The Simulation Cycle: Integration of GT-POWER, GT-VTrain, and VTDesign for the Optimization of NASCAR Valve Events

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Presentation Overview

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- Role of Simulation at ECR Engines
- GT VTrain Simulation Overview
- GT Power Simulation Overview
- Integration of GT Power and GT VTrain
- Genetic Algorithm Optimization
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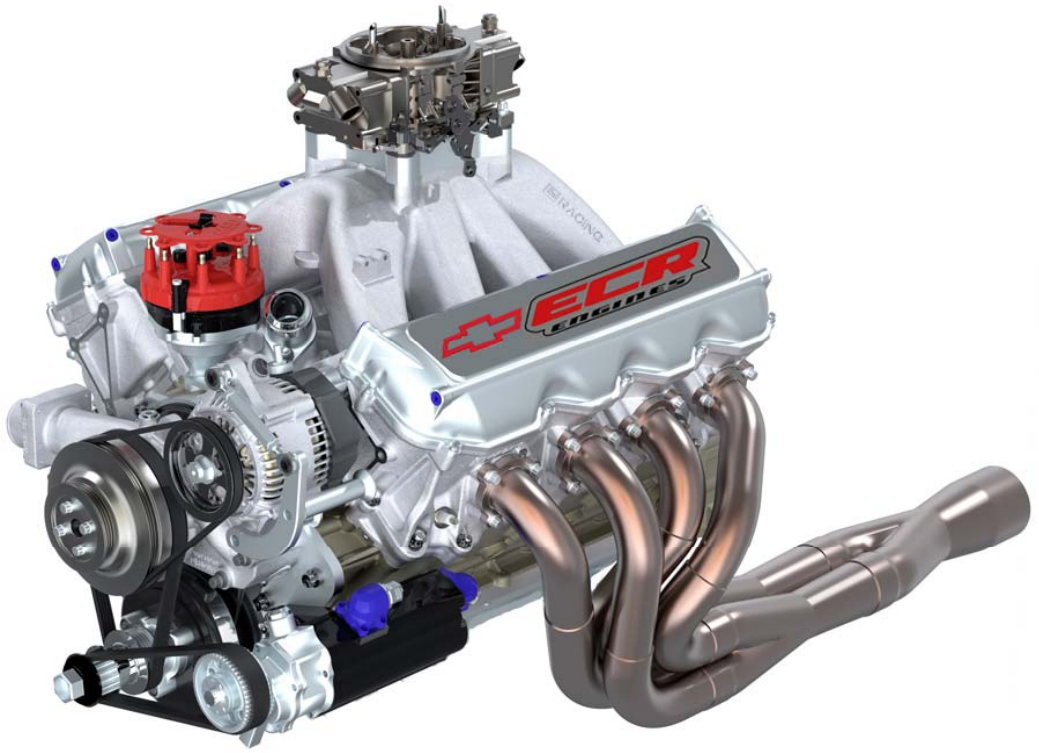
- Questions

Introduction

- 7 NASCAR Nextel Cup engine programs
- 5 NASCAR Nationwide engine programs
- 600+ Engines a year
- 5.8L, 90°, OHV V8
- 830+ hp
- 530+ ft-lbs
- 9,800 rpm redline
- 140+ hp/L
- Wide operating range
  - 5,400 to 9,800 rpm



Role of Simulation at ECR Engines

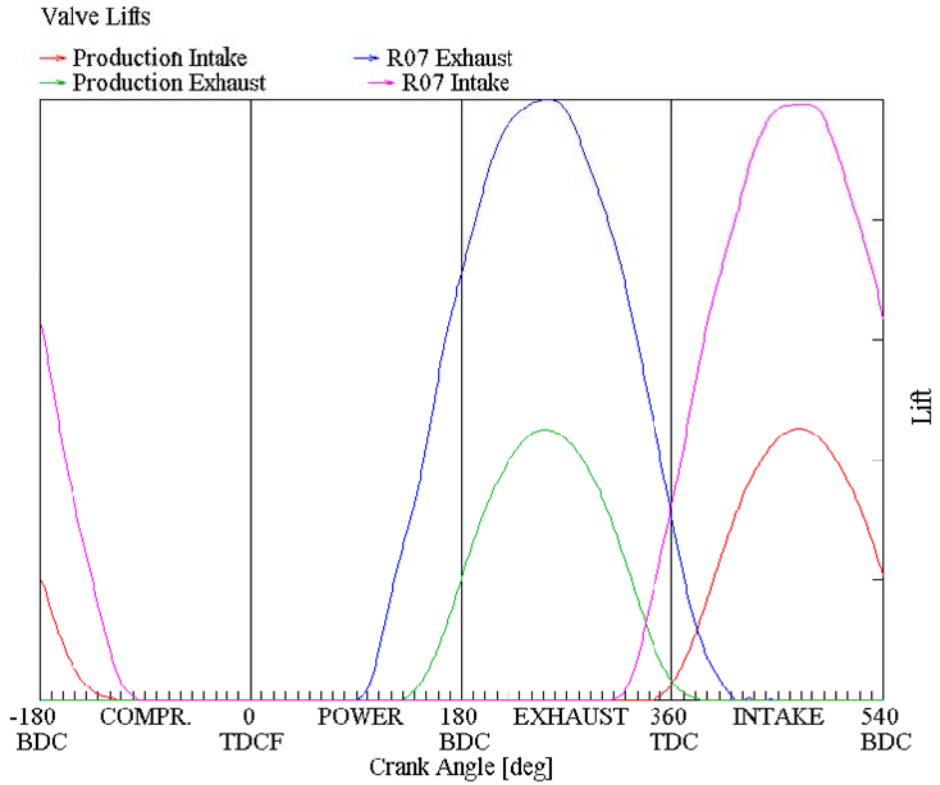
- The cam and valvetrain package that is currently being raced was developed with the aid of the GT-Suite packages
  - Camshaft profile designed in VTDesign
  - Resulting dynamic valve lift characterized in GT-VTrain
  - Engine power was successfully predicted / improved in GT-POWER
- Simulation allows ideas to be tested without having to manufacture new parts
  - Reduced development time
  - Allows testing of physically impractical scenarios
  - Reduces cost by eliminating a range of physical tests

GT-VTrain Model Overview

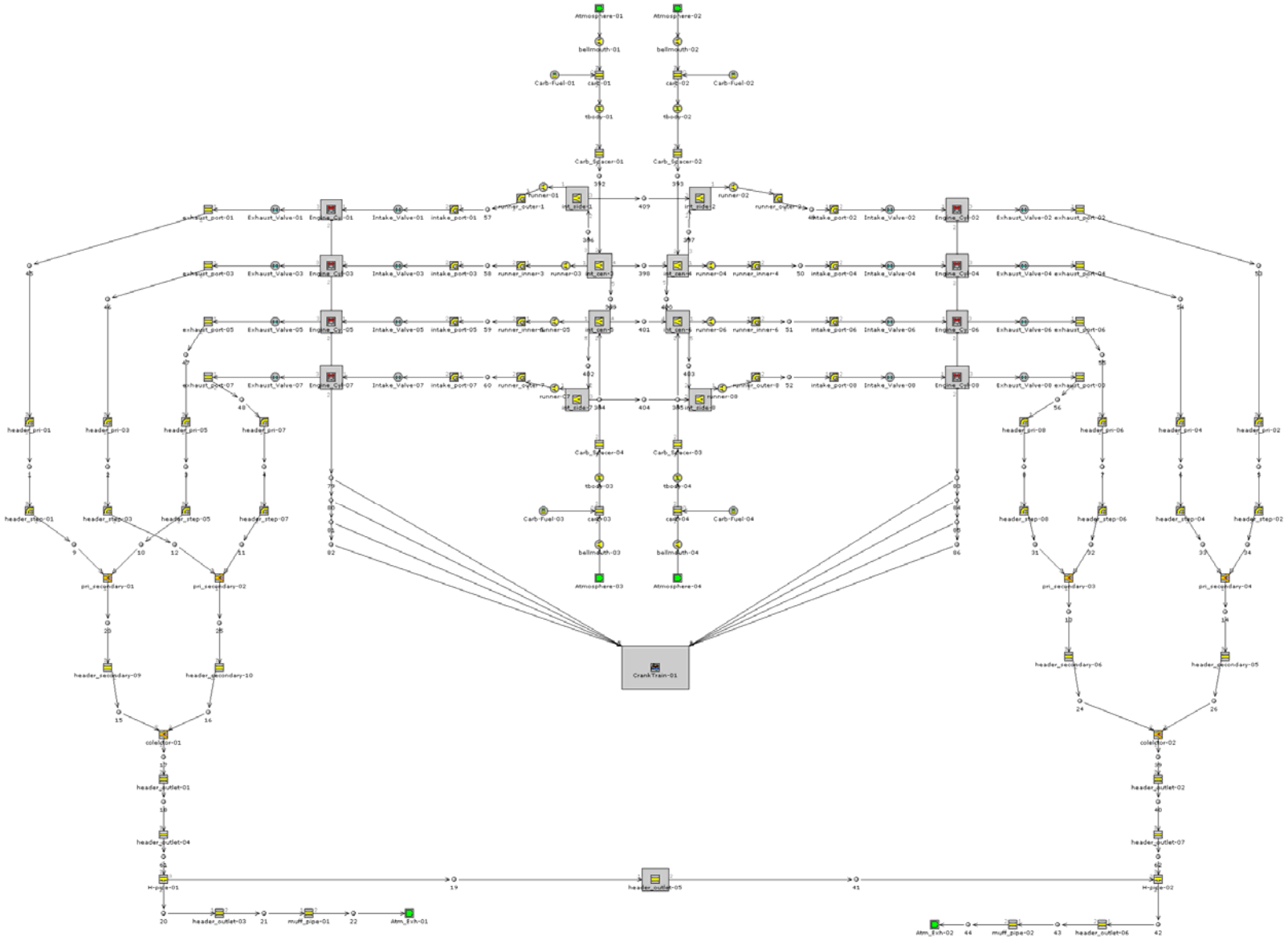
- Full multiple cylinder dynamic model
- Coupled cam and crankshaft
- Simulation is tuned/validated against measured motoring valve lift data as well as crankshaft torsional twist data from a firing engine
- Physically impossible to measure running valve lifts due to high lift (0.900+ in.) and geometrical constraints
- Cylinder pressure is applied to the valves to capture the effects it has on the valve event profile
- As a result of late intake valve closure the applied cylinder pressure will reduce valve bounce that would otherwise give inaccurate power results

GT-VTrain Model Overview

- With only two valves per cylinder, high valve lift and long durations are required for outstanding high speed engine performance
- The high accelerations required to achieve the desired lift profiles result in multiple durability issues



GT-POWER Simulation Overview



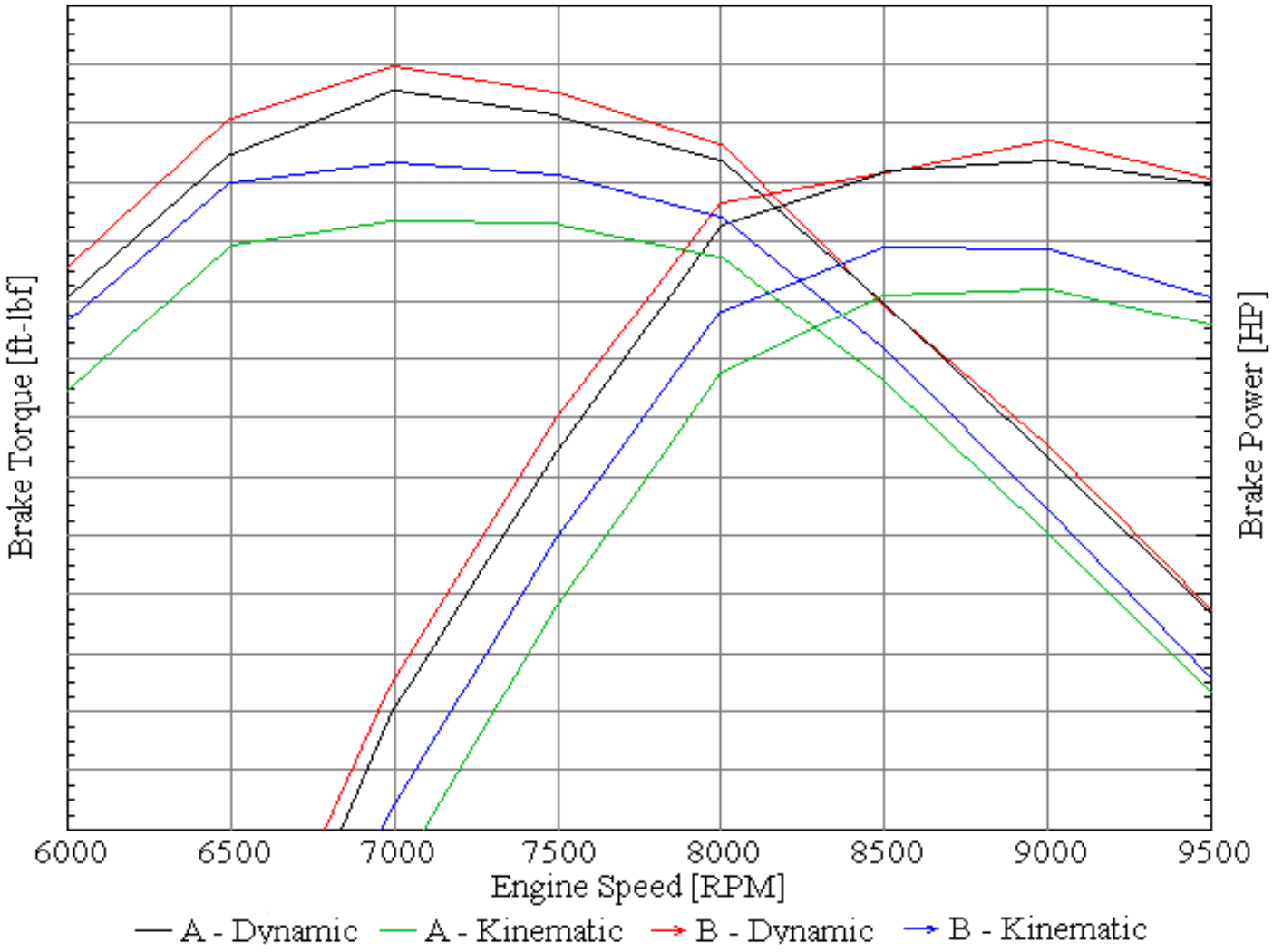
GT-POWER Simulation Overview

- Captured the complete 1-D flow path
- Imposed burn rates from measured data
- Utilized individual cylinder engine speed dependent valve lift profiles from GT-VTrain model
- Complex intake manifold geometry characterized through intake port pressure measurements
- Utilized high pressure ratio exhaust port flow data

Integration of GT-POWER and GT-VTrain

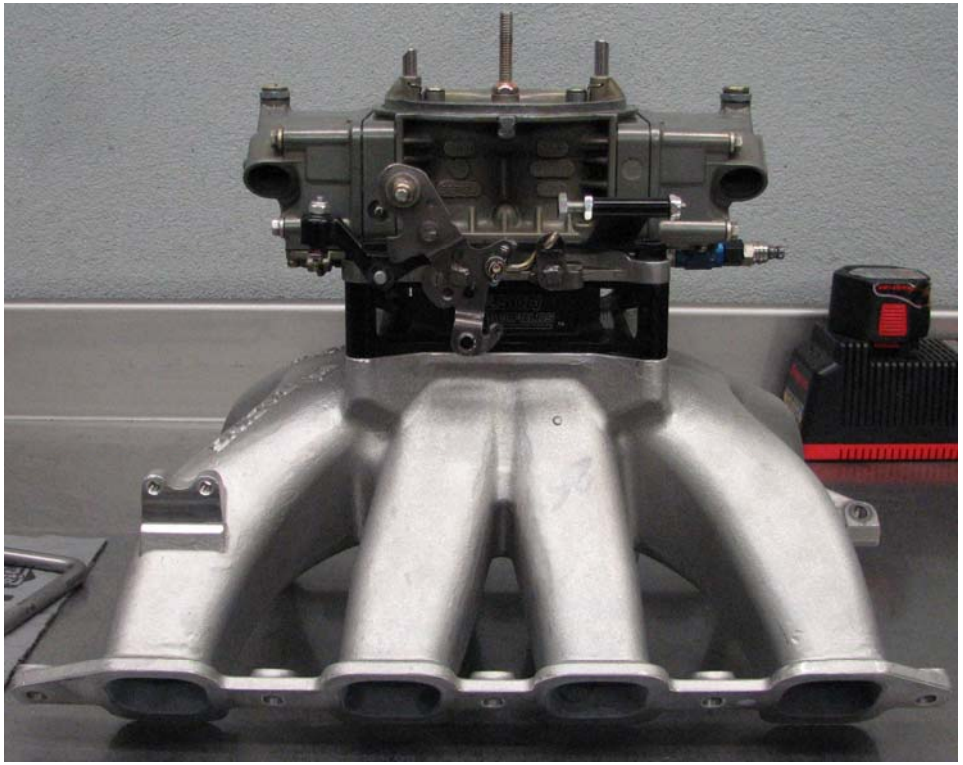
- Originally at ECR the GT-POWER simulation used kinematic valve lift profiles or measured motoring valve lift data
- Correlation with measured power when using either source of data was not accurate enough for the small gains that are typical in an already highly optimized engine
- With the integration of the detailed GT-VTrain model the GT-POWER simulation has been able to accurately predict the impacts of valvetrain changes on overall engine performance
- Valve lift profile used in GT-POWER is easily imported from the GT-VTrain *.gdt file
  - ValveCamConn – utilized an RLT dependence object under “Variable Profile Dependency Object”
  - RLTDependence – based on an input of engine speed the “Dependence Object” references to an “XYTableDependency”
  - XYTableDependency – then references an series of “XYTableGT” which can read the valve lift profile out of the *.gdt file

Integration of GT-POWER and GT-VTrain



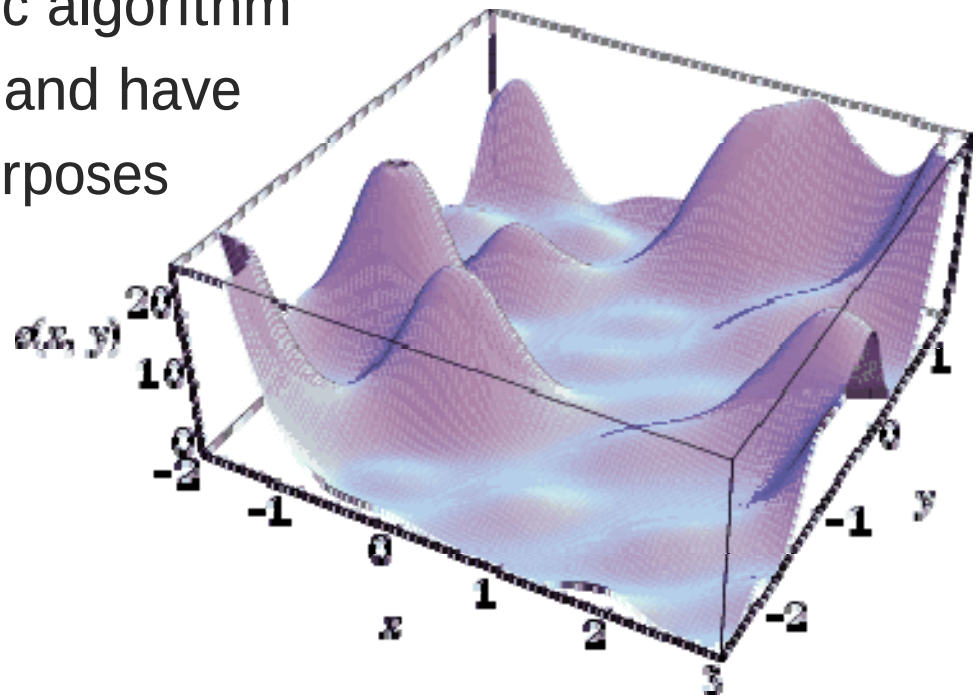
Genetic Algorithm Optimization of Valve Events

- As consequence of the NASCAR rules, there are large cylinder to cylinder performance differences
  - Centralized location of single carburetor
  - Unequal length / shape of intake runners
  - Crossplane crankshaft
- Highly tuned intake / exhaust pressure waves
- Performance can be gained by tailoring certain engine components to optimize the cylinder-cylinder performance differences



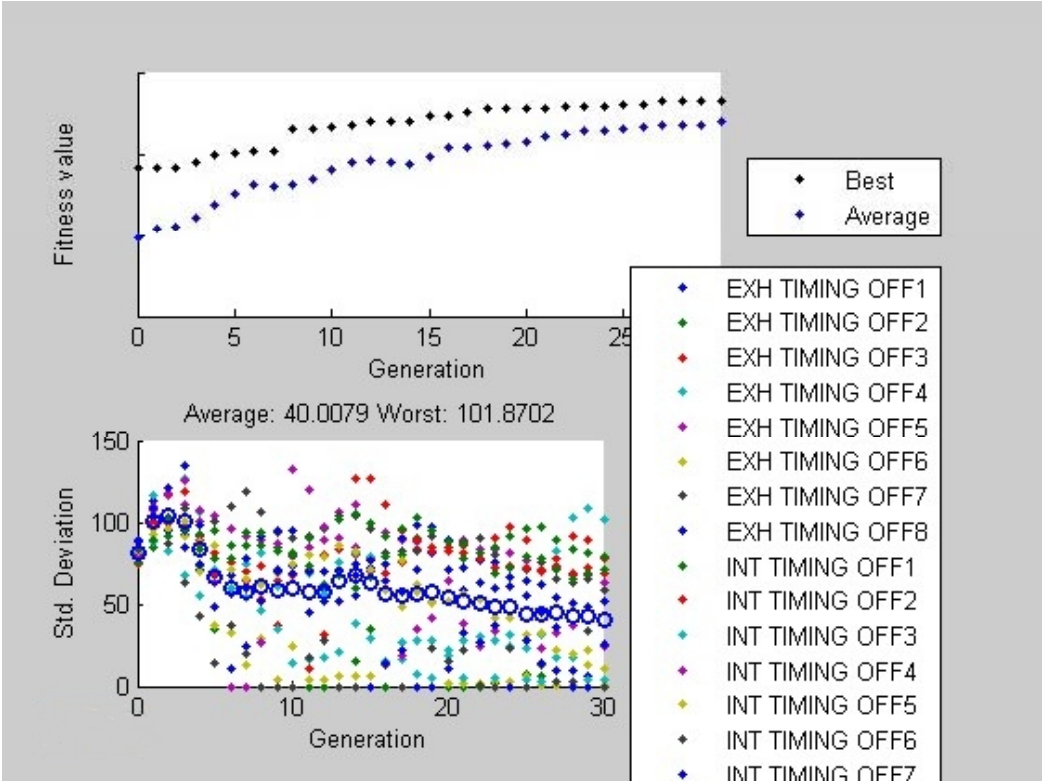
Genetic Algorithm Optimization of Valve Events

- Genetic algorithm optimizations excel at optimizing highly irregular response surfaces
- High performance engines that depend on strong intake and exhaust wave tuning for their power production will exhibit a highly nonuniform response surface
- We have based our genetic algorithm off of the codes in Matlab and have modified it for our own purposes

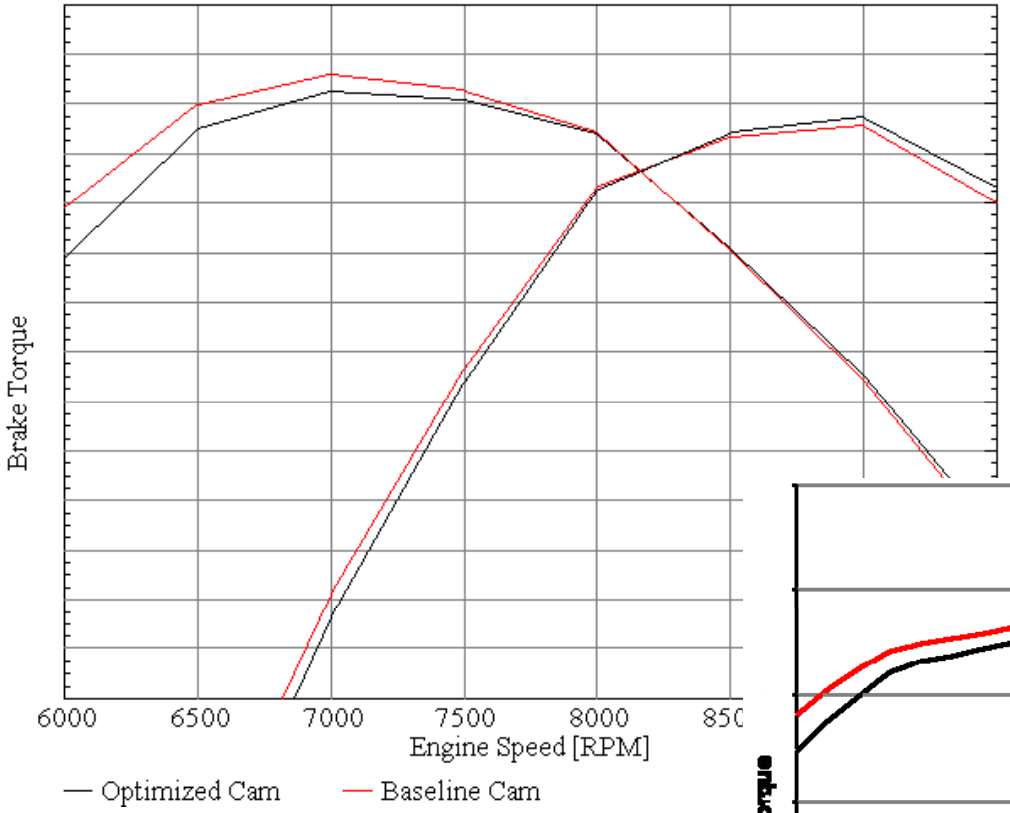


Genetic Algorithm Optimization of Valve Events

- Ran a genetic algorithm optimization on individual cylinder lobe timings
- Optimization goal was a weighted average of two engine speeds
- Optimization ran over 3000 iterations over a weeklong period
- The optimized lobe timings resulted in a favorable increase in low speed torque with only a small decrease in high speed engine performance
- The simulation correlated very well with actual engine performance

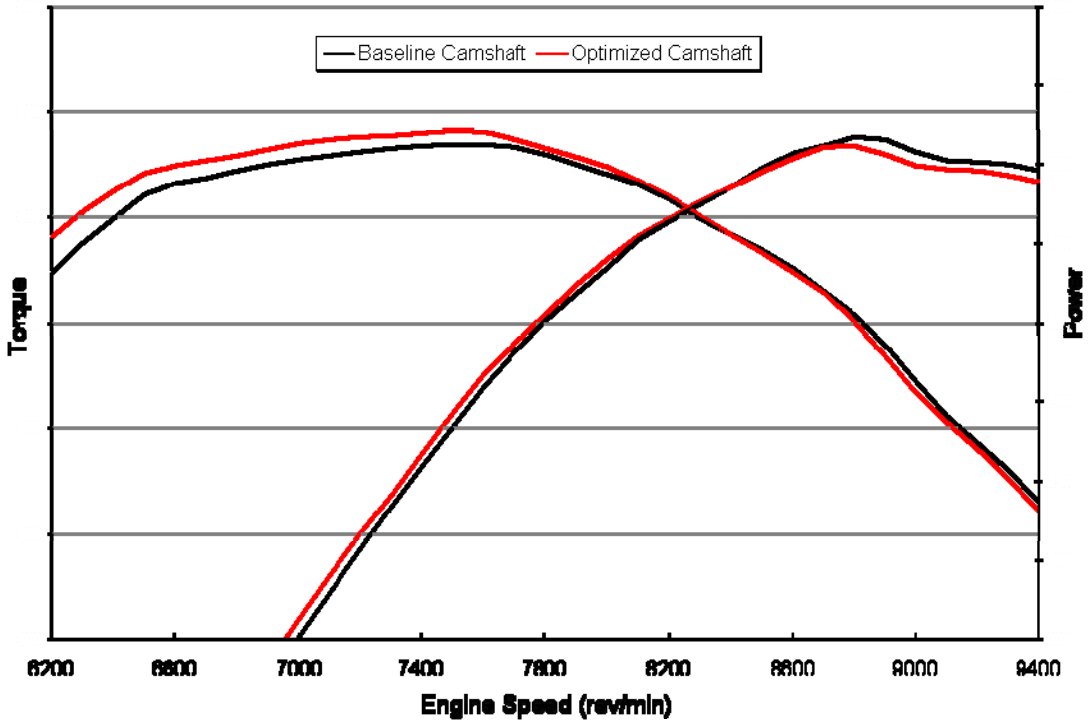


Genetic Algorithm Optimization of Valve Events



Simulated Data

Measured Dynamometer Data



Conclusions

- Due to the nature of our engines and their operating characteristics, using a detailed valvetrain model is a necessity in order to have accurate power predictions
- A highly accurate engine simulation coupled with a genetic algorithm optimization can rapidly advance the power output of our engines
- Utilizing optimization allows the engineer to explore an expansive simulation field without excessive hours of input running the model

Questions?

2008 Daytona 500 Finish – Clint Bowyer