Three Pressure Analysis (TPA)

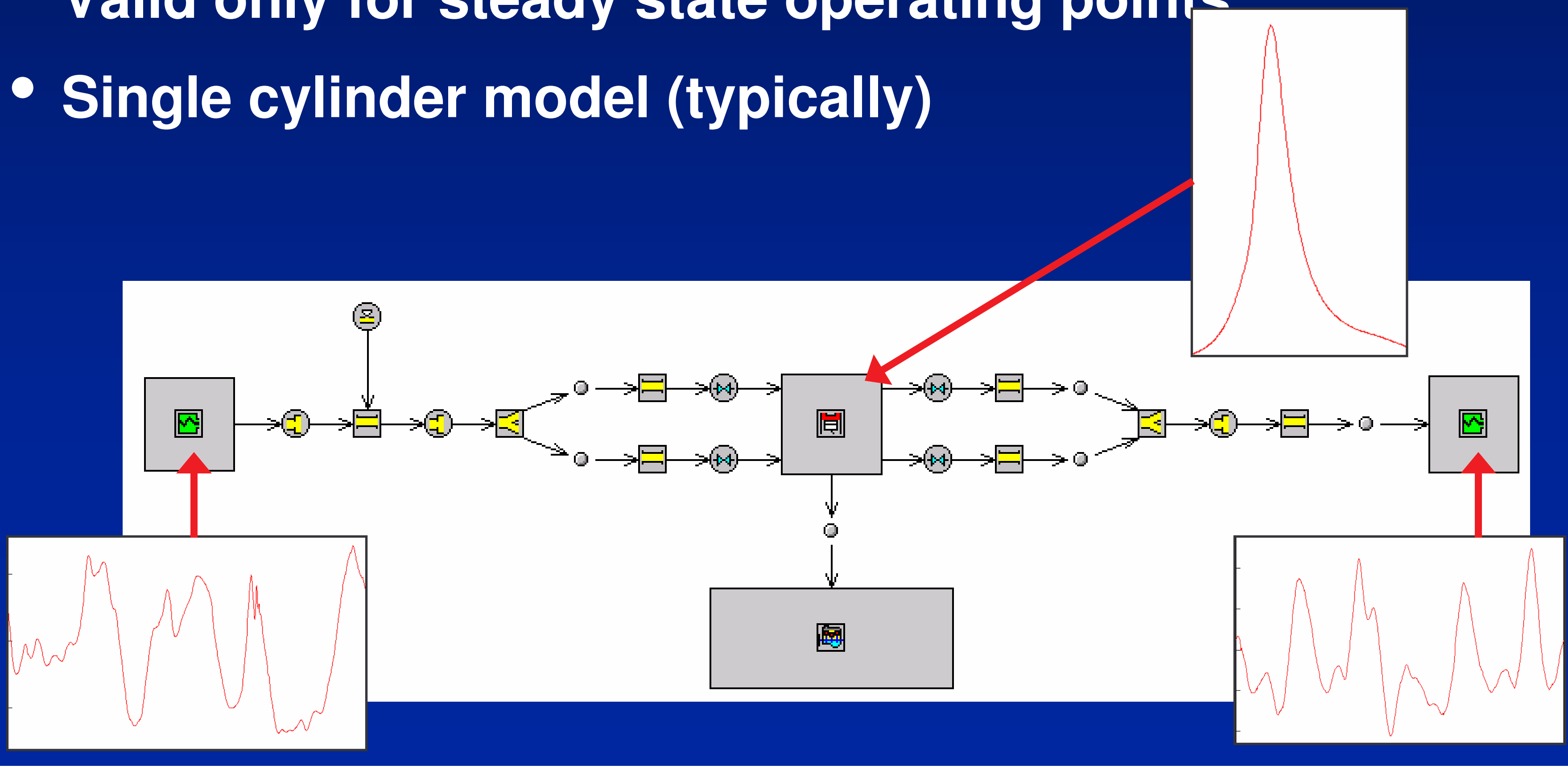
Gamma Technologies

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

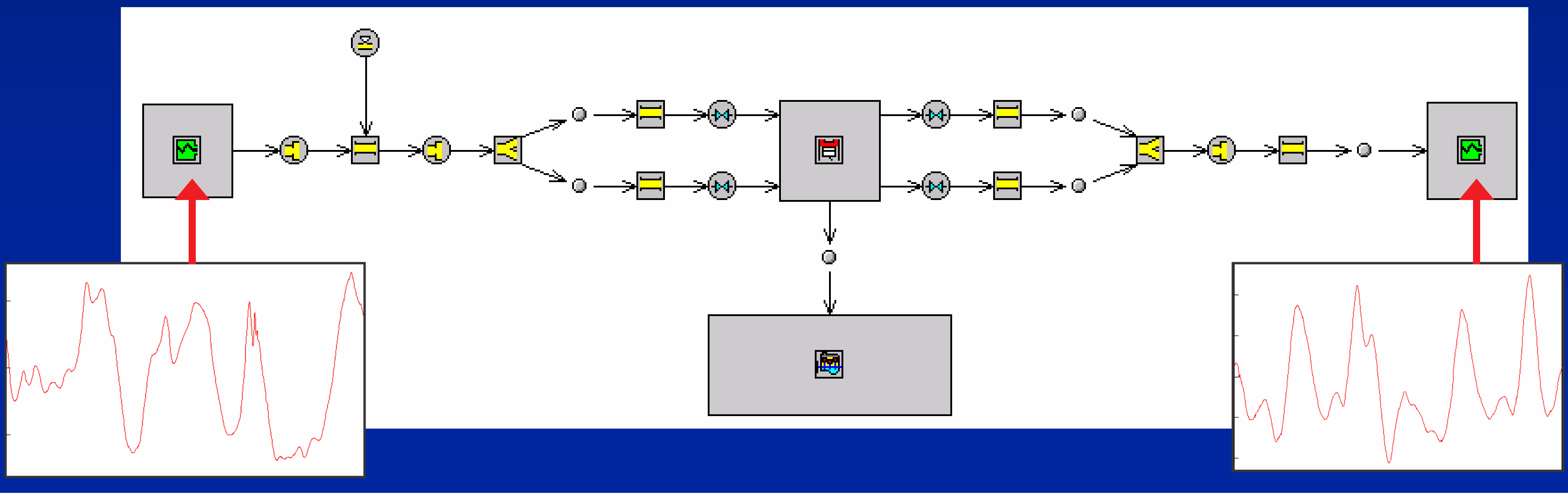
TPA Operation

- 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)



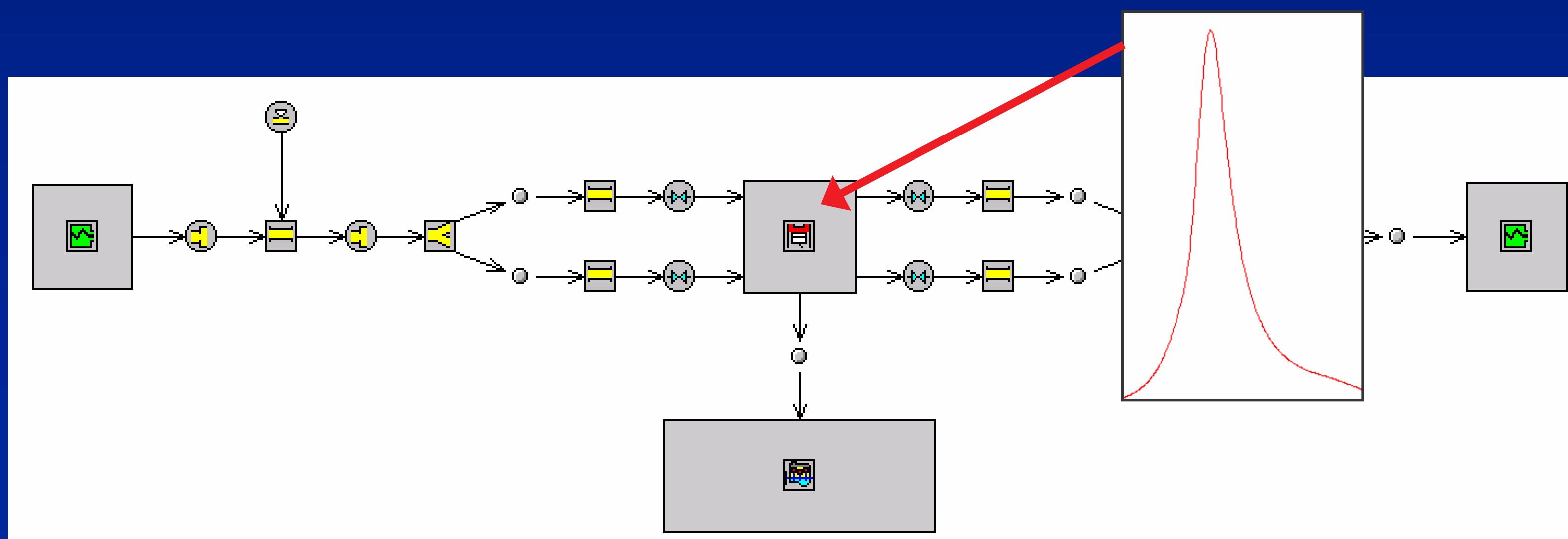
1. Impose Port Pressures

- **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….**



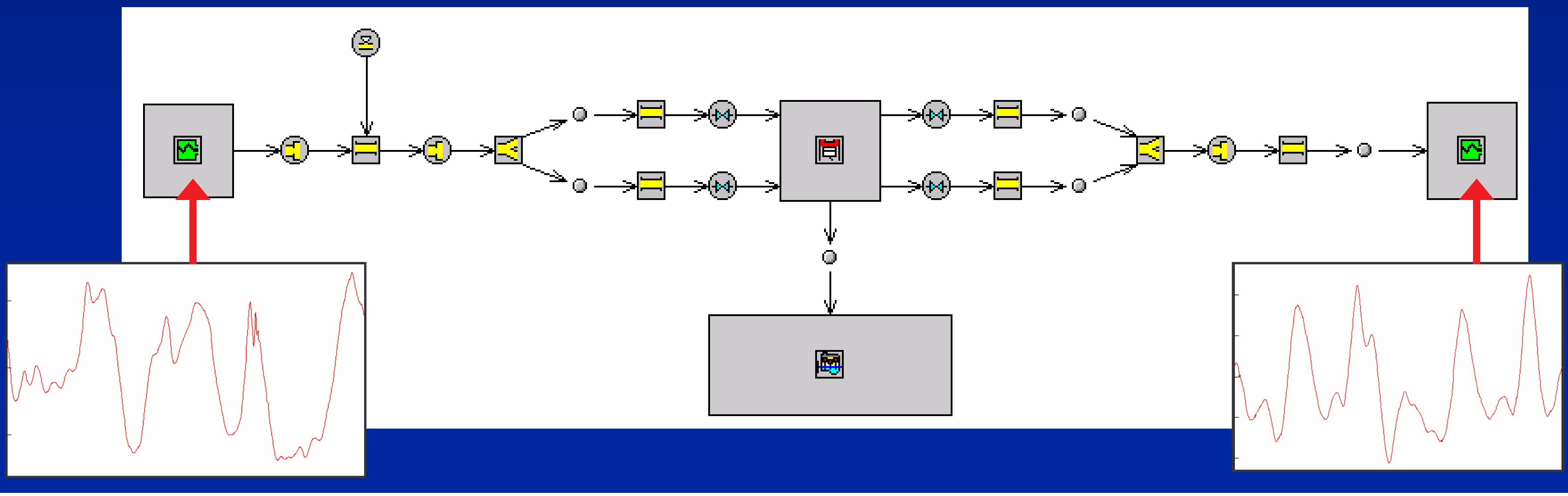
2. Calc. Burn Rate

- 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

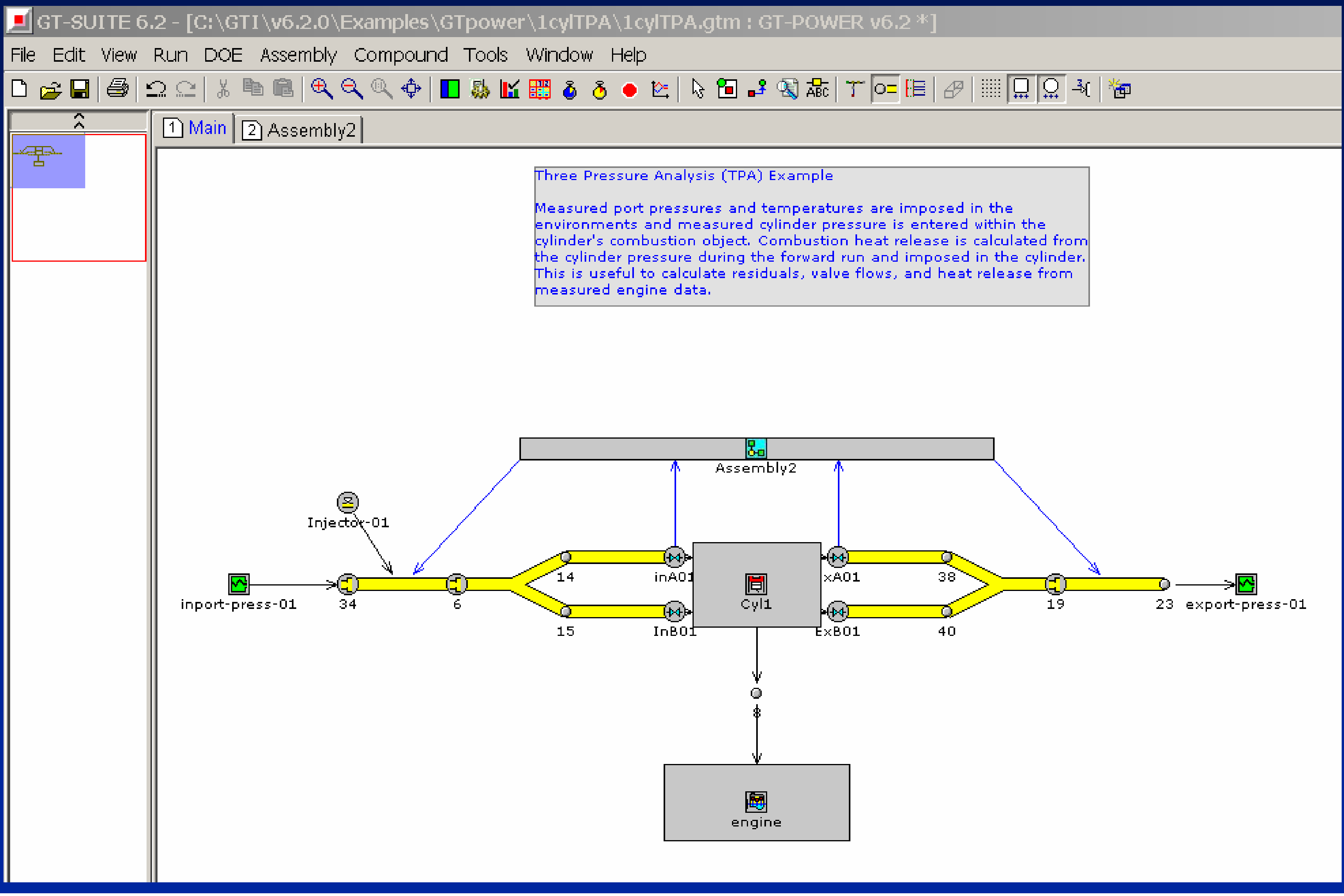
- Store the computed burn rate at IVC
- Apply the burn rate during combustion in this cycle
- Run to cycle end
- Repeat the three steps 5-7 cycles until convergence
- Output combustion object for use in predictive calculations



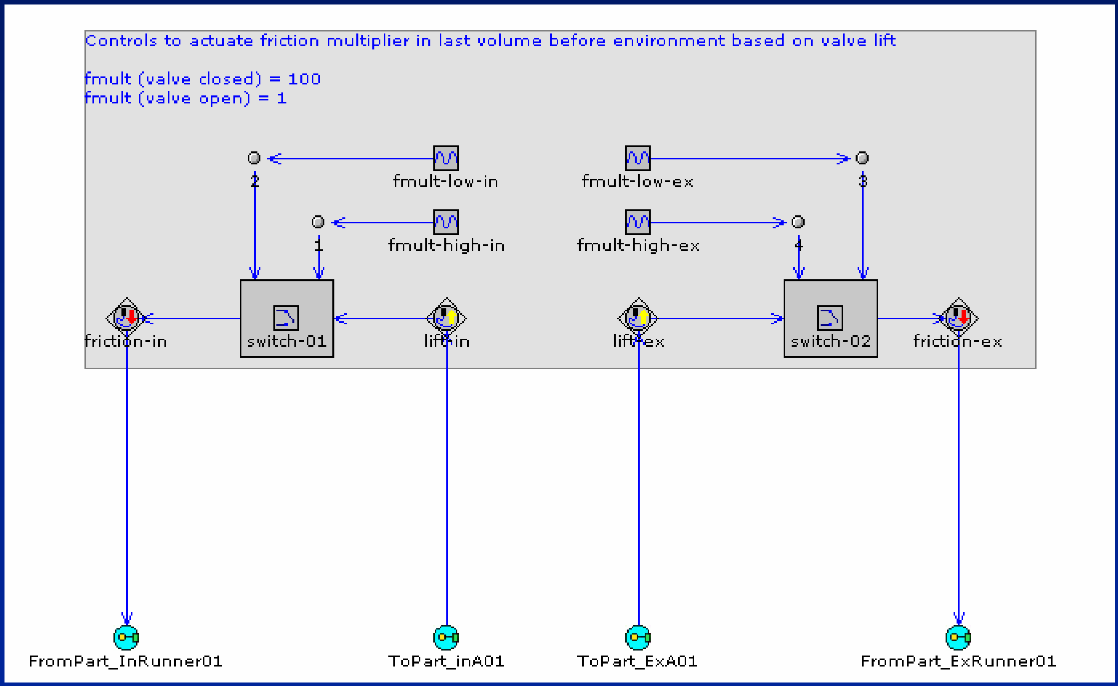
Comparison of TPA to Use of ‘EngHeatRel’

- 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 Pcyl
- Particularly useful for part-load data analysis

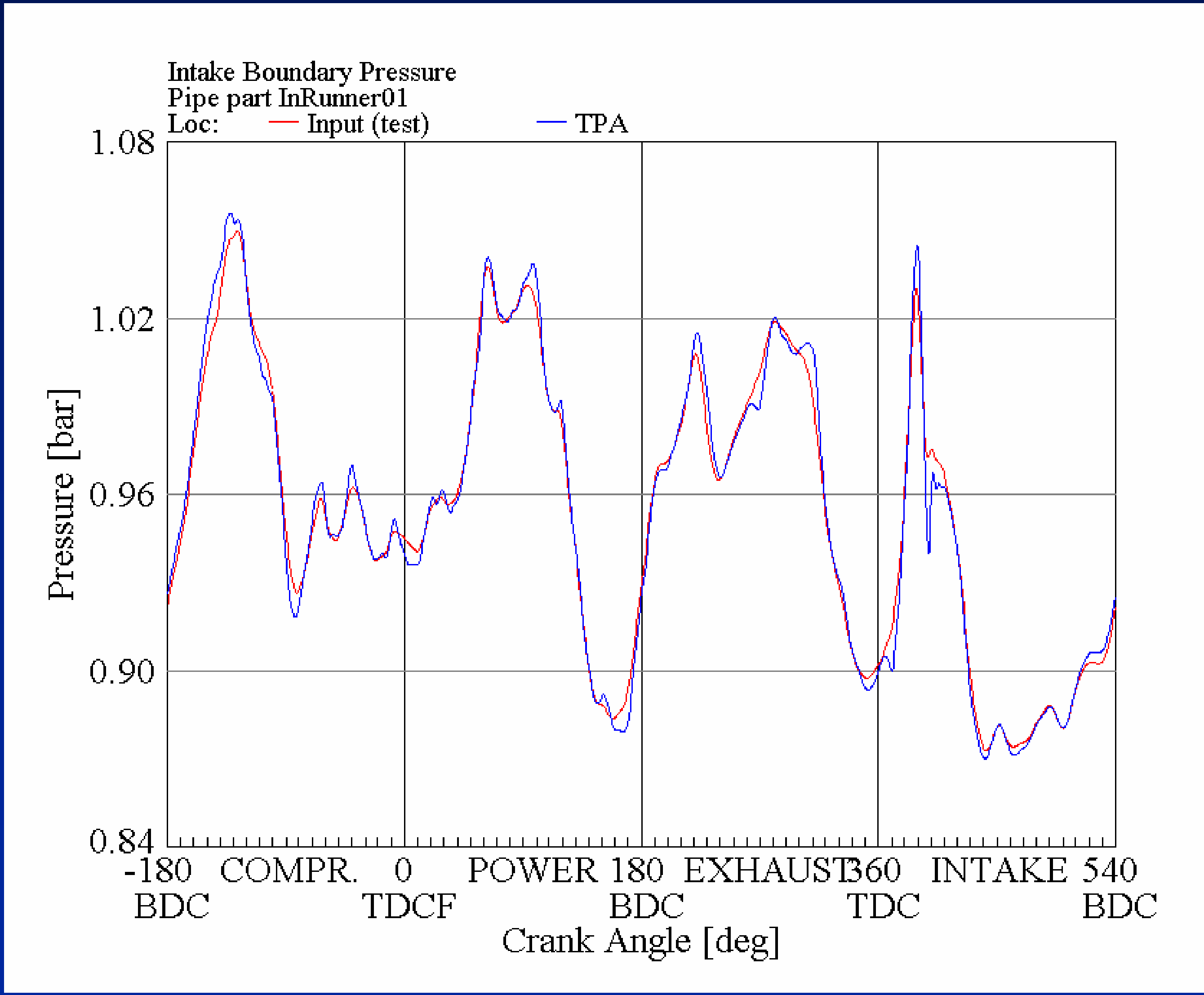
Model Set-Up


GT-SUITE 6.2 - [C:\GTI\v6.2.0\Examples\GTpower\1cylTPA\1cylTPA.gtm : GT-POWER v6.2 *]
File Edit View Run DOE Assembly Compound Tools Window Help
1 Main
2 Assembly2
Three Pressure Analysis (TPA) Example
Measured port pressures and temperatures are imposed in the environments and measured cylinder pressure is entered within the cylinder's combustion object. Combustion heat release is calculated from the cylinder pressure during the forward run and imposed in the cylinder. This is useful to calculate residuals, valve flows, and heat release from measured engine data.
Assembly2
Injector-01
inport-press-01
34
6
14
15
inA01
InB01
Cyl1
xA01
ExB01
38
40
19
23
export-press-01
8
engine

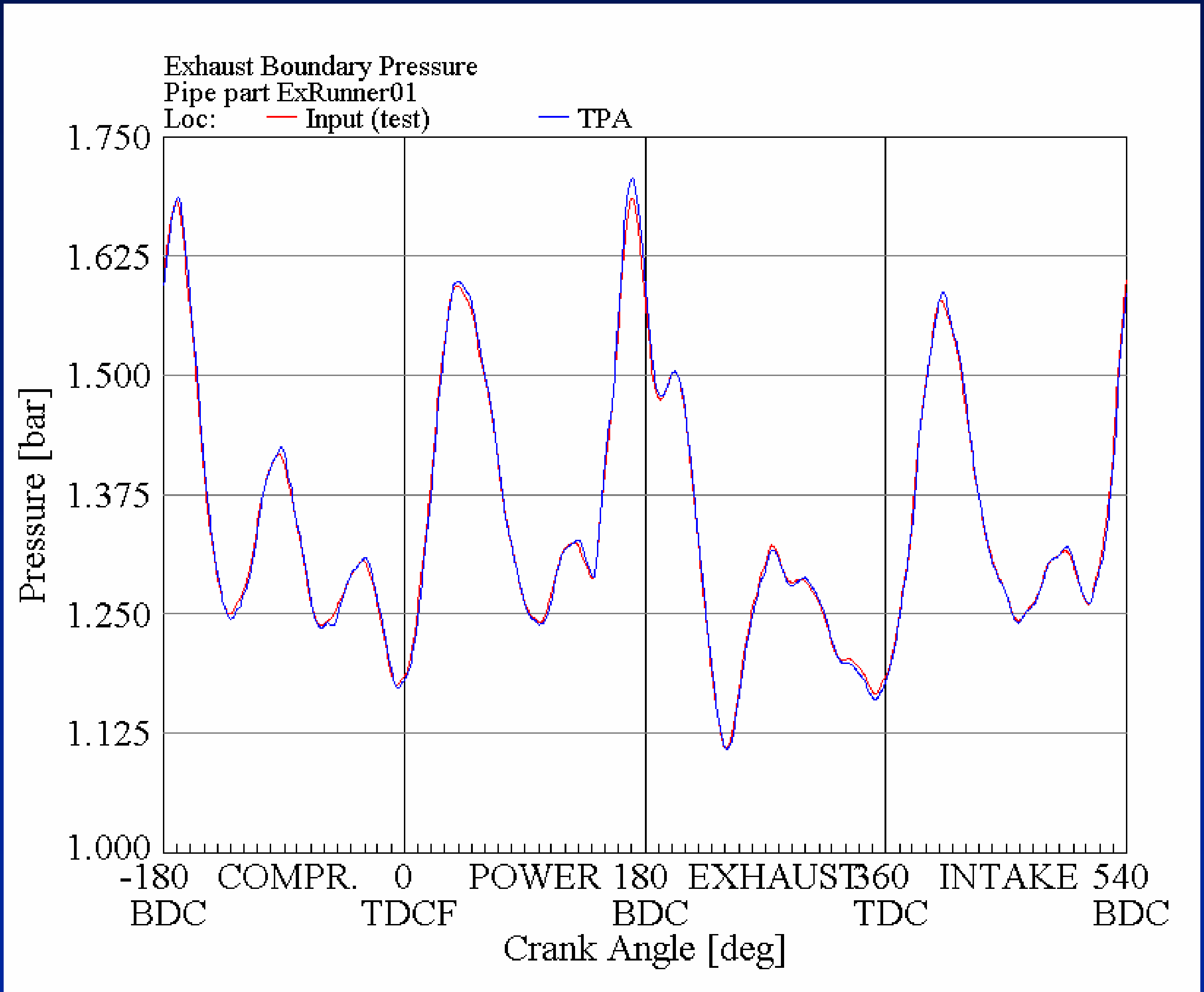
Damping of Spurious Waves



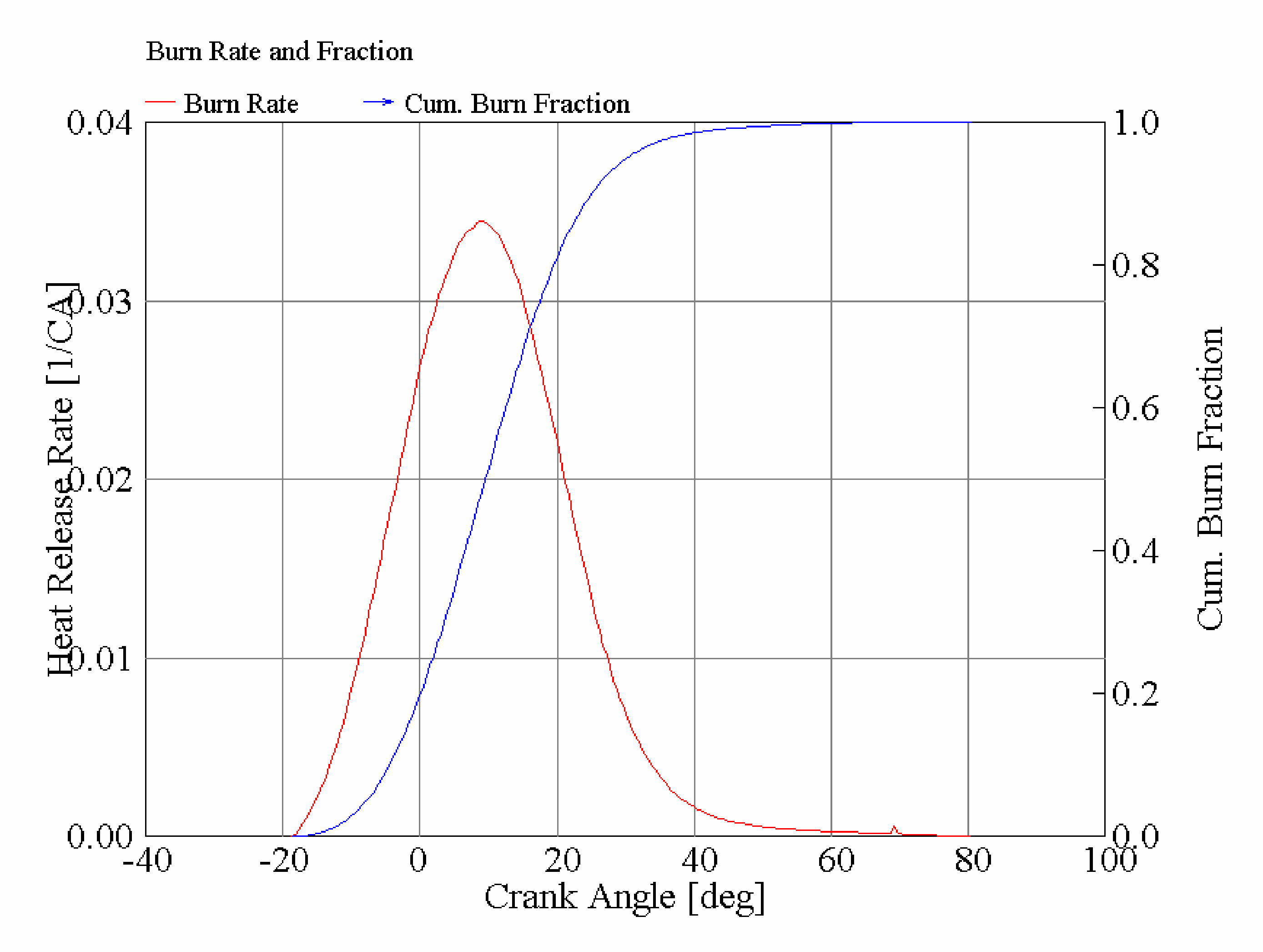
Intake Port Pressure



Exhaust Port Pressure

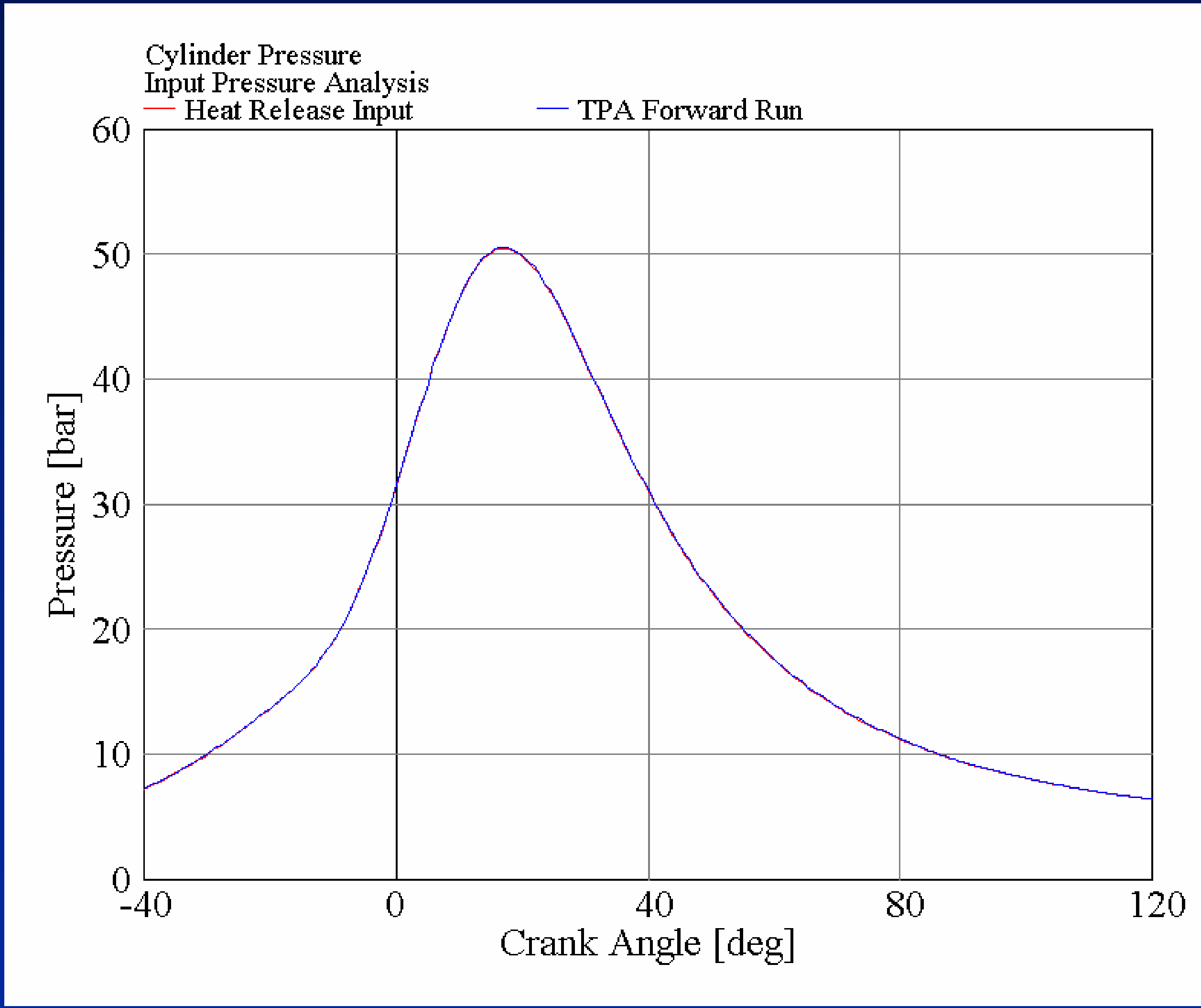


Burn Rate

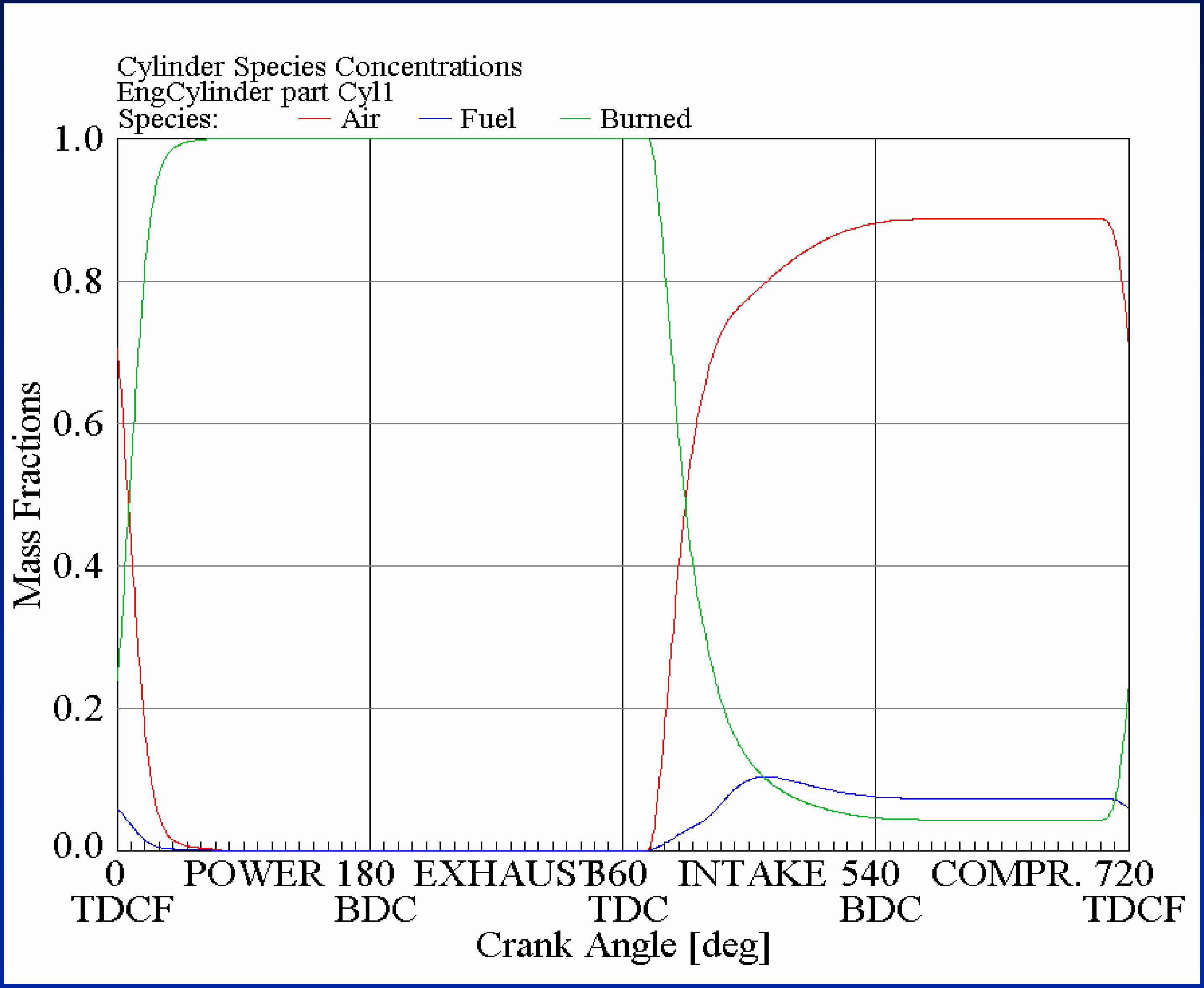


Burn Rate and Fraction
Burn Rate
Cum. Burn Fraction
0.04
0.03
0.02
0.01
0.00
Heat Release Rate [1/CA]
1.0
0.8
0.6
0.4
0.2
0.0
Cum. Burn Fraction
-40
-20
0
20
40
60
80
100
Crank Angle [deg]

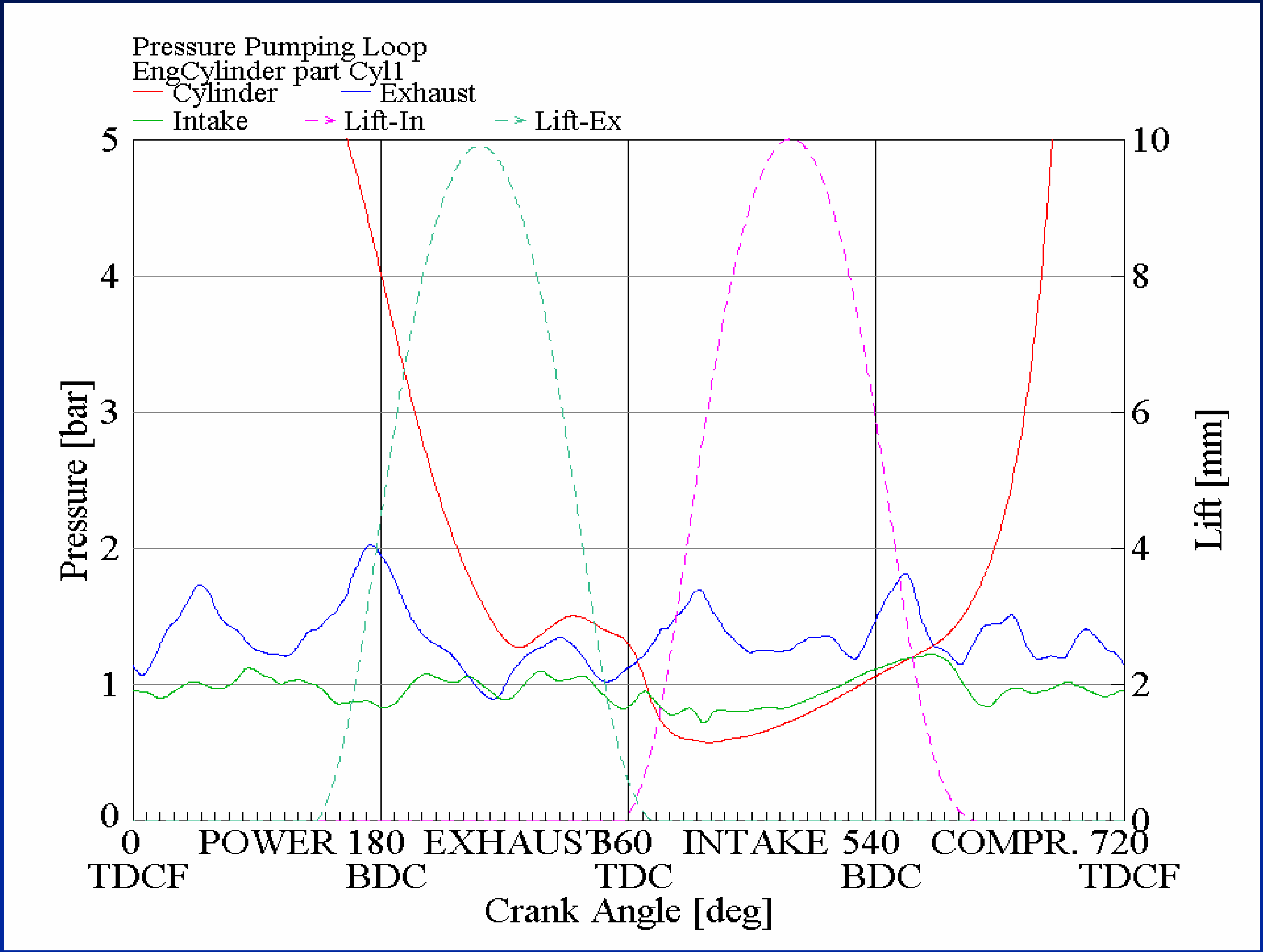
Cylinder Pressure Match



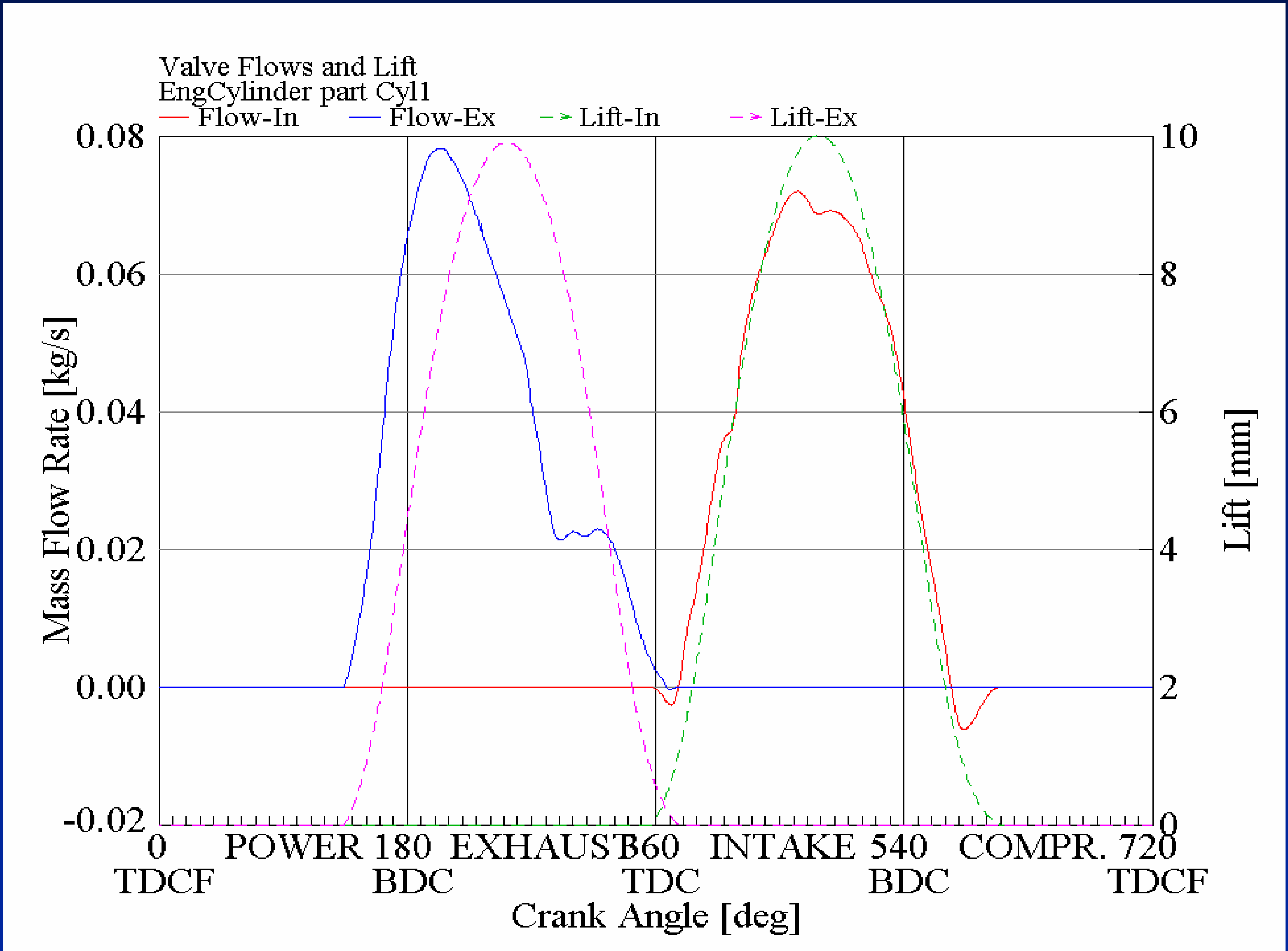
Cylinder Mass Fractions



Cylinder and Port Pressures



Valve Lift and Flows



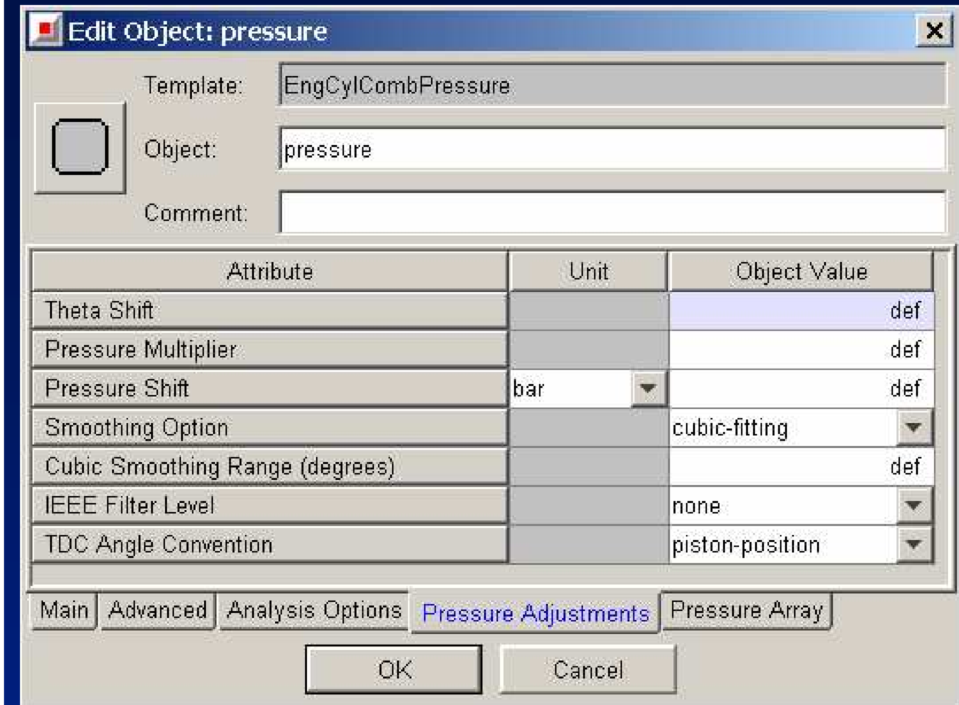
Tables

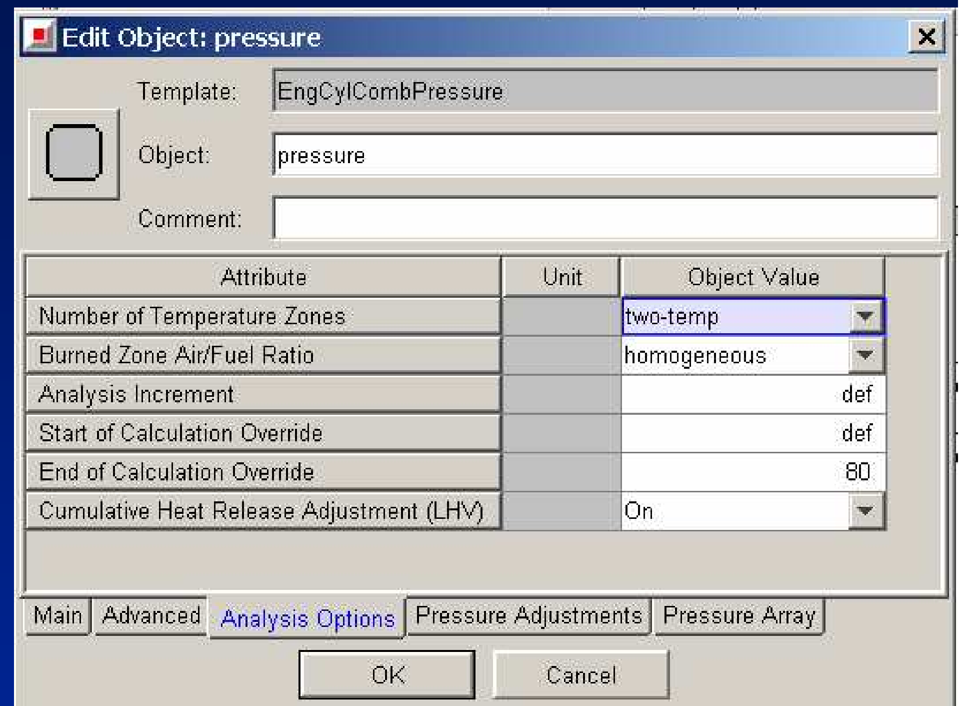
Pressure Parameters

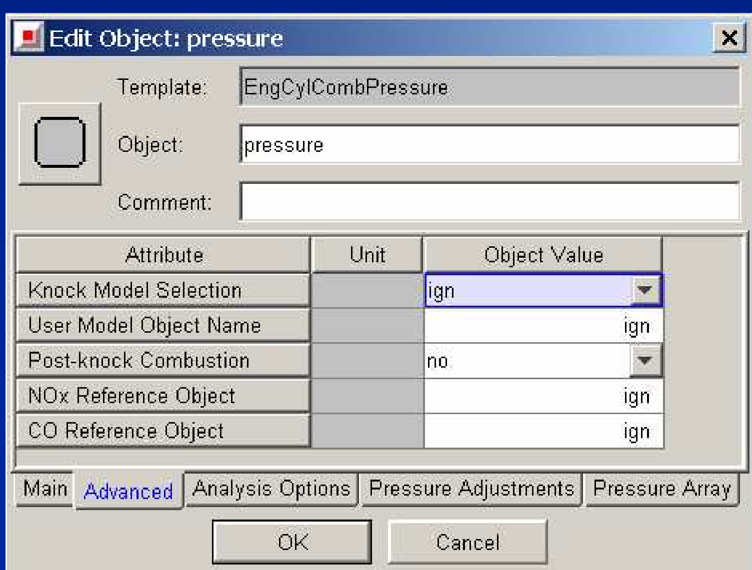
Object Name	Cyl1
IMEP [bar]	11.047
PMEP [bar]	-0.956
Pmax [bar]	50.44
CA at Pmax	17.00
dP/dCA max (bar/CA)	1.65
Compr Slope 1.(-90 to -70)	1.305
2.(20 deg bef spk/inj)	1.288
3.(-90 to spk/inj)	1.296
Pres Smoothing Effect RMS [bar]	0.0004

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





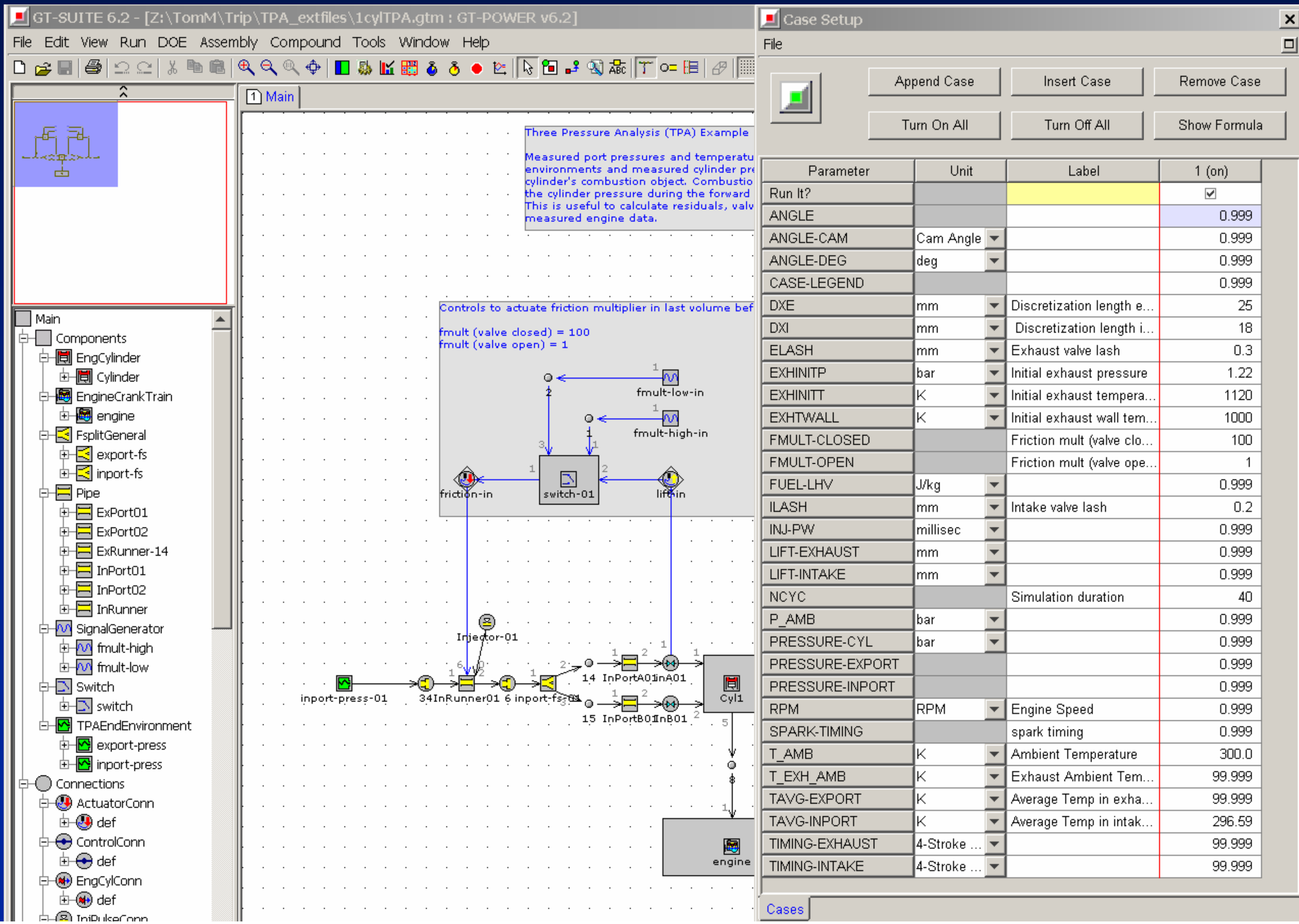


Input Options

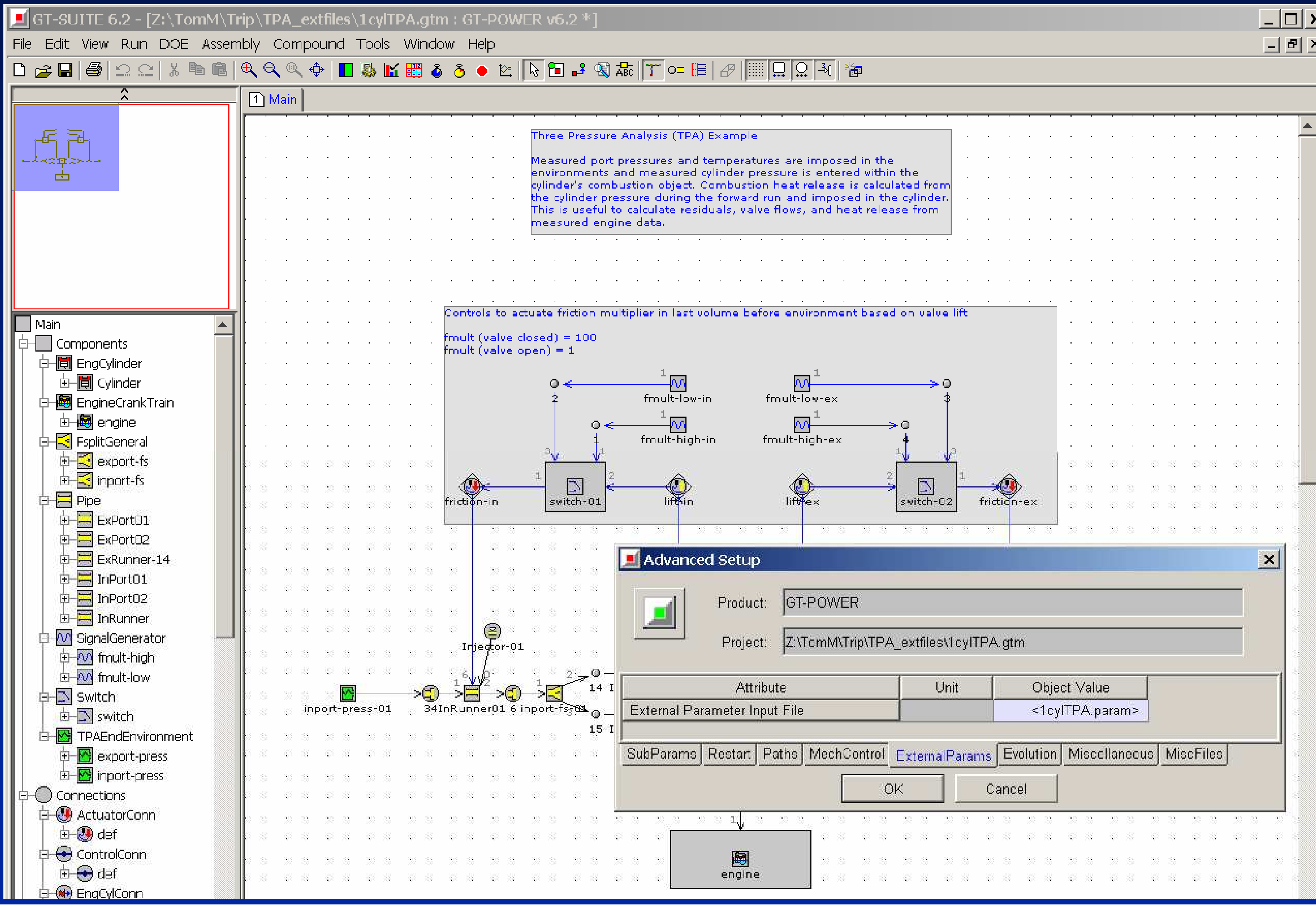
TPA Ties Together Test and Simulation

- 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



Setting up Link to Test Cell Data



Setting up Link to Test Cell Data

1cyltpa.param

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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 <<
```

1cyltpa.txt

CrankAngle	CamAngle	Pinlet	Pexhaust	Pcyl	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