baseline model.
- >> no need to look in GT-POST for the Target! <<

Parameter to be Varied	Lower Value of the Range	Upper Value of the Range	Param. Initial	Resolution (% of Range)	Case	Case Handling	Final Value
-	-	-	-	-	-	-	-
HTM_ExhaustPortRun	0.5	2	1	1	1	Independent	1.32368
DIA_BackPressure	30	50	40	1	1	Independent	36.0793
HTM_IntakePortRun	1	2	1.5	1	1	Independent	1.28204
FM_IC	1	3	2	1	1	Independent	1.68435
DIA_Inlet	40	60	50	1	1	Independent	49.5783
-	-	-	-	-	-	-	-

- …

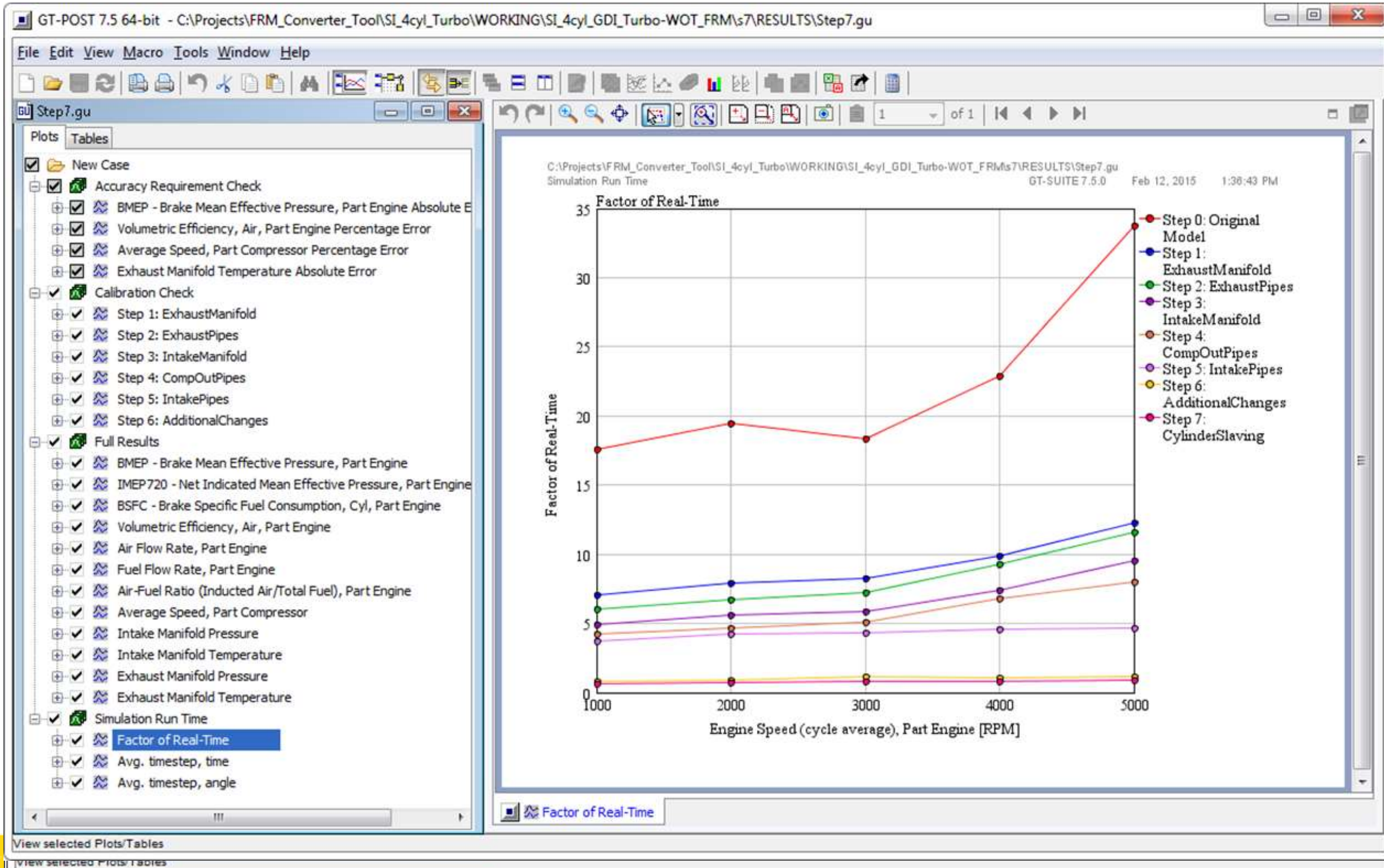
FRM转换工具

- 转换过程中的所有文件，能有组织的存在子文件夹中，在对应的导航目录中可以调整和重新执行任意一步(产生一个新的 “branch”)



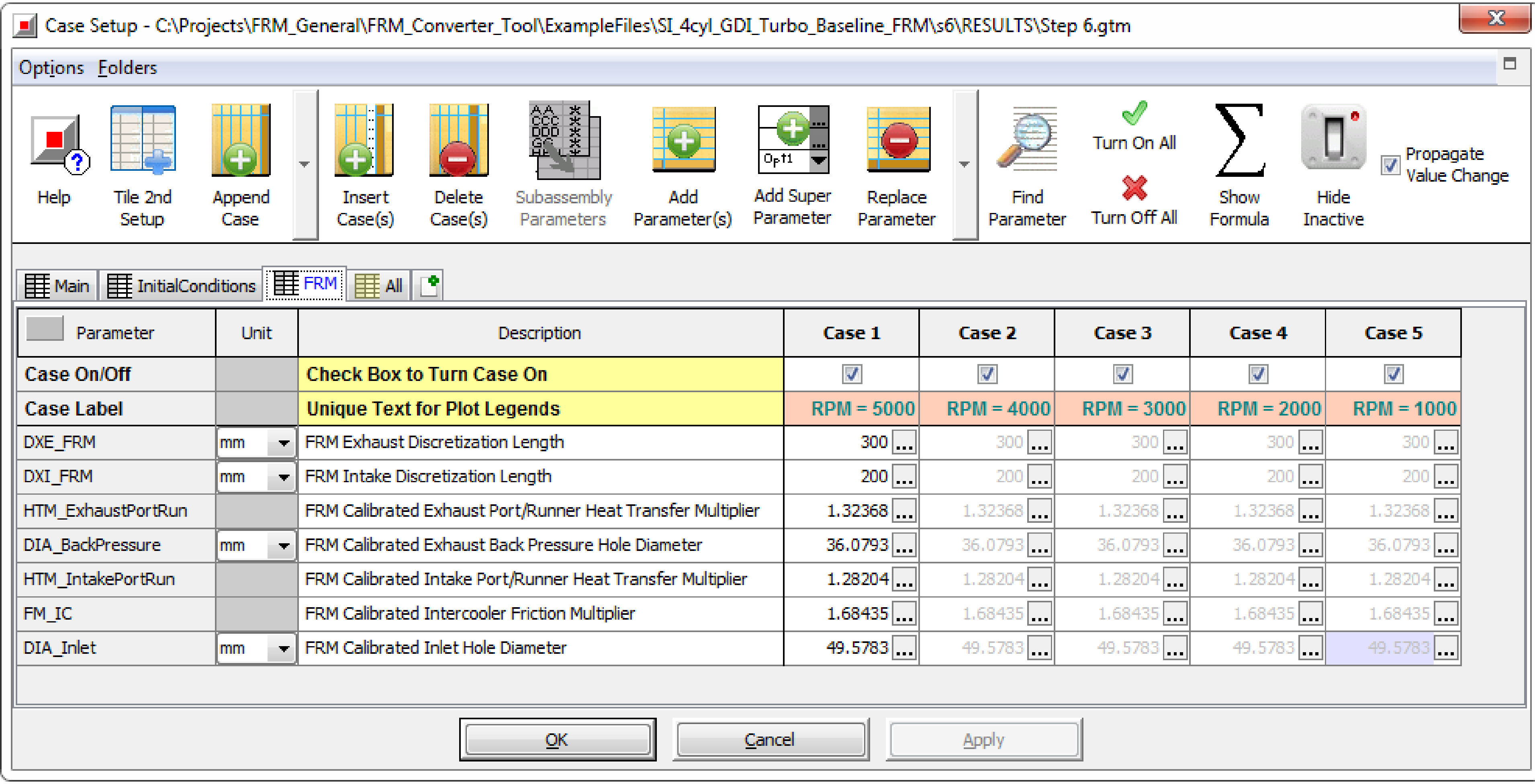
FRM转换工具

- 所有关键的RLT结果自动存在一个Report File (*.gu)中，去跟踪转换的准确性和每一步转换运行时间的提升度



FRM转换工具

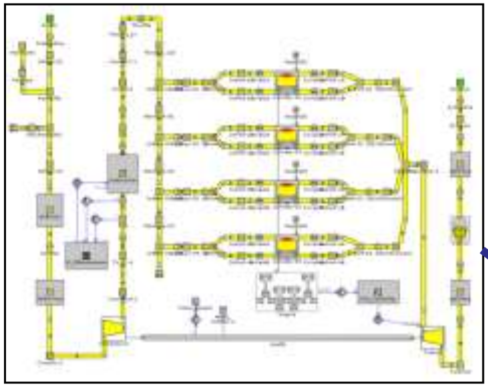
- 最终的模型包含了所有所需标定参数

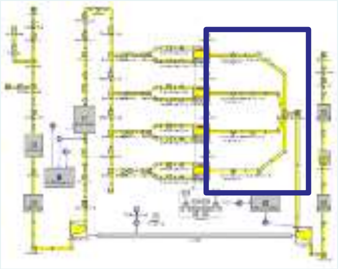
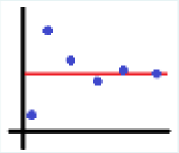
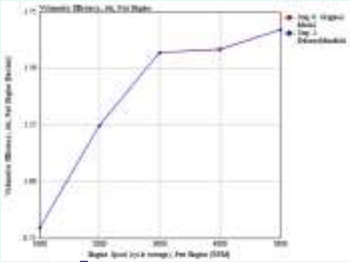
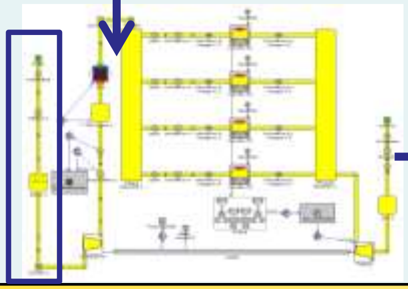
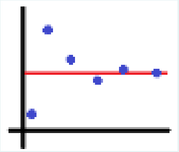
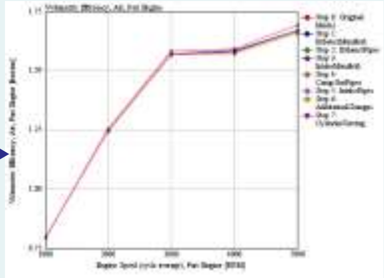


Parameter	Unit	Description	Case 1	Case 2	Case 3	Case 4	Case 5
Case On/Off		Check Box to Turn Case On	☑	☑	☑	☑	☑
Case Label		Unique Text for Plot Legends	RPM = 5000	RPM = 4000	RPM = 3000	RPM = 2000	RPM = 1000
DXE_FRM	mm	FRM Exhaust Discretization Length	300	300	300	300	300
DXI_FRM	mm	FRM Intake Discretization Length	200	200	200	200	200
HTM_ExhaustPortRun		FRM Calibrated Exhaust Port/Runner Heat Transfer Multiplier	1.32368	1.32368	1.32368	1.32368	1.32368
DIA_BackPressure	mm	FRM Calibrated Exhaust Back Pressure Hole Diameter	36.0793	36.0793	36.0793	36.0793	36.0793
HTM_IntakePortRun		FRM Calibrated Intake Port/Runner Heat Transfer Multiplier	1.28204	1.28204	1.28204	1.28204	1.28204
FM_IC		FRM Calibrated Intercooler Friction Multiplier	1.68435	1.68435	1.68435	1.68435	1.68435
DIA_Inlet	mm	FRM Calibrated Inlet Hole Diameter	49.5783	49.5783	49.5783	49.5783	49.5783

FRM转换工具 - 目前的流程，v7.5 B2

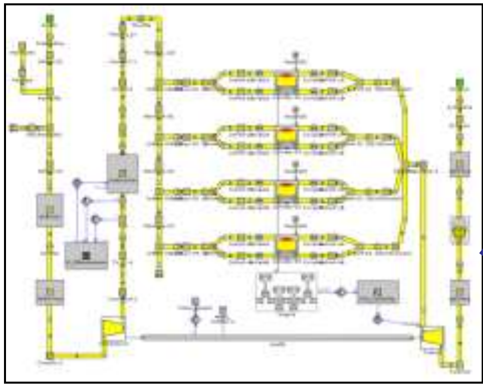
- **Baseline Model:**

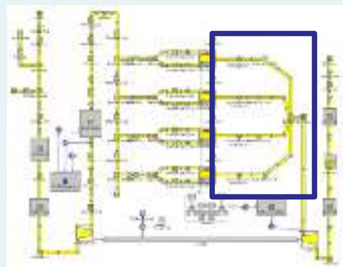
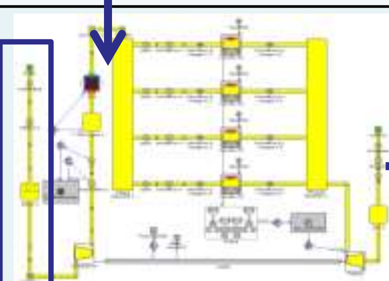


	Simplify a Subsystem	Setup and Run Calibration	Run All Cases and Verify Results
•**Step 1:**	•1.a. 	•1.b. 	•1.c. 
•**(Steps 1-N):**	•…	•…	•…
•**Final Step:**			

FRM转换工具 - 下一版本流程，v2016

- **Baseline Model:**



	Simplify a Subsystem	Setup Calibration	Run All Cases and Verify Results
• **Step 1:**	 • 1.a.	• (only setup) • 1.b.	• 1.c.
• **(Steps 1-N):**	• …	• …	• …
• **Final Step:**		• (only setup)	

• No Running of the Model until the Final Step is Complete, where the entire process is then ran as a "Batch" without <u>any</u> user interaction!

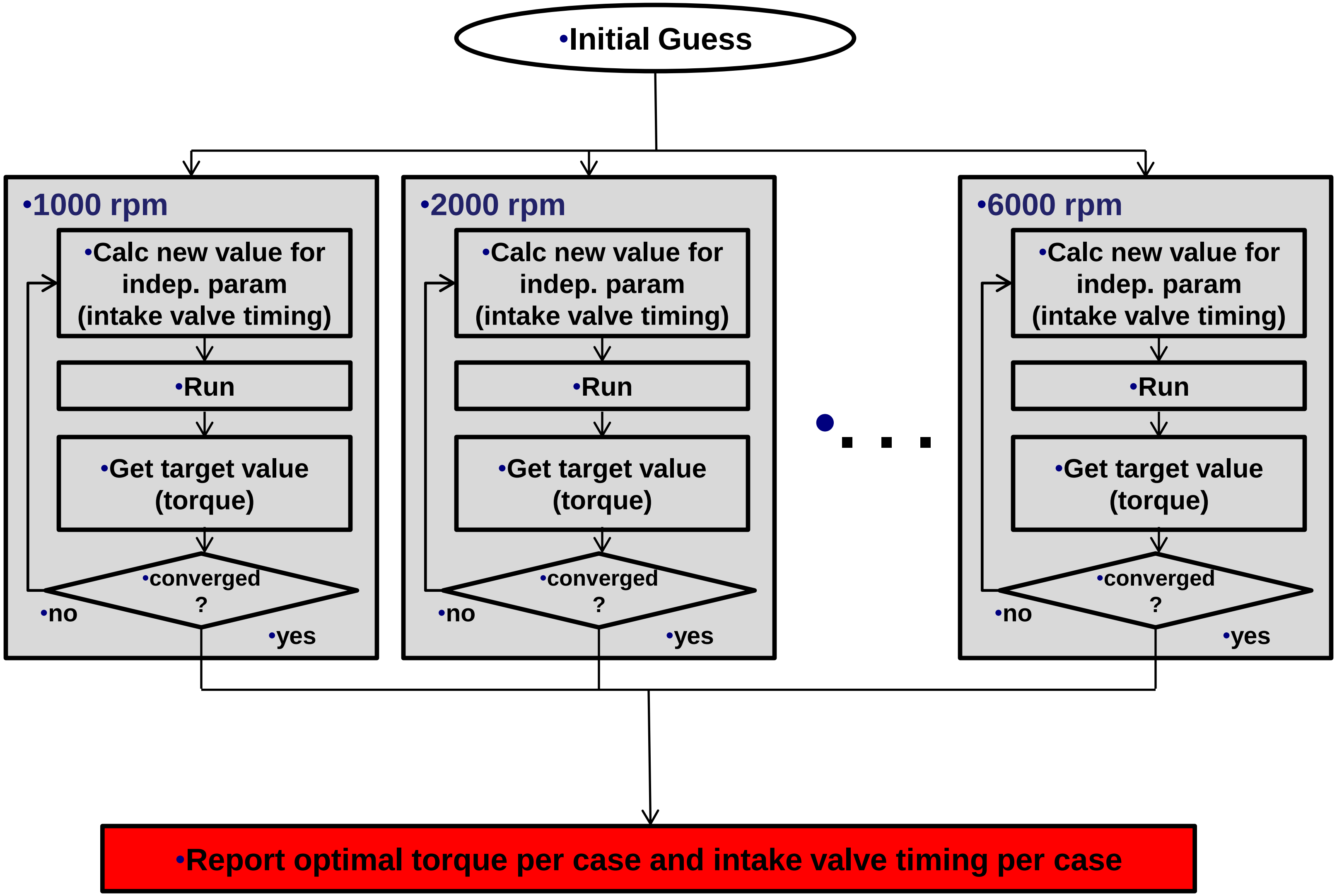
内容

- 增压器方面应用
- 预测燃烧模型
- 配气机构耦合应用
- FRM转化工具
- 高级优化功能

高级功能,直接优化

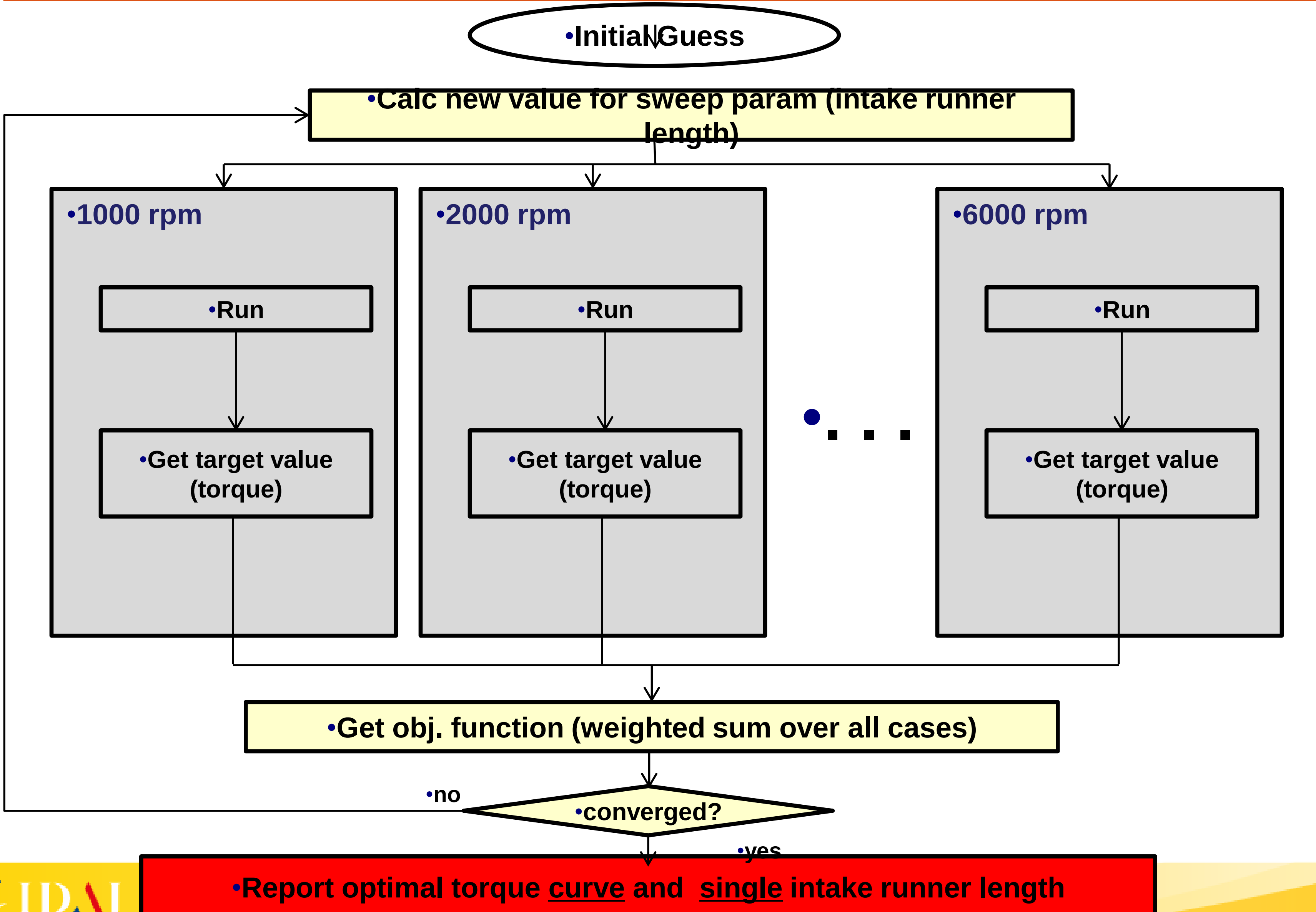
- 采用分布式计算能最大效率的进行优化运算
  - 对于给定的优化迭代，能同时进行分布式的多case计算
  - 多次迭代计算过程中，也能同时进行计算
- 容错架构设计- 当某个case或迭代出现错误后，能继续进行优化计算
- 对于所有case能优化出一个或多个 “Sweep” 参数
  - 对所有case获得单个的优化值
  - 优化对象是拟合曲线（如：最大力矩线）
- 允许混合优化（sweep+independent）
  - 为每个case找到 “Case Independent” 的参数值
    - 如找到一个每个case不同的正时值，同时找到满足所有caser 歧管长度

只有独立优化的运行图



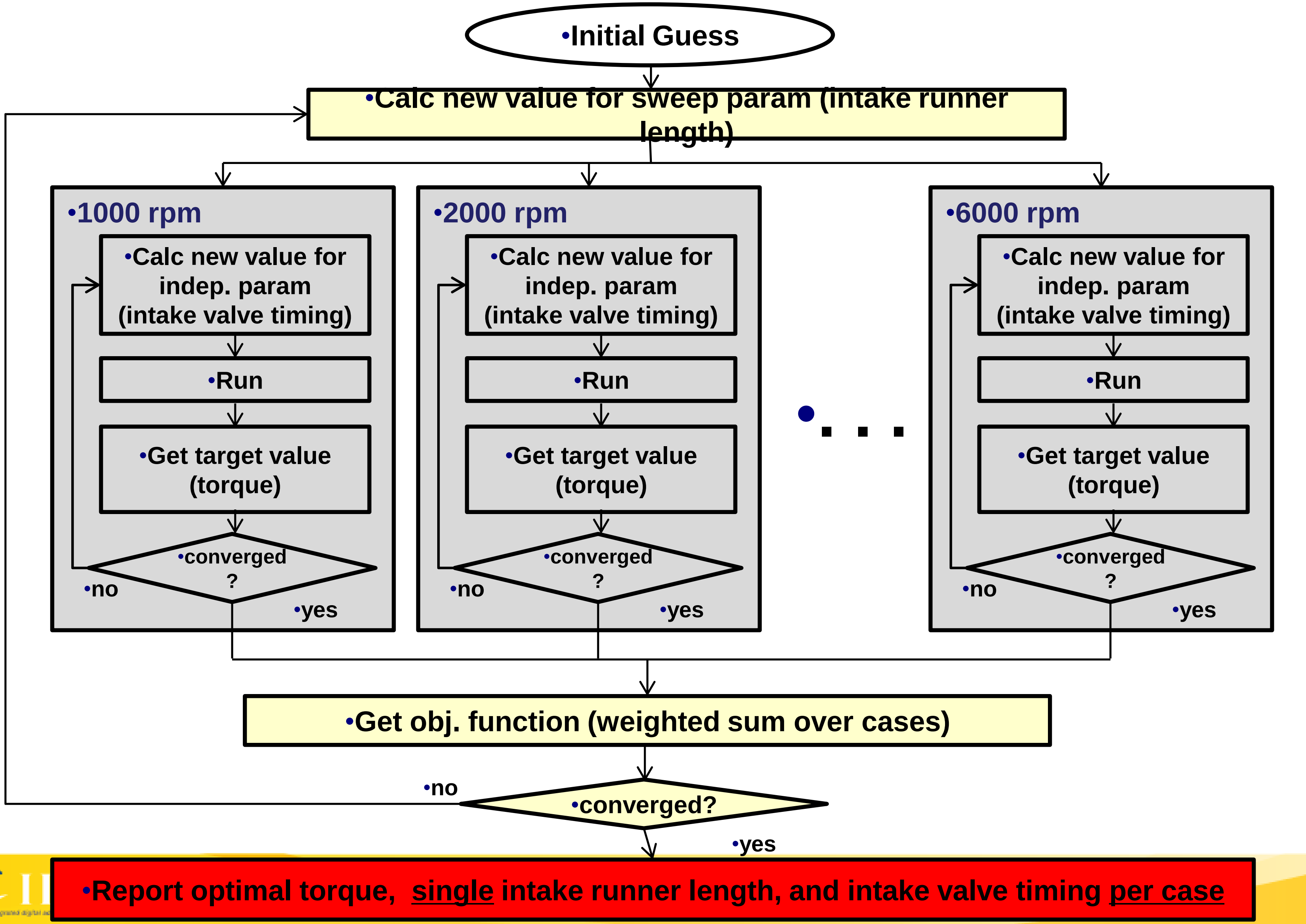
•Initial Guess
•1000 rpm
•Calc new value for indep. param (intake valve timing)
•Run
•Get target value (torque)
•converged ?
•no
•yes
•2000 rpm
•Calc new value for indep. param (intake valve timing)
•Run
•Get target value (torque)
•converged ?
•no
•yes
•. . .
•6000 rpm
•Calc new value for indep. param (intake valve timing)
•Run
•Get target value (torque)
•converged ?
•no
•yes
•Report optimal torque per case and intake valve timing per case

只有“扫掠”优化的运行图



•Initial Guess
•Calc new value for sweep param (intake runner length)
•1000 rpm
•Run
•Get target value (torque)
•2000 rpm
•Run
•Get target value (torque)
•6000 rpm
•Run
•Get target value (torque)
•Get obj. function (weighted sum over all cases)
•no
•converged?
•yes
•Report optimal torque curve and single intake runner length

混合优化的运行图



•Initial Guess
•Calc new value for sweep param (intake runner length)
•1000 rpm
•Calc new value for indep. param (intake valve timing)
•Run
•Get target value (torque)
•converged ?
•no
•yes
•2000 rpm
•Calc new value for indep. param (intake valve timing)
•Run
•Get target value (torque)
•converged ?
•no
•yes
•. . .
•6000 rpm
•Calc new value for indep. param (intake valve timing)
•Run
•Get target value (torque)
•converged ?
•no
•yes
•Get obj. function (weighted sum over cases)
•no
•converged?
•yes
•Report optimal torque, single intake runner length, and intake valve timing per case

总结

- 在发动机性能上应用的模板会越来越多，也越来越精确
- 平台化的功能更强大
- 扩展性能也更好

谢谢大家！