



Three Pressure Analysis (TPA)

Gamma Technologies

What is TPA?

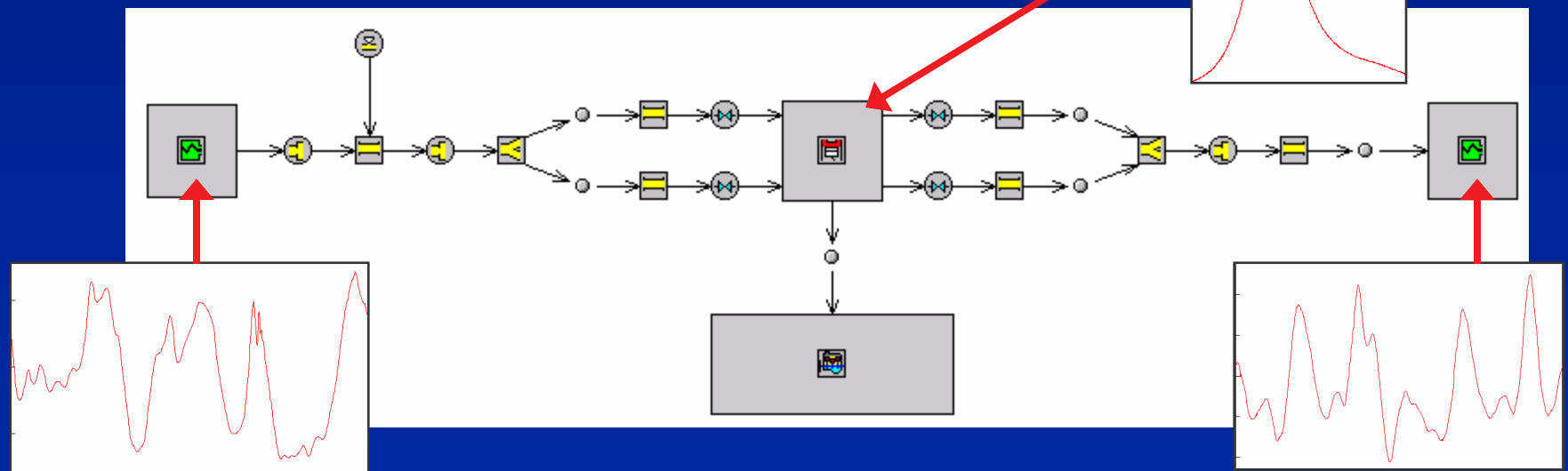


- Three Pressure Analysis
- A simulation based method to analyze test cell data to determine quantities that are difficult or impossible to measure directly:
 - Apparent burn rate
 - Residual fraction
 - Trapping ratio
 - Valve mass flow profiles
- Similar to methods used in the industry, e.g. by BMW, PSA and others
- Step towards integration of GT-SUITE with test cell data acquisition system

TPA Operation



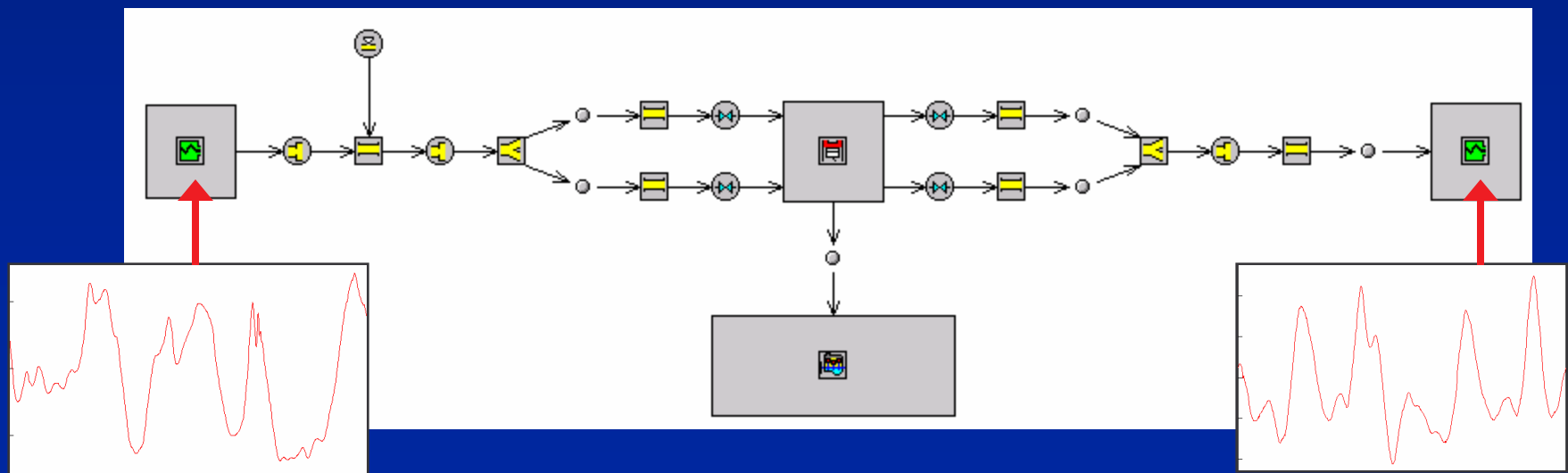
- Focuses on a cylinder, cuts-off rest of system, replacing it by measured port pressures
- Input cylinder pressure to get combustion rate
- Valid only for steady state operating points
- Single cylinder model (typically)



1. *Impose Port Pressures*



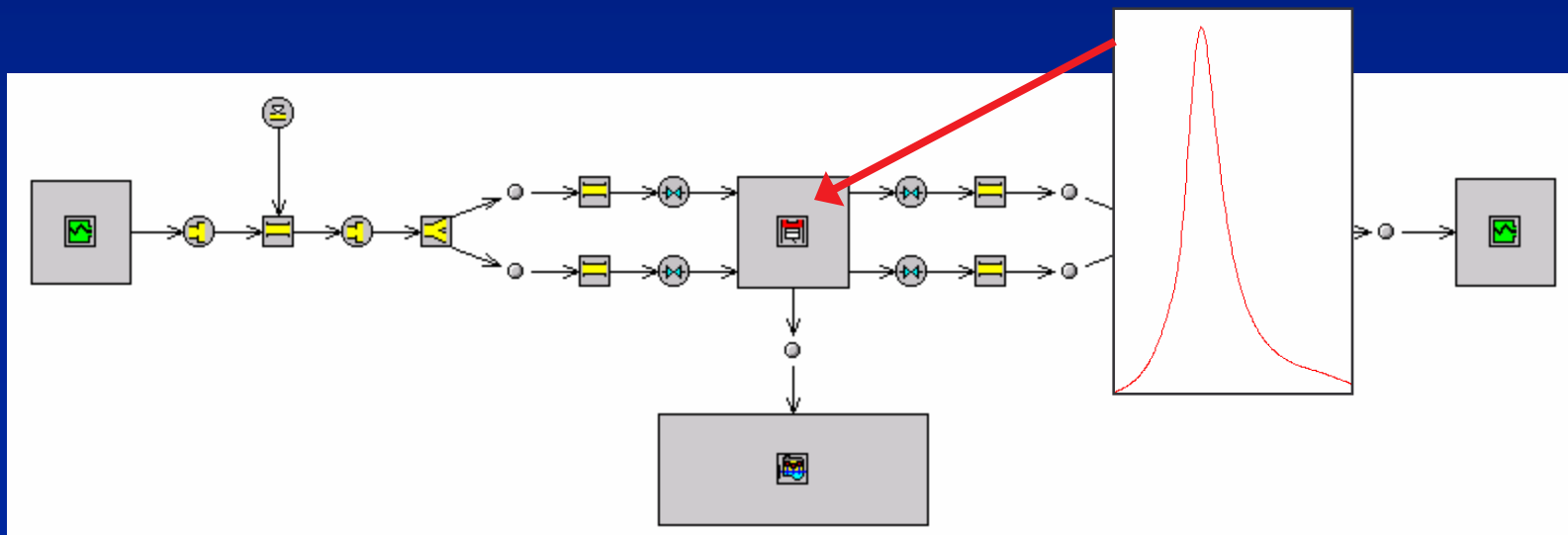
- Build 1-cyl engine model (or start from a full engine model and reduce it to isolate one cylinder + ports)
- Impose measured port pressures
- Special '**TPAEndEnvironments**' have been provided, accounting for back flows (temp. and composition)
- Run simulation in the usual fashion
- Pause at IVC to generate the burn profile....



2. Calc. Burn Rate



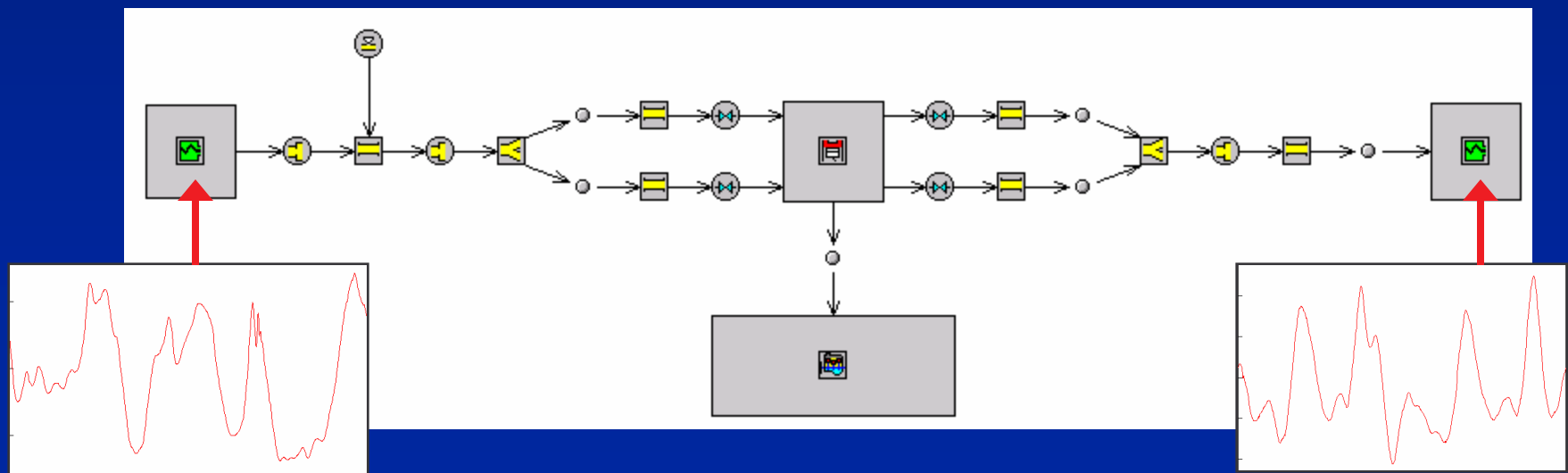
- Impose measured cylinder pressure
- IVC conditions obtained from prediction of step 1 (trapped mass, residuals)
- Run reverse cycle analysis to calculate fuel burn rate
 - ‘EngCylCombPressure’ – new combustion template
 - Exactly the same thermodynamic model as predictive runs
 - Heat transfer from previous cycle



3. Continue the cycle



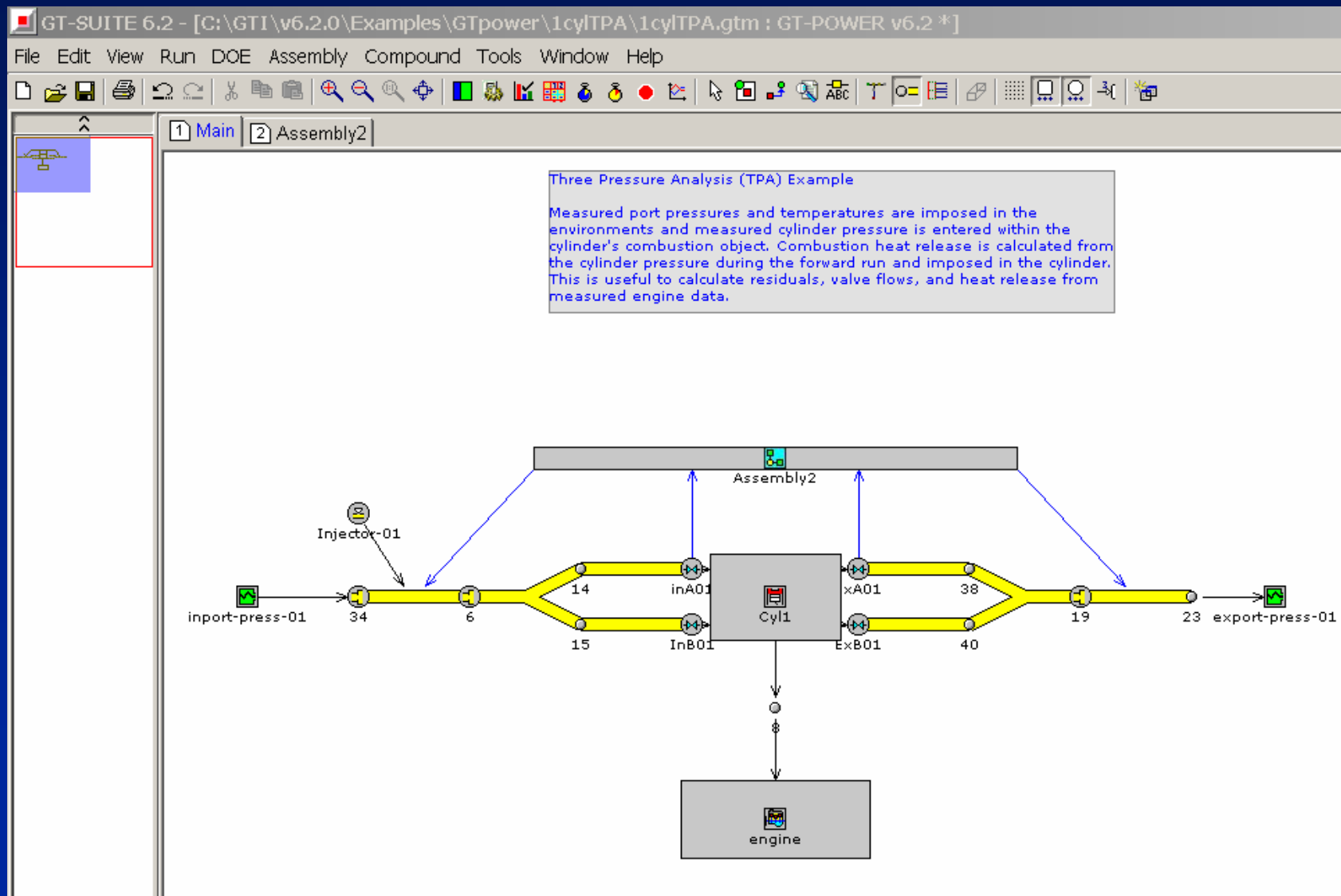
- Store the computed burn rate at IVC
- Apply the burn rate during combustion in this cycle
- Run to cycle end
- Repeat the three steps 5-7 cycles until convergence
- Output combustion object for use in predictive calculations



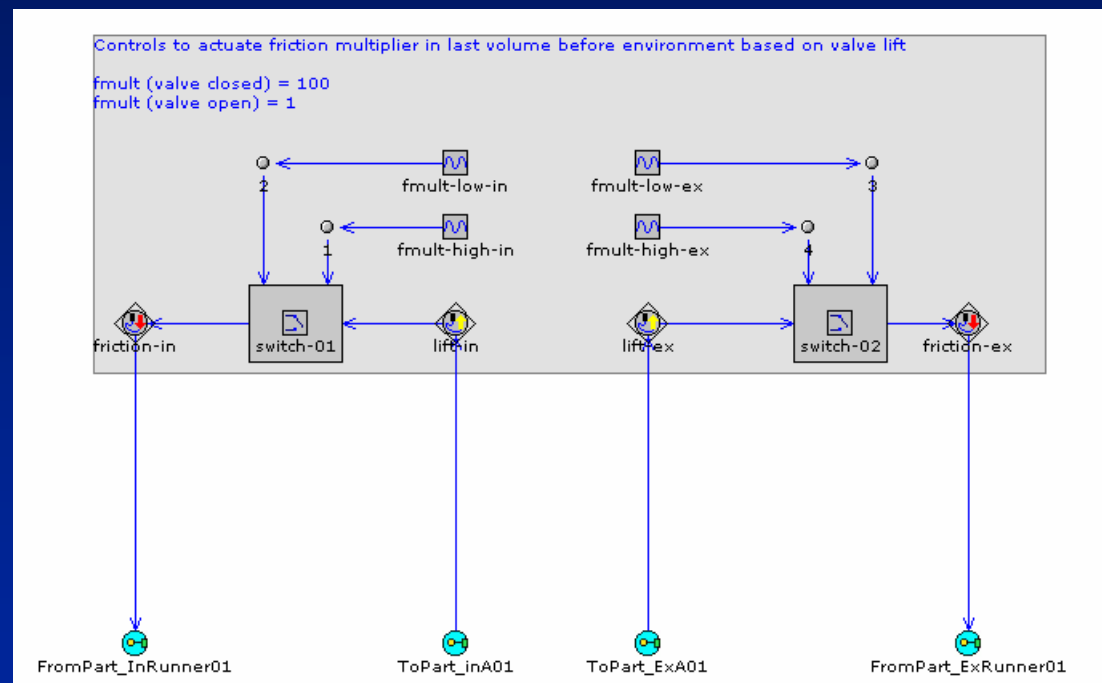
Comparison of TPA to Use of 'EngHeatRel'



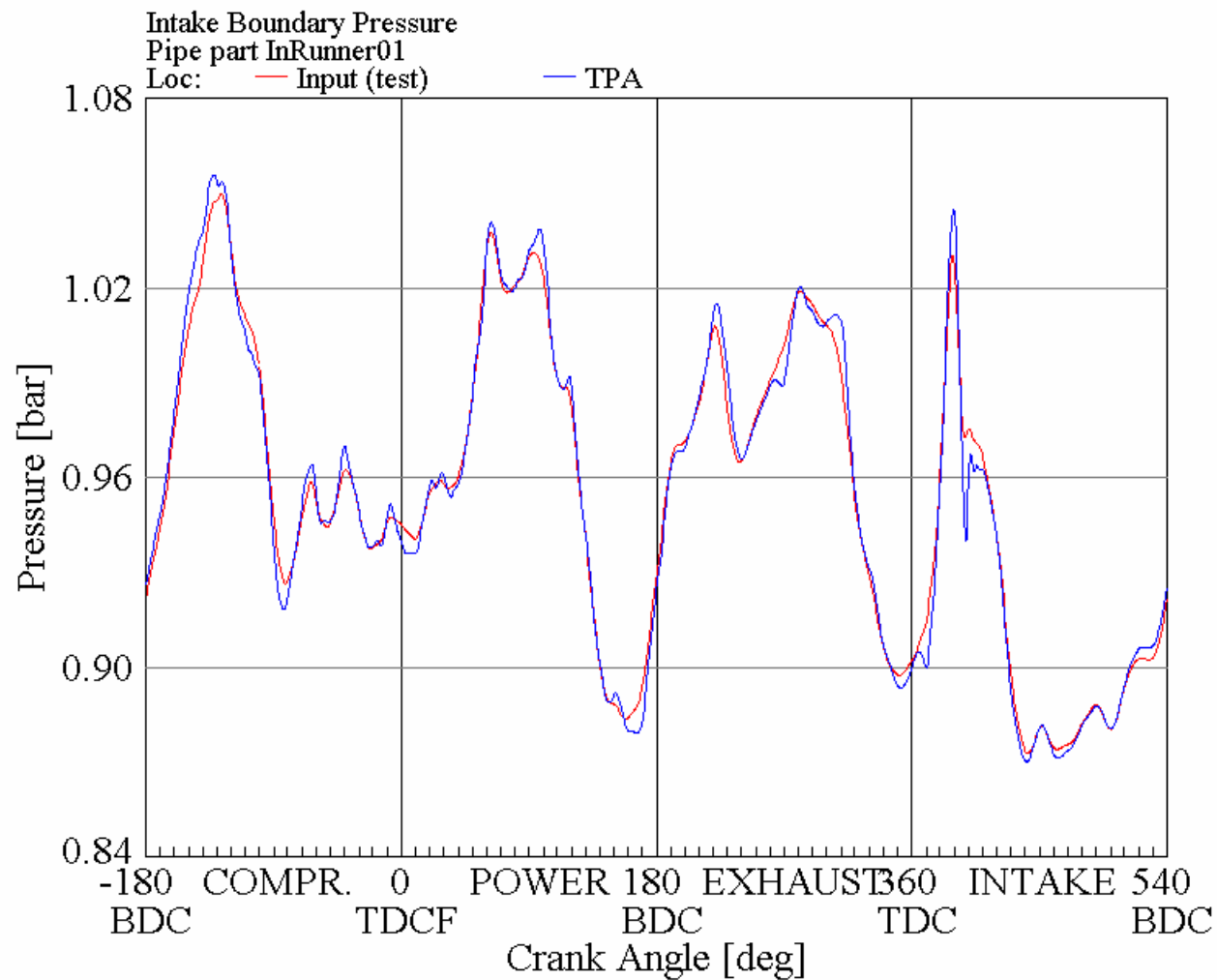
- TPA removes uncertainty about cylinder contents at IVC inherent in 'EngHeatRel':
 - Residual fraction
 - Trapping Ratio
- Allows use of various cylinder heat transfer options which are not possible in 'EngHeatRel':
 - Flow, User, Hg-profile
 - TWallDetail, TWallSoln
- Provides immediate check on validity of results by applying the generated burn rate to predict P_{cyl}
- Particularly useful for part-load data analysis



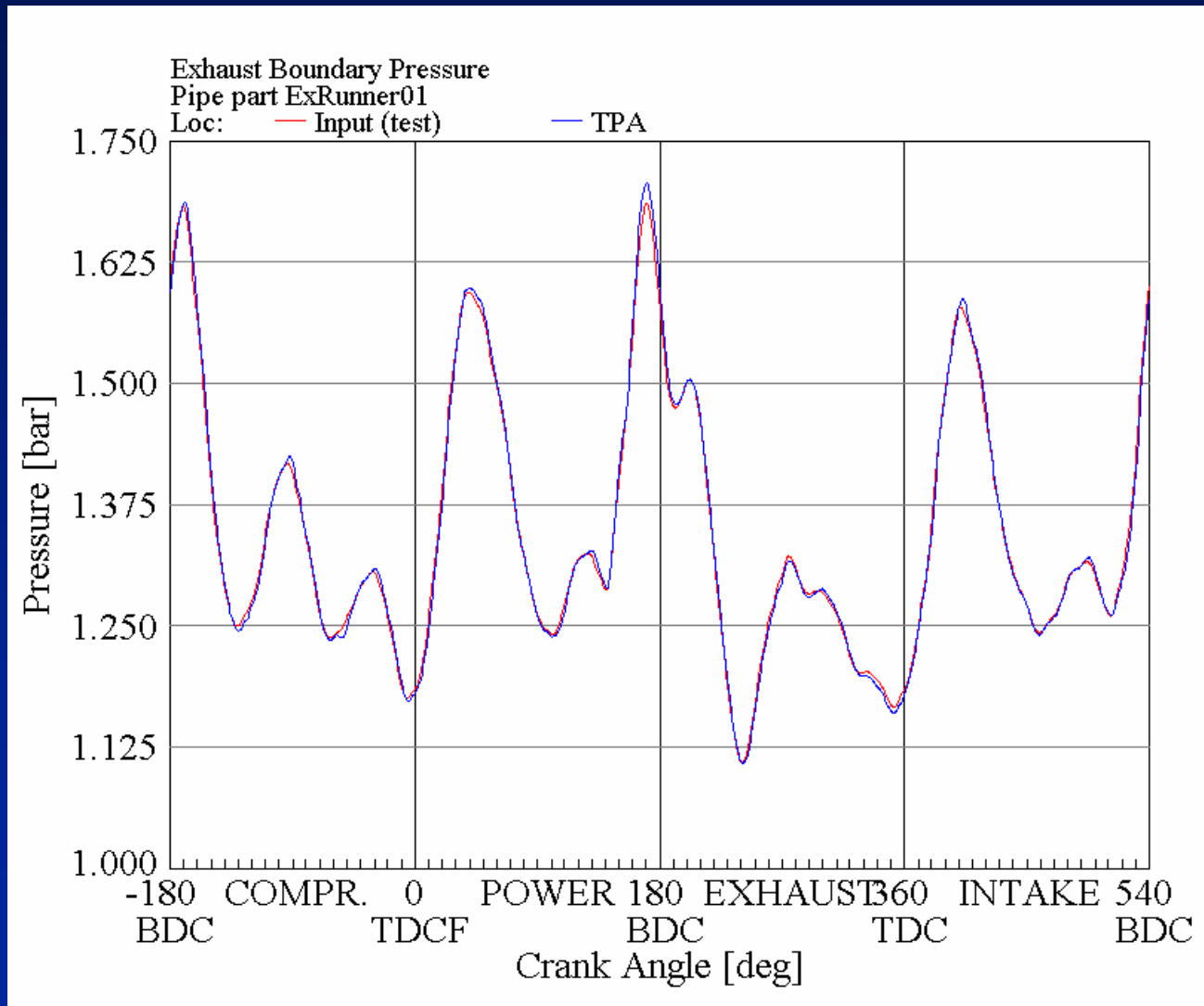
Damping of Spurious Waves



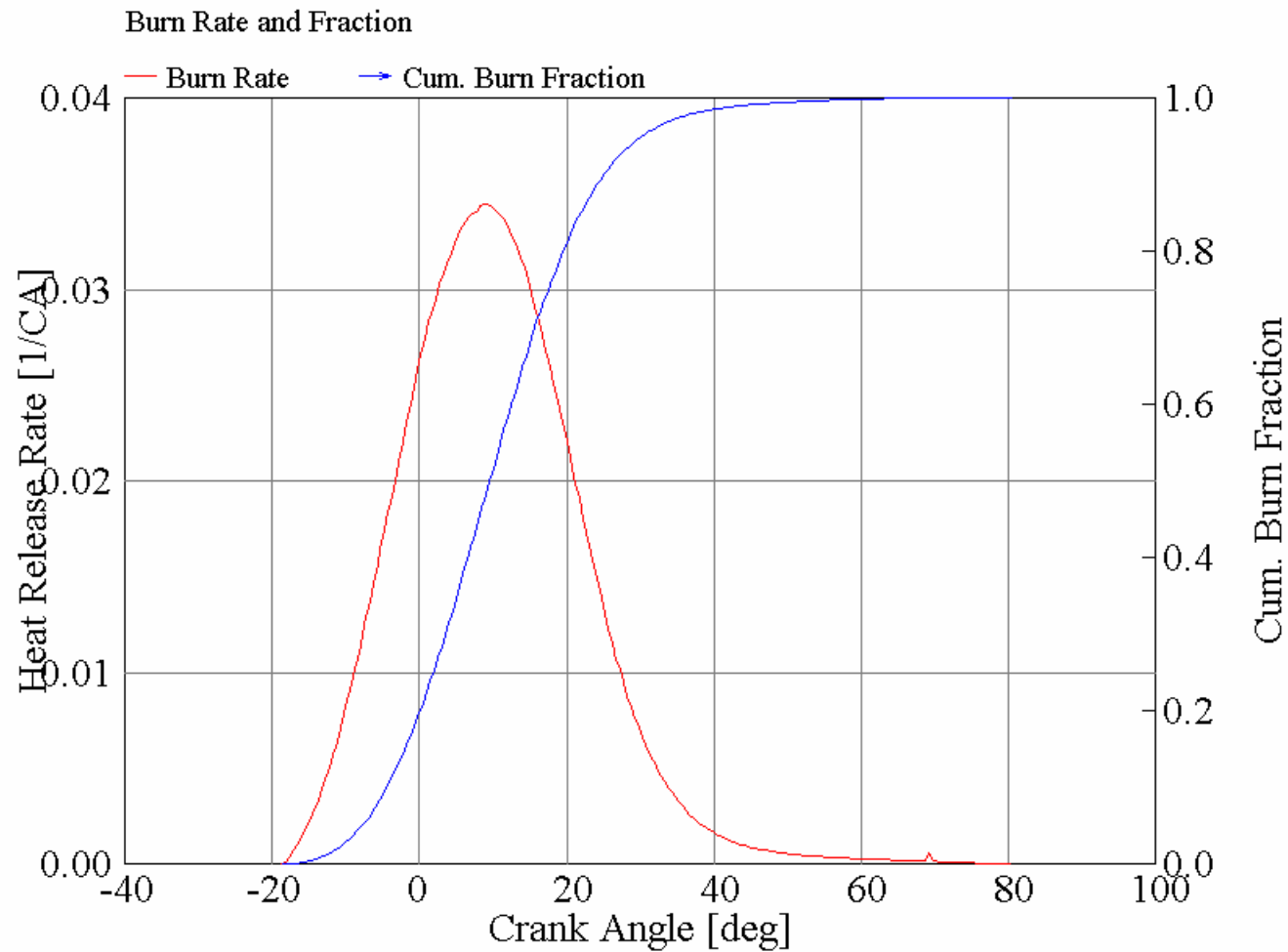
Intake Port Pressure



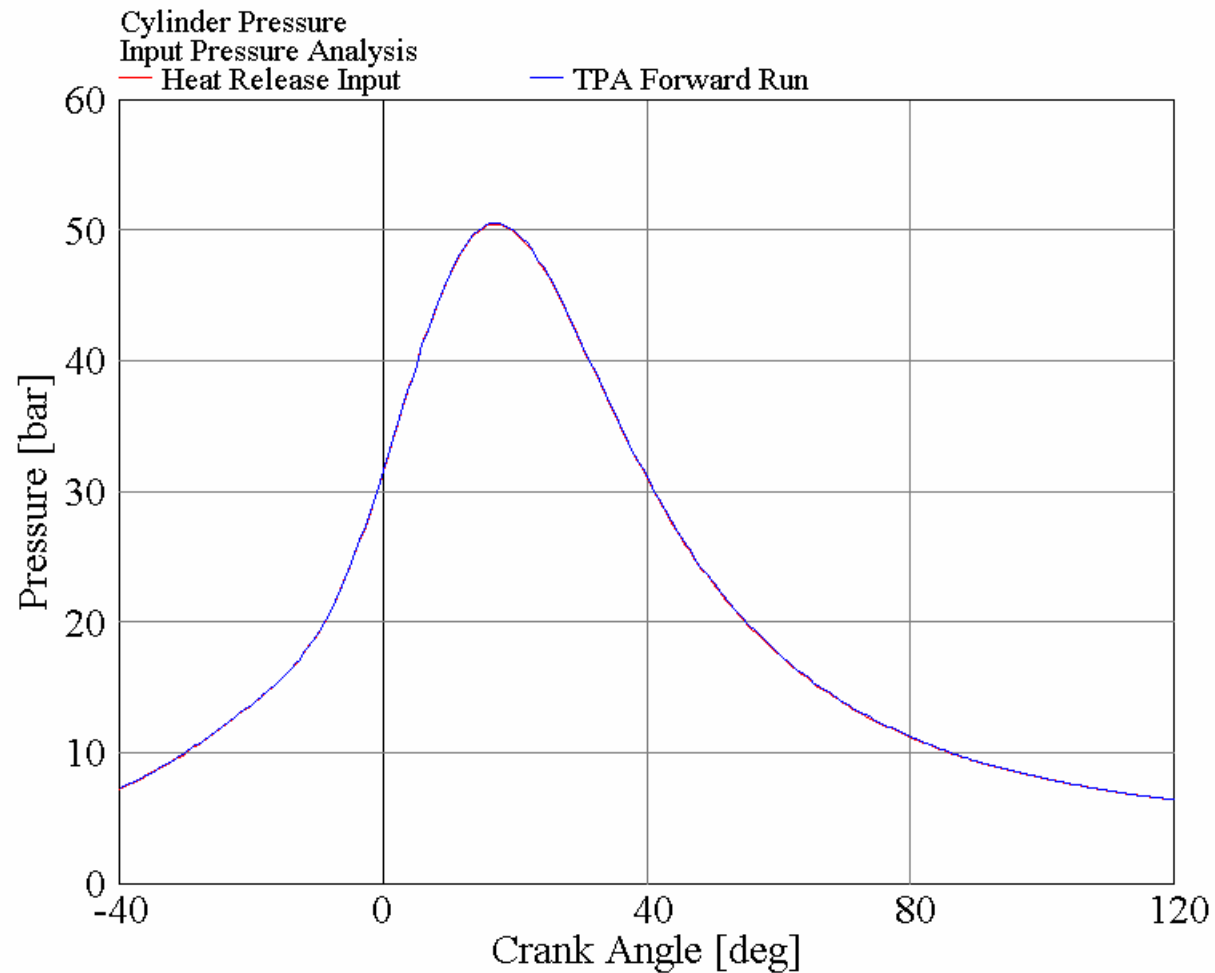
Exhaust Port Pressure



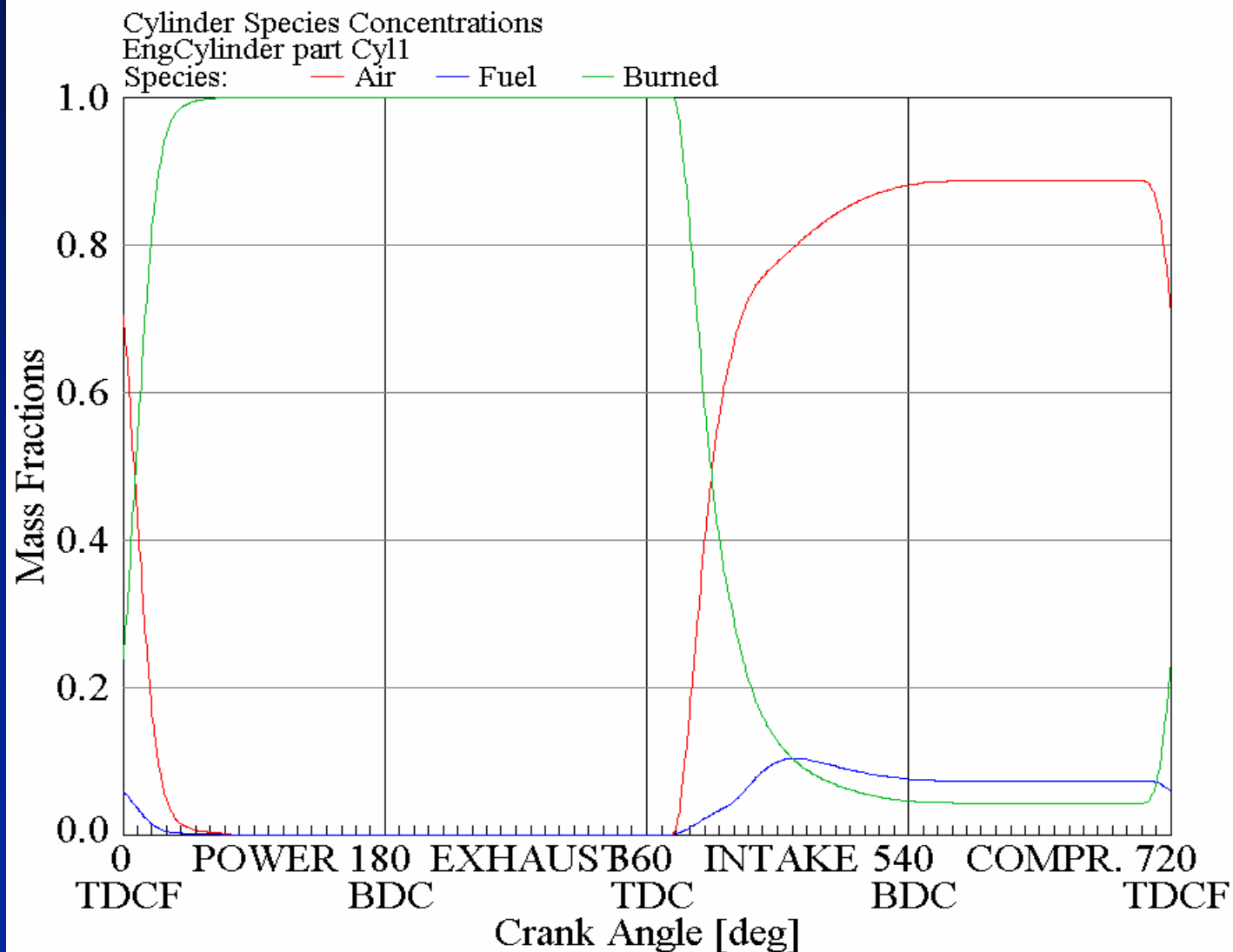
Burn Rate



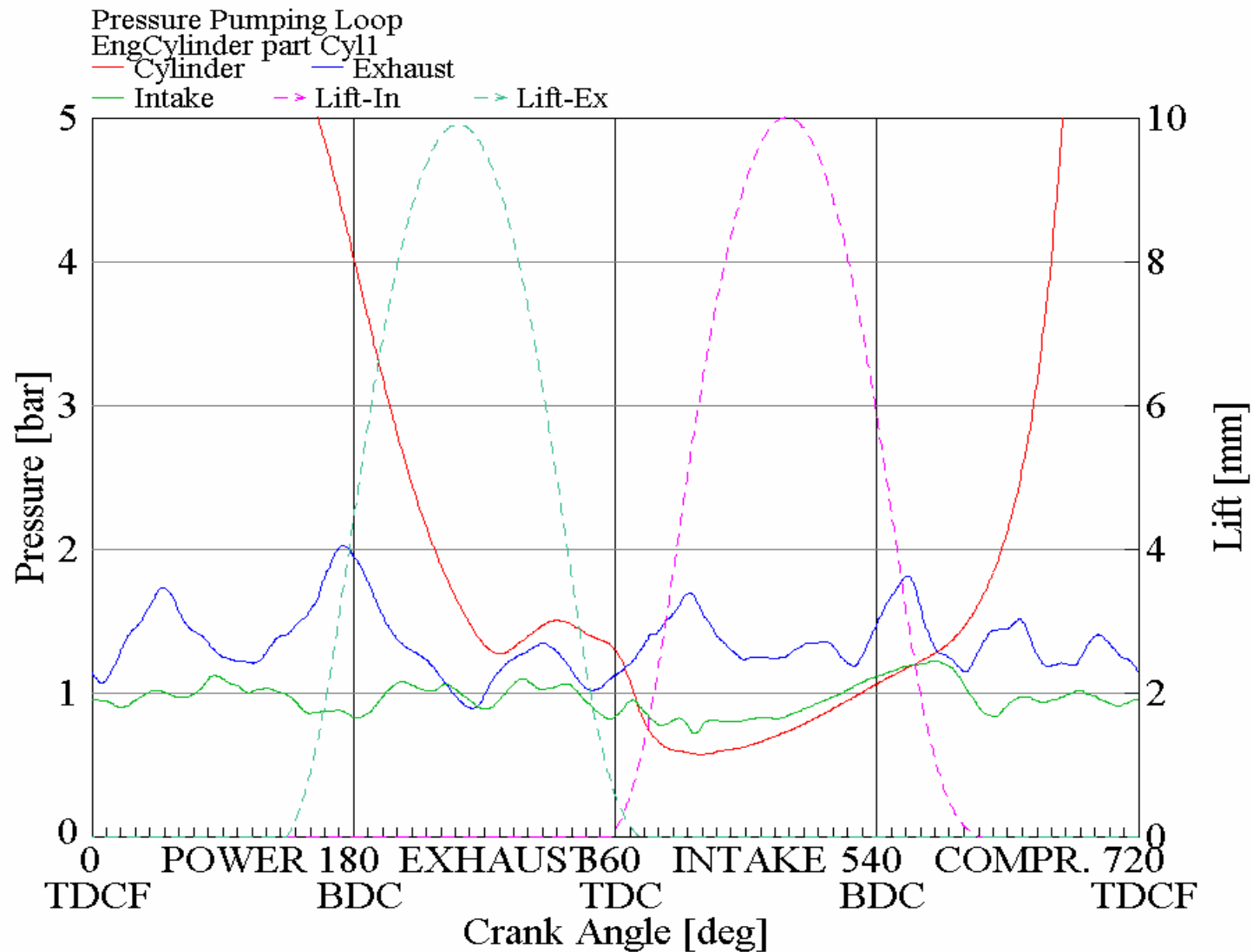
Cylinder Pressure Match



Cylinder Mass Fractions



Cylinder and Port Pressures



Valve Lift and Flows



Tables

Pressure Parameters

Object Name	Cyl1
IMEP [bar]	11.047
PMEP [bar]	-0.956
Pmax [bar]	50.44
CA at Pmax	17.00
dP/dCA max (bar/CA)	1.65
Compr Slope 1. (-90 to -70)	1.305
2. (20 deg bef spk/inj)	1.288
3. (-90 to spk/inj)	1.296
Pres Smoothing Effect RMS [bar]	0.0004

Heat Release Parameters

Object Name	Cyl1
Burned Fuel Fraction	1.000
=== Combustion Start ===	-20.50
2% Burn Point	-11.06
10% Burn Point	-4.43
50% Burn Point	9.54
75% Burn Point	17.51
90% Burn Point	25.10
=== Combustion End ===	75.50
10-90% Burn Duration	29.53
Max Burn Rate (1/CA)	0.034
Max Unburned Gas Temp [K]	954.5
Max Burned Gas Temp [K]	2776.2
Fuel Energy (LHV) Mult.	0.994
App. Indicated Effy. (%)	30.40
Missing Fuel Fraction	0.0000



Edit Object: pressure

Template: EngCylCombPressure

Object: pressure

Comment:

Attribute	Unit	Object Value
Theta Shift		def
Pressure Multiplier		def
Pressure Shift	bar	def
Smoothing Option		cubic-fitting
Cubic Smoothing Range (degrees)		def
IEEE Filter Level		none
TDC Angle Convention		piston-position

Main Advanced Analysis Options **Pressure Adjustments** Pressure Array

OK Cancel

Edit Object: pressure

Template: EngCylCombPressure

Object: pressure

Comment:

Attribute	Unit	Object Value
Number of Temperature Zones		two-temp
Burned Zone Air/Fuel Ratio		homogeneous
Analysis Increment		def
Start of Calculation Override		def
End of Calculation Override		80
Cumulative Heat Release Adjustment (LHV)		On

Main Advanced **Analysis Options** Pressure Adjustments Pressure Array

OK Cancel

Edit Object: pressure

Template: EngCylCombPressure

Object: pressure

Comment:

Attribute	Unit	Object Value
Knock Model Selection		ign
User Model Object Name		ign
Post-knock Combustion		no
NOx Reference Object		ign
CO Reference Object		ign

Main **Advanced** Analysis Options Pressure Adjustments Pressure Array

OK Cancel

Input Options

TPA Ties Together Test and Simulation



- **TPA can be used by test engineers to extract more information from test data:**
 - Mass trapped
 - Residual fraction trapped
 - Trapping ratio (blow-through of intake into exhaust)
 - Details of valve mass flows
 - Execution of emissions models
- **More reliable combustion information can be provided from the tests to simulation engineers:**
 - Burn rate profiles, rather than heat release profiles
 - These profiles are self-validated by the procedure
 - Same methodology is used consistently by both teams

Setting up Link to Test Cell Data



GT-SUITE 6.2 - [Z:\TomM\Trip\TPA_extfiles\1cylTPA.gtm : GT-POWER v6.2]

File Edit View Run DOE Assembly Compound Tools Window Help

1 Main

Three Pressure Analysis (TPA) Example

Measured port pressures and temperature environments and measured cylinder pressure cylinder's combustion object. Combustion the cylinder pressure during the forward. This is useful to calculate residuals, valve measured engine data.

Controls to actuate friction multiplier in last volume before

frmult (valve closed) = 100
frmult (valve open) = 1

friction-in

switch-01

lift-in

frmult-low-in

frmult-high-in

inport-press-01

34InRunner01

6InPortA0InA01

14InPortB0InB01

15InPortB0InB01

Injector-01

Cyl1

engine

Case Setup

File

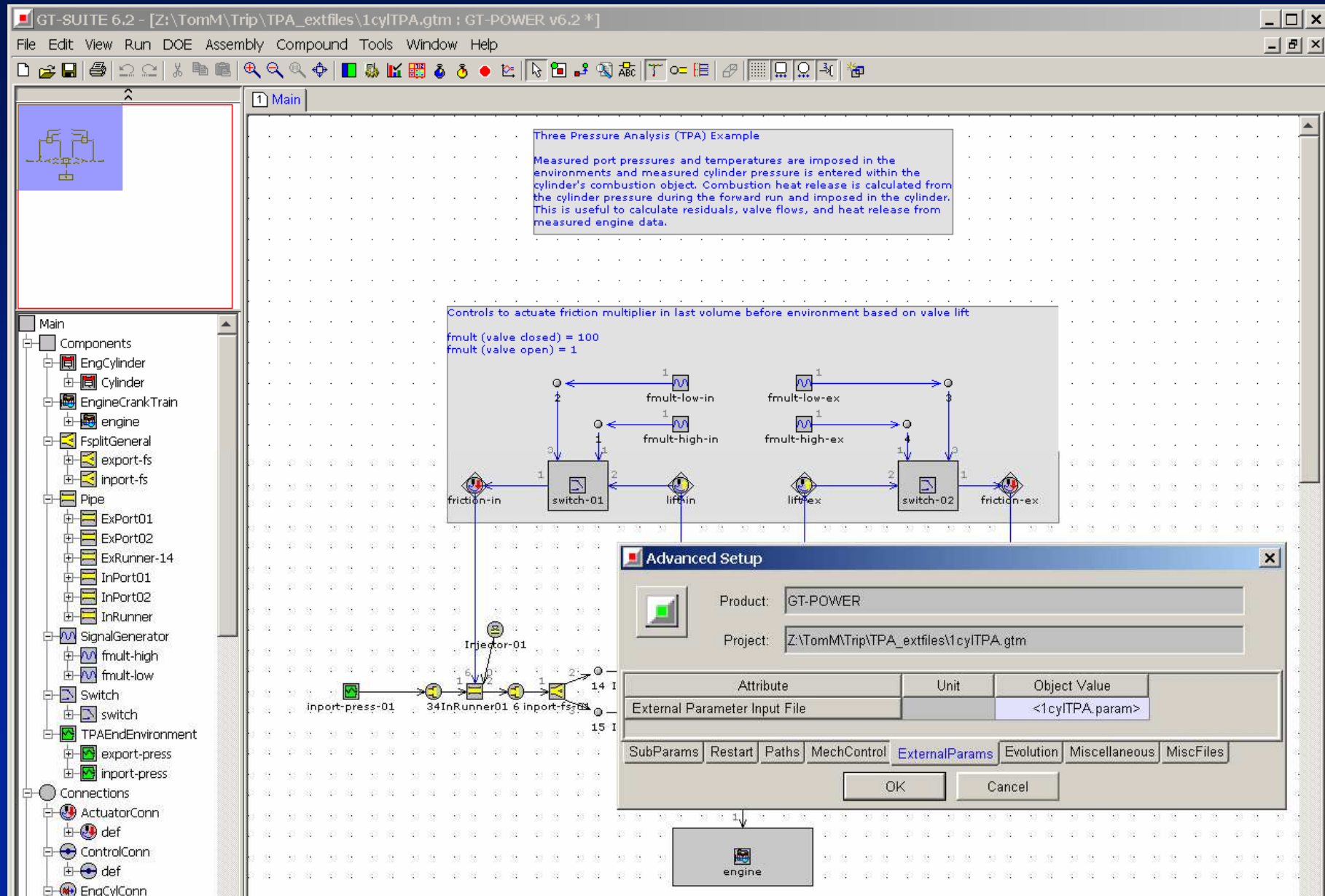
Append Case Insert Case Remove Case

Turn On All Turn Off All Show Formula

Parameter	Unit	Label	1 (on)
Run It?			<input checked="" type="checkbox"/>
ANGLE			0.999
ANGLE-CAM	Cam Angle		0.999
ANGLE-DEG	deg		0.999
CASE-LEGEND			0.999
DXE	mm	Discretization length e...	25
DXI	mm	Discretization length i...	18
ELASH	mm	Exhaust valve lash	0.3
EXHINITP	bar	Initial exhaust pressure	1.22
EXHINITT	K	Initial exhaust tempera...	1120
EXHTWALL	K	Initial exhaust wall tem...	1000
FMULT-CLOSED		Friction mult (valve clo...	100
FMULT-OPEN		Friction mult (valve ope...	1
FUEL-LHV	J/kg		0.999
ILASH	mm	Intake valve lash	0.2
INJ-PW	millisec		0.999
LIFT-EXHAUST	mm		0.999
LIFT-INTAKE	mm		0.999
NCYC		Simulation duration	40
P_AMB	bar		0.999
PRESSURE-CYL	bar		0.999
PRESSURE-EXPORT			0.999
PRESSURE-IMPORT			0.999
RPM	RPM	Engine Speed	0.999
SPARK-TIMING		spark timing	0.999
T_AMB	K	Ambient Temperature	300.0
T_EXH_AMB	K	Exhaust Ambient Tem...	99.999
TAVG-EXPORT	K	Average Temp in exha...	99.999
TAVG-IMPORT	K	Average Temp in intak...	296.59
TIMING-EXHAUST	4-Stroke ...		99.999
TIMING-INTAKE	4-Stroke ...		99.999

Cases

Setting up Link to Test Cell Data



Setting up Link to Test Cell Data



1cyltpa.param

1cyltpa.txt

External Parameter File for three pressure analysis

CASE-LEGEND = Three_Pressure_Analysis_Example

External File References

ANGLE = <1cylTPA.txt;1/2>

ANGLE-CAM = <1cylTPA.txt;2/2>

ANGLE-DEG = <1cylTPA.txt;1/2>

PRESSURE-INPORT = <1cylTPA.txt;3/2>

PRESSURE-EXPORT = <1cylTPA.txt;4/2>

PRESSURE-CYL = <1cylTPA.txt;5/2>

LIFT-INTAKE = <1cylTPA.txt;6/2>

LIFT-EXHAUST = <1cylTPA.txt;7/2>

Misc. Test Parameters

RPM = 5000

SPARK-TIMING = -20.15

P_AMB = 1

T_AMB = 300

T_EXH_AMB = 330

TAVG-EXPORT = 1055.01

TAVG-INPORT = 296.59

INJ-PW = 8.33122

TIMING-INTAKE = 0

TIMING-EXHAUST = 0

FUEL-LHV = 4.395e+007

USER1 = 0

USER2 = 0

USER3 = 0

>> EOF <<

CrankAngle CamAngle Pinlet Pexhaust P cyl Liftintake Liftexhaust

deg	deg	bar	bar	bar	mm	mm
-360.00	-180.00	0.902	1.185	1.300	0.284	0.871
-359.50	-179.75	0.902	1.187	1.293	0.301	0.844
-359.00	-179.50	0.903	1.189	1.286	0.319	0.817
-358.50	-179.25	0.903	1.191	1.278	0.336	0.790
-358.00	-179.00	0.904	1.193	1.270	0.353	0.764
-357.50	-178.75	0.904	1.195	1.261	0.373	0.740
-357.00	-178.50	0.905	1.198	1.252	0.393	0.716
-356.50	-178.25	0.905	1.200	1.242	0.413	0.692
-356.00	-178.00	0.906	1.203	1.232	0.434	0.668
-355.50	-177.75	0.907	1.206	1.222	0.457	0.647
-355.00	-177.50	0.907	1.209	1.211	0.480	0.626
-354.50	-177.25	0.908	1.212	1.199	0.503	0.605
-354.00	-177.00	0.909	1.216	1.187	0.526	0.584
-353.50	-176.75	0.909	1.219	1.175	0.552	0.566
-353.00	-176.50	0.910	1.223	1.163	0.578	0.547
-352.50	-176.25	0.911	1.228	1.150	0.604	0.529
-352.00	-176.00	0.911	1.232	1.137	0.630	0.510
-351.50	-175.75	0.912	1.236	1.123	0.659	0.494
-351.00	-175.50	0.912	1.241	1.110	0.688	0.478
-350.50	-175.25	0.913	1.245	1.096	0.717	0.462
-350.00	-175.00	0.914	1.250	1.082	0.746	0.446
-349.50	-174.75	0.915	1.254	1.068	0.778	0.432
-349.00	-174.50	0.917	1.259	1.053	0.810	0.418
-348.50	-174.25	0.918	1.264	1.039	0.842	0.404
-348.00	-174.00	0.920	1.268	1.024	0.874	0.390
-347.50	-173.75	0.921	1.272	1.009	0.909	0.378
-347.00	-173.50	0.923	1.276	0.995	0.944	0.366
-346.50	-173.25	0.925	1.280	0.981	0.979	0.354