EXCITE™ Designer and Powerunit for High Performance Applications

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Introduction

- Many of the same challenges with production engine design and analysis occur when designing and analyzing high performance engines
  - Compact, light weight
  - High specific output
  - Cost effective
  - Short design cycle
- Many of the same analysis techniques are used for both applications
  - CAD Modeling
  - Up-front classical analysis tools
  - Advanced tools such as EXCITE™ Designer and Powerunit (along with others) become critical in the process
- While the same issues can occur in either application, the issues with high performance engines tend to be more extreme and occur sooner in an engine's lifecycle

Introduction (Cont'd.)

- High Performance applications
  - Racing series such as Formula 1, Indycar, NASCAR
  - Becoming more common today is the use of production automobiles and components being used in race series
    - Allows reduction in cost
    - Overlap with production vehicles
    - Marketing
    - Examples include,
      - IMSA/WEC GTLM class (Ford GT, Corvette, Porsche 911, Ferrari 488, BMW)
      - GT3/GT4 Road Racing (Ford Mustang, McLaren, Mercedes, etc.)
  - Production performance cars

Introduction (Cont'd.)

- Where do AVL EXCITE™ Designer and Powerunit fit in the design and development process?
  - Initial concept phase choices are made using classical tools
    - Initial bearing sizing
    - Crankshaft counterweighting and balance
  - Intermediate phase utilizes EXCITE™ Designer for 1D dynamics and torsional vibration analysis
  - Advanced phase utilizes EXCITE™ Powerunit for 3D flexible dynamics, bearing performance, and durability
    - Bearing Elastohydrodynamic lubrication analysis (EHD)
    - Crankshaft durability analysis
    - Support of other functions, e.g., cylinder block durability

Introduction (Cont'd.)

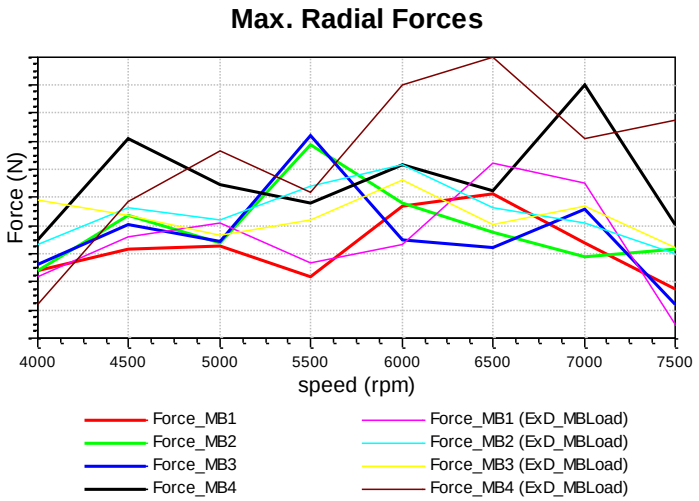
- Examples
  - EXCITE™ Designer
    - 60° V6 intermediate phase design
    - Torsional vibration analysis
    - Main bearing load
  - EXCITE™ Powerunit
    - 60° V6 advanced phase design
    - 60° V6 stress and fatigue analysis
    - High performance V8 stress and fatigue analysis
    - High performance V8 connecting rod bearing analysis

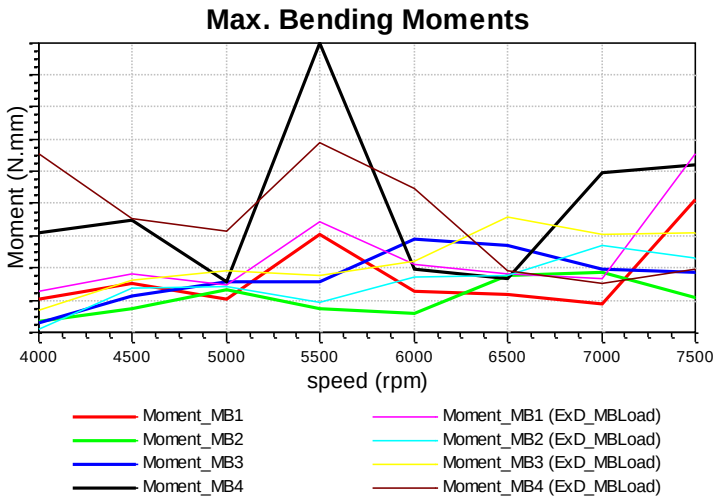
60° V6 Race Car Crankshaft Design & Analysis

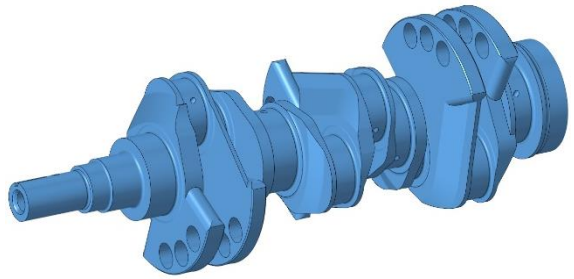
- Reduced mass, custom machined from one piece of material, with Tungsten inserts
  - Utilized classical tools and CAD to design crankshaft
  - Utilized Excite Designer and Autoshaft to calculate main bearing loads and unbalance (MBLoad) for preliminary design
  - Utilized Excite Powerunit for advanced analysis

Excite Designer Analysis

- Standard 1D calculations, such as torsional vibration
- EXCITE™ Designer main bearing and webload calculations with shaft modeler calculations
- Can set up designed experiment to investigate effect of counterweighting on main bearing forces and moments

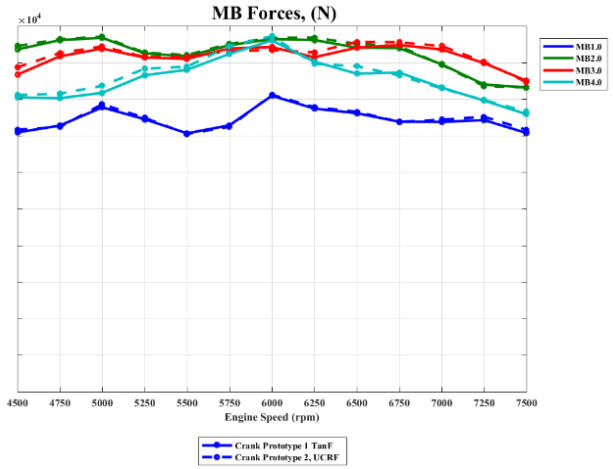


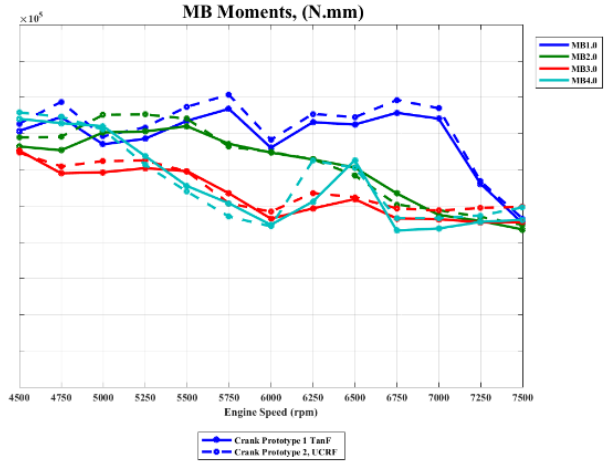


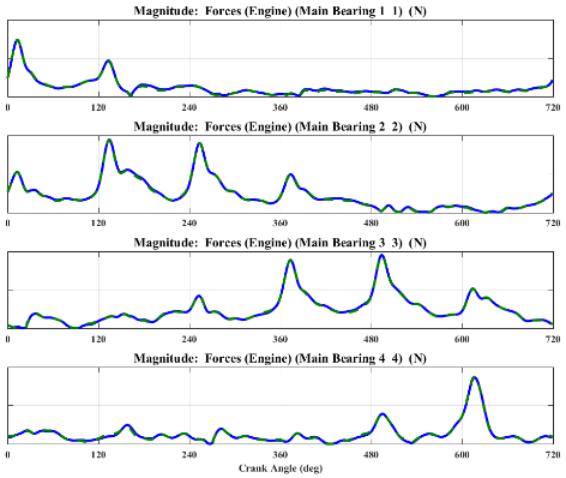


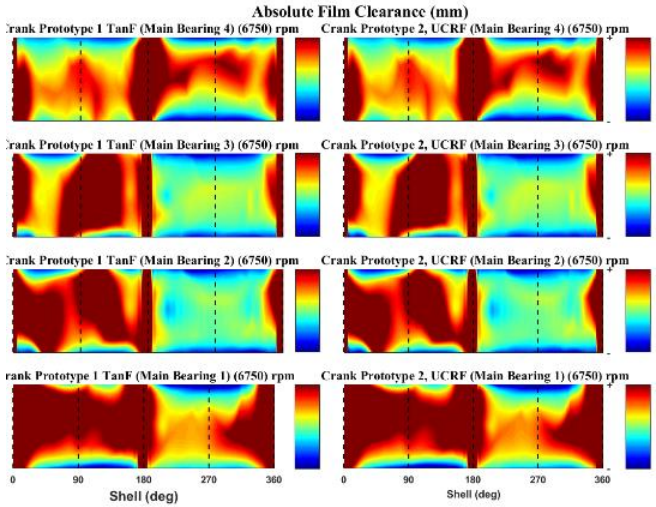
Excite Powerunit Analysis

- Flexible 3D EXCITE™ Powerunit
  - Bearing performance
  - Crankshaft durability
  - Load generation for cylinder block durability



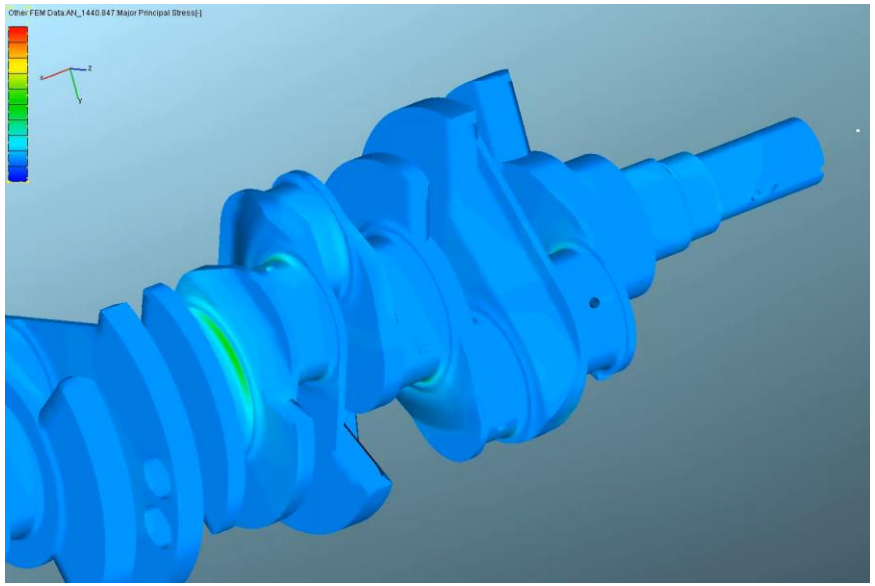




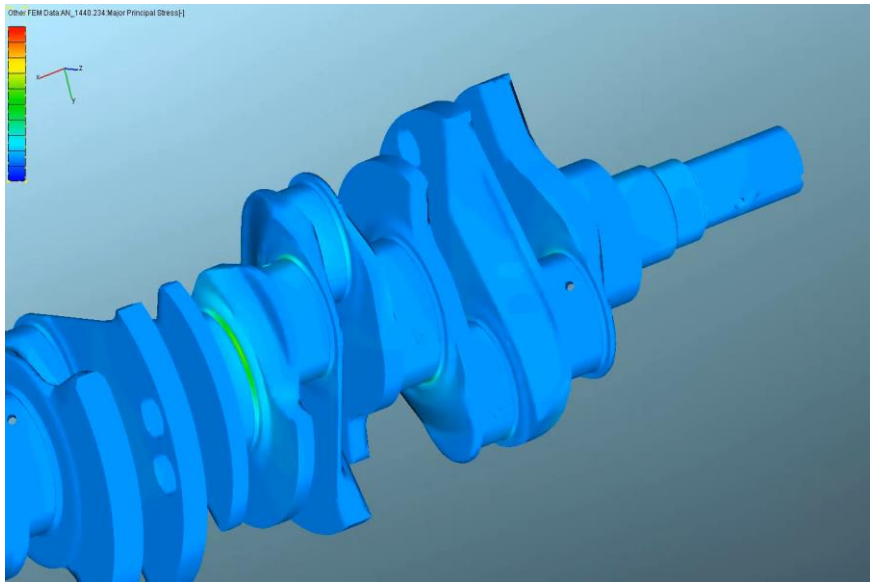


Excite Powerunit Analysis, (Cont'd.)

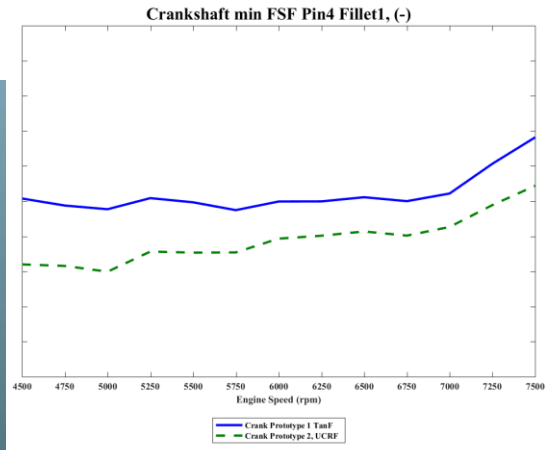
- Stress and fatigue analysis

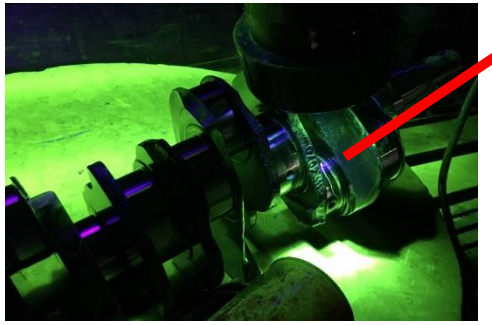


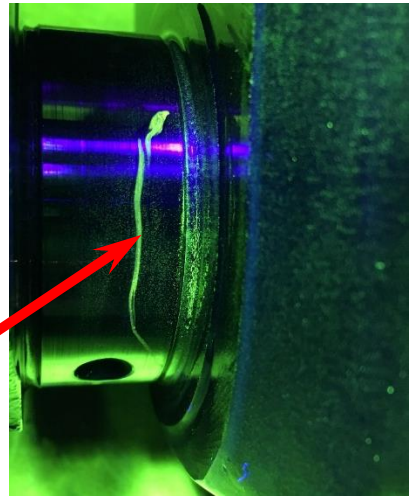
Prototype1-Tangential Fillet



Prototype2-Undercut, Rolled Fillet

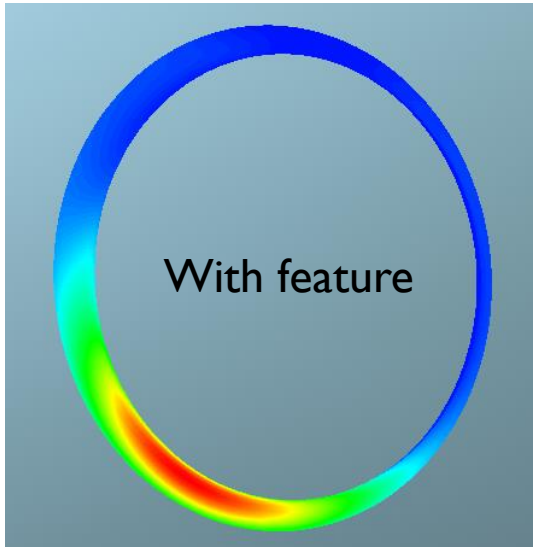


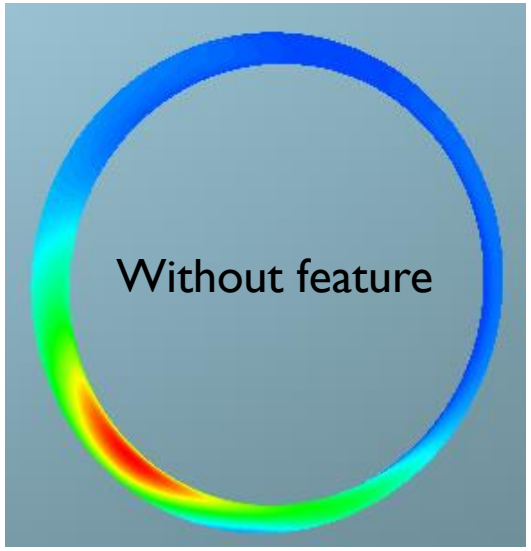


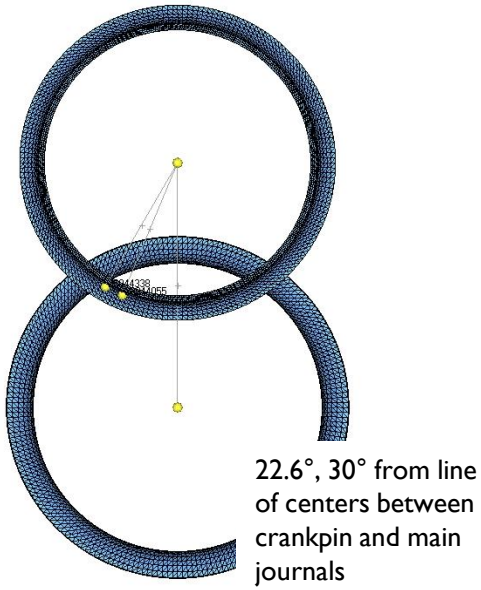


Ford High Performance Engine

- Fillet Fatigue Safety Factor Analysis
- Evaluated two alternatives to improve fatigue safety factor (FSF) in a crankpin fillet
  - First Alternative
    - Highest stress occurs at ~39deg ATC for cheek (web) with feature
    - Highest stress occurs at ~42deg ATC for cheek (web) without feature
    - Difference in Max Principal Stress is < 1%, so no difference in FSF
  - Second alternative (implemented)
    - Improvement of > 12% in FSF







Fillet Fatigue Safety Factor Analysis

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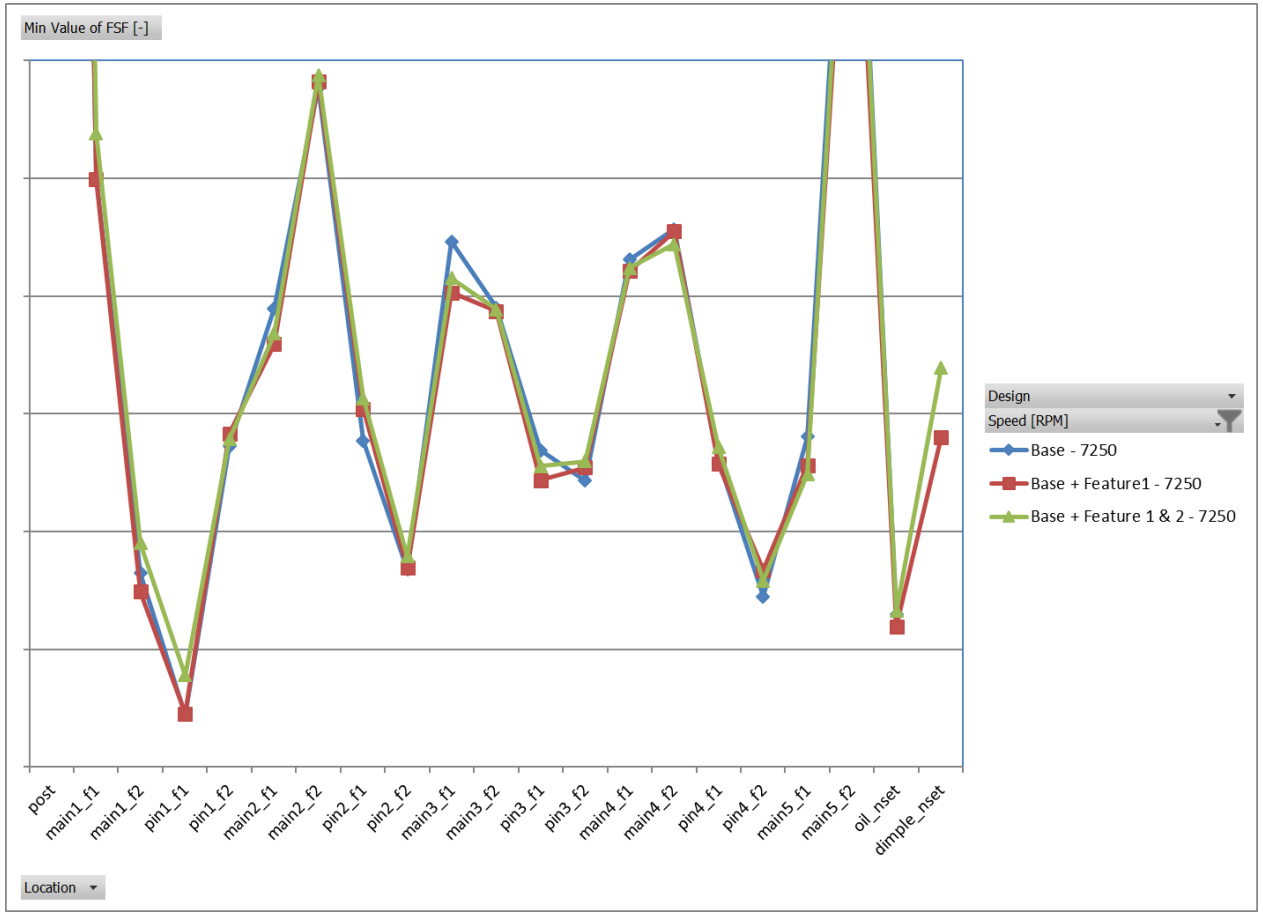
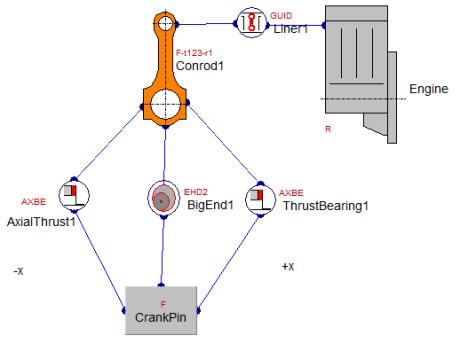
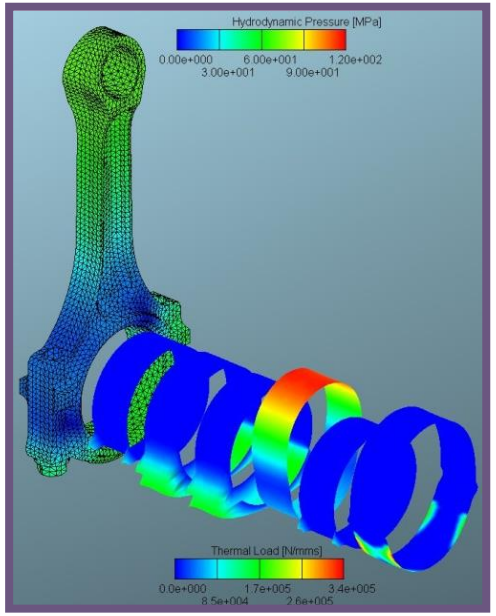


Connecting rod EHD analysis

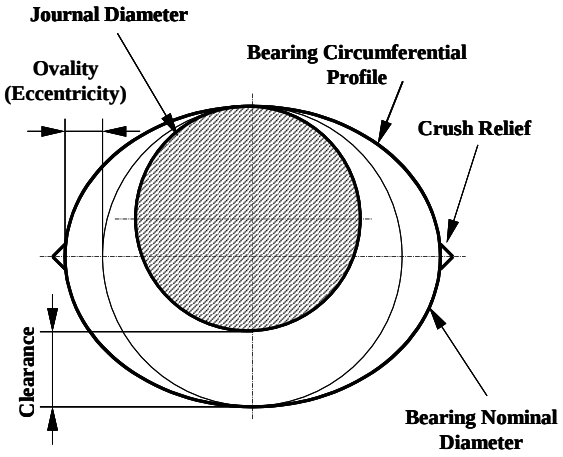
- High performance, high speed, V8 engine
- Model assumptions
  - Single cylinder
  - Flexible conrod/flexible crank pin
  - Bearing/shaft misalignment
  - Circumferential profile variations
  - Axial profile variations
  - Mass conserving bearing model, feeding oil hole, side leakage
  - Dynamic loads
  - Capable of assessing the influence of bearing housing shape on bearing system performance



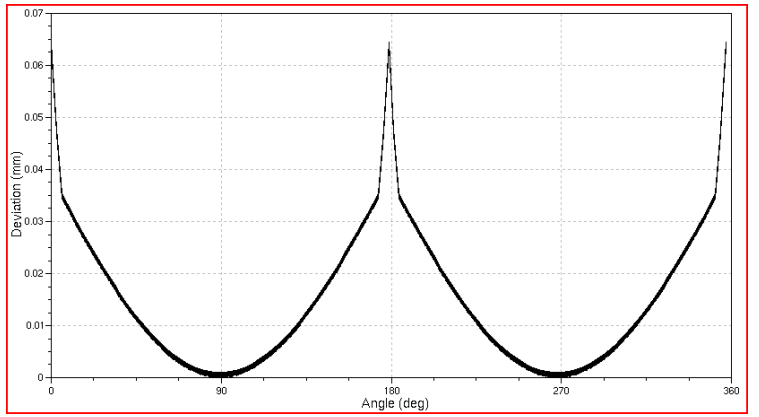


Connecting rod EHD analysis (Cont'd.)

- Able to assess influence of bearing shape on bearing performance
- Includes clearance, eccentricity, crush relief, journal shape

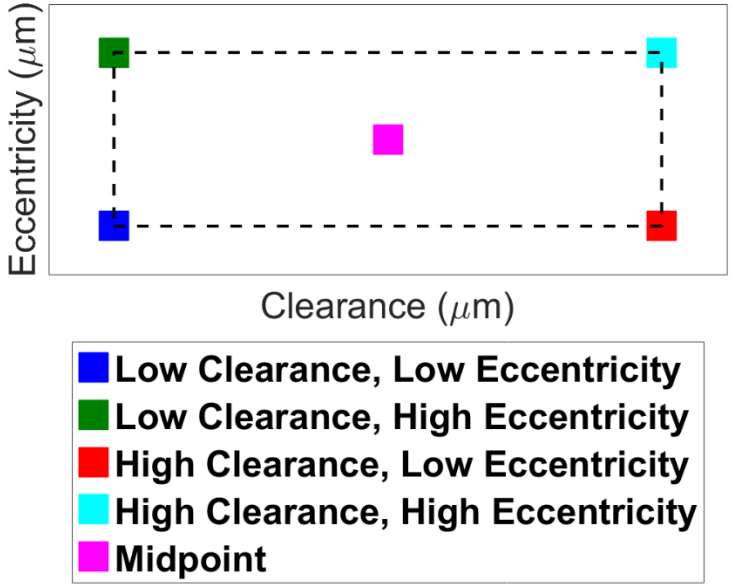


Definition of Bearing Clearance

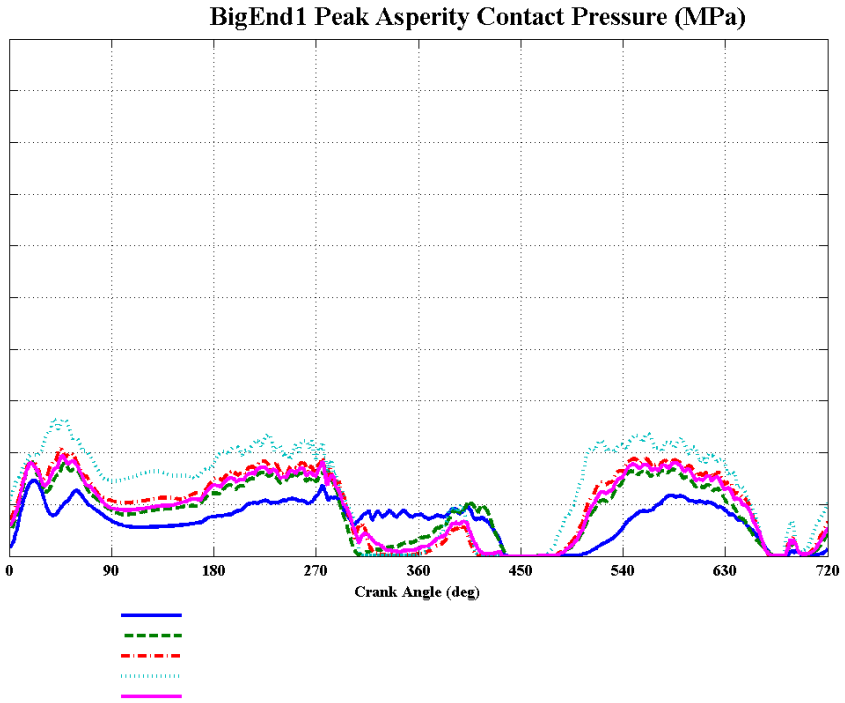


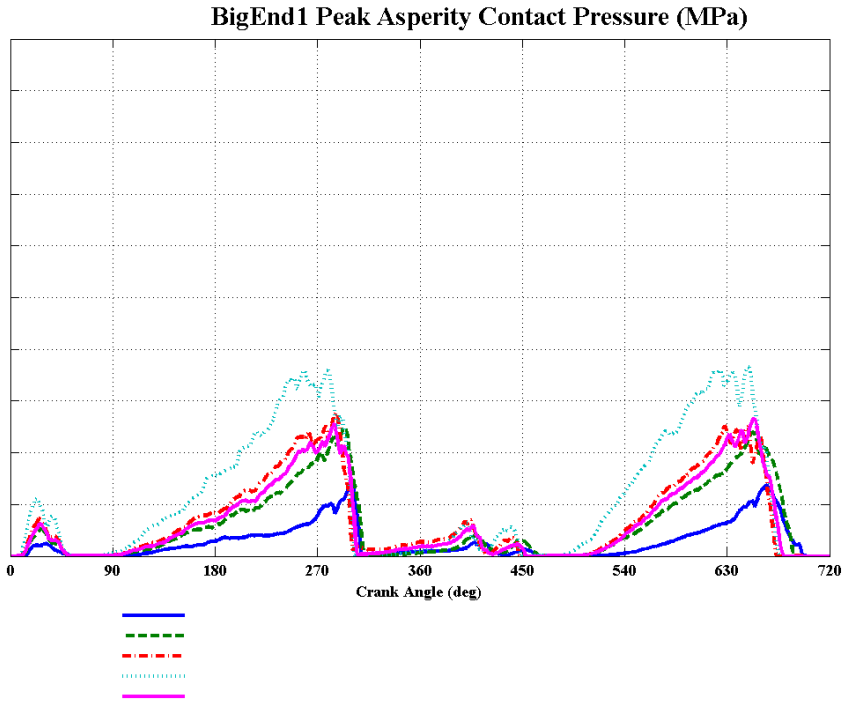
Connecting rod EHD analysis (Cont'd.)

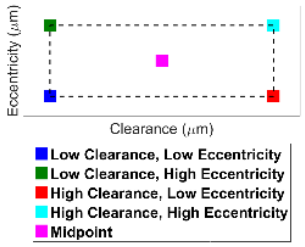
- Analysis conditions
  - Min, mean, max eccentricity
  - Min, mean, max clearance
  - 2000, 4750, 7500, 8000 rpm, WOT



Connecting rod EHD analysis results

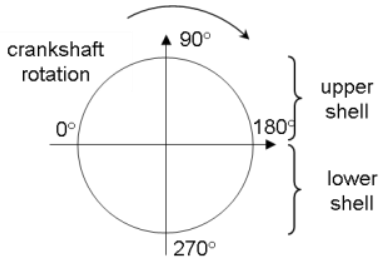






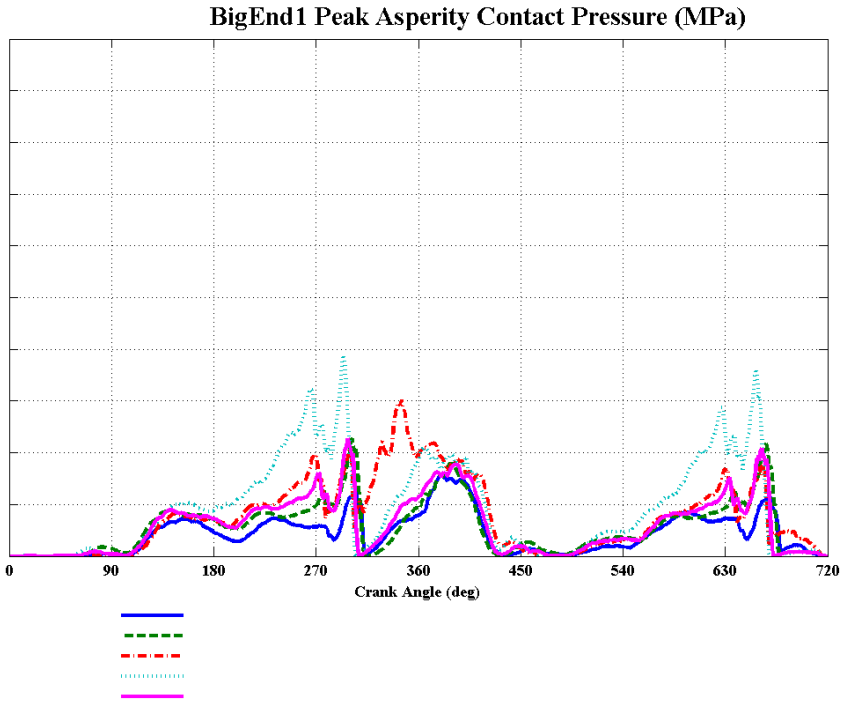
2000rpm

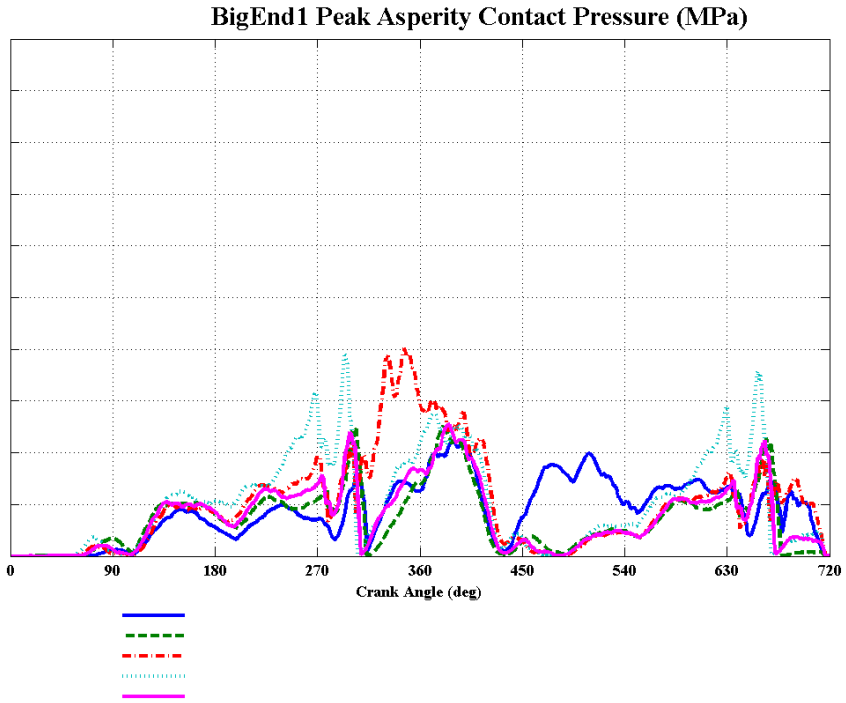
4750rpm

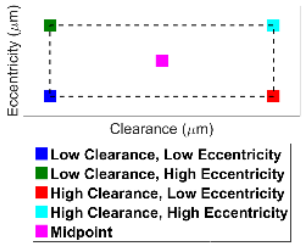


Total pressure increasing with speed

Connecting rod EHD analysis results



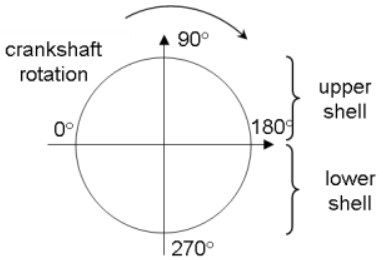




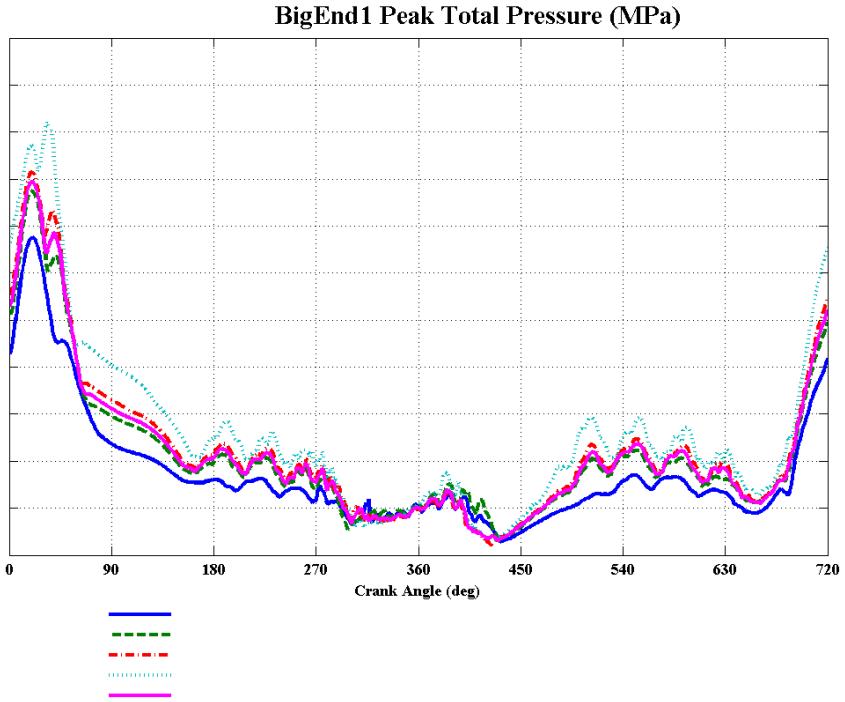
7500rpm

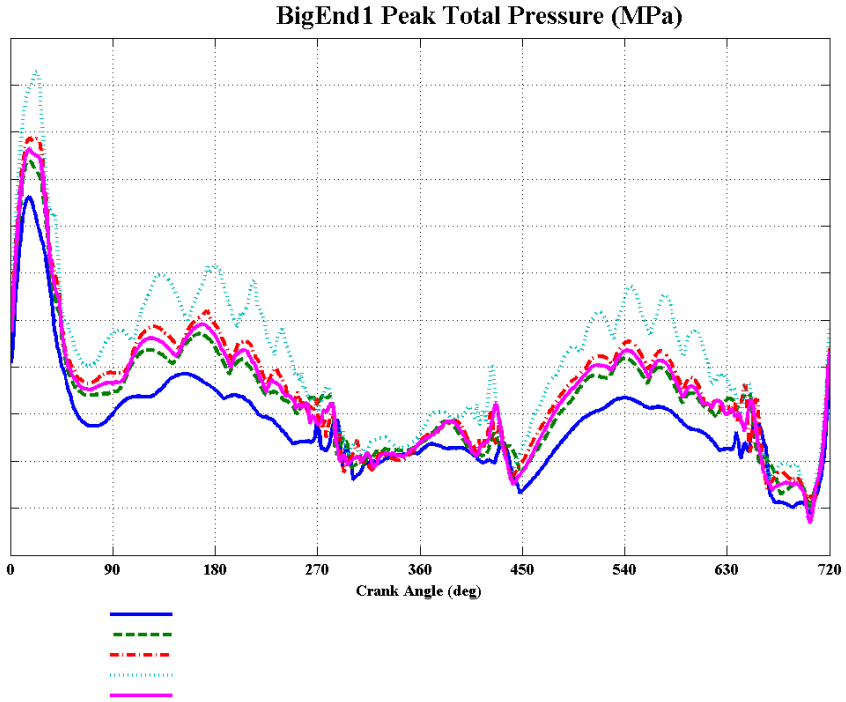
8000rpm

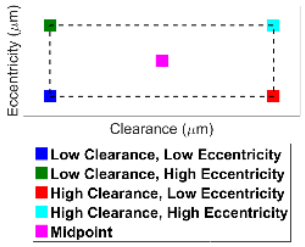
Total pressure increasing with speed



Connecting rod EHD analysis results



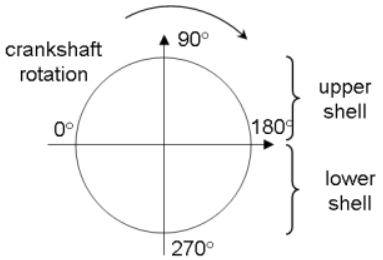




2000rpm

4750rpm

Total pressure increasing with speed



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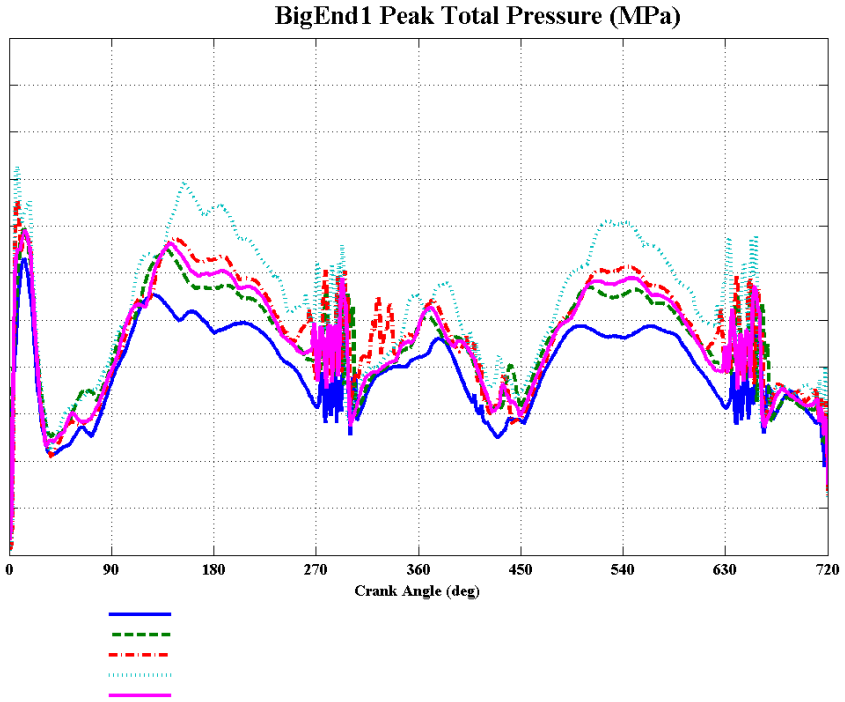
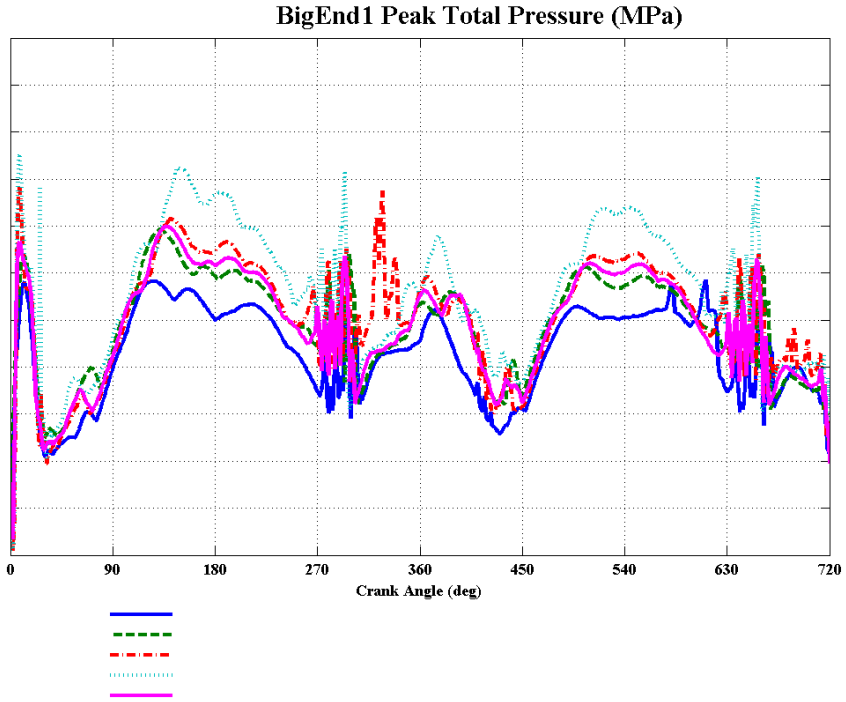
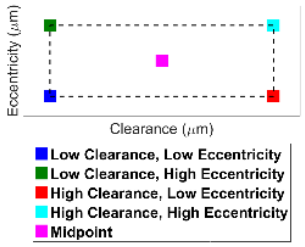


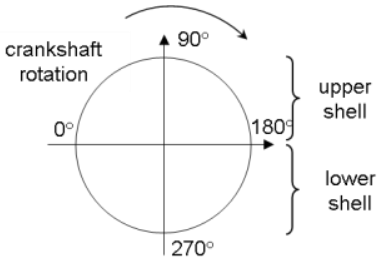




7500rpm

8000rpm

Total pressure increasing with speed



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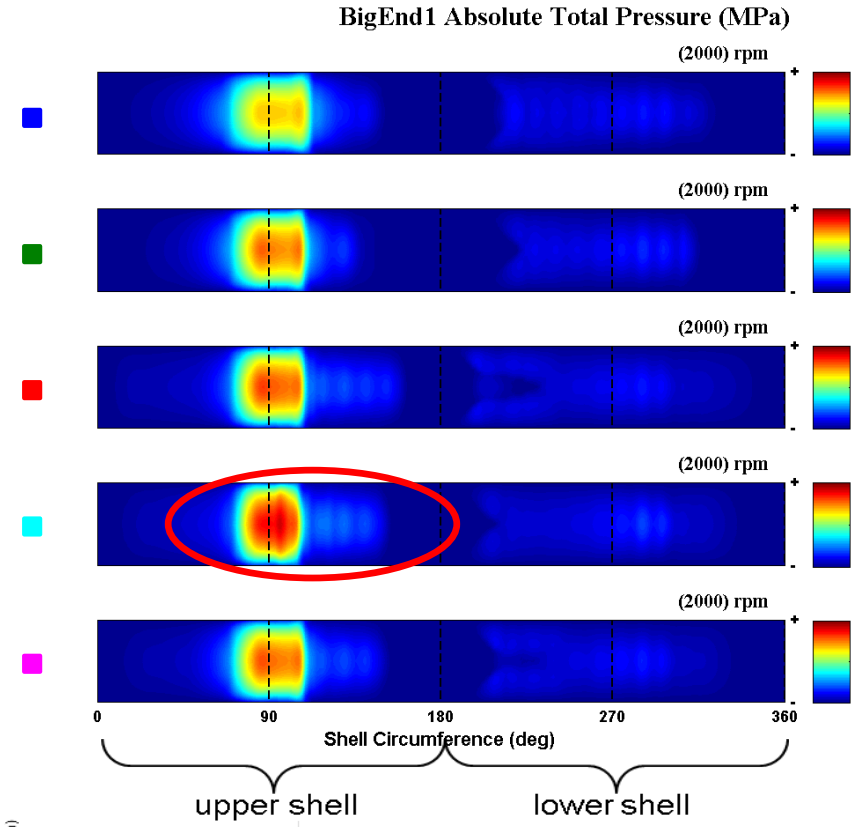
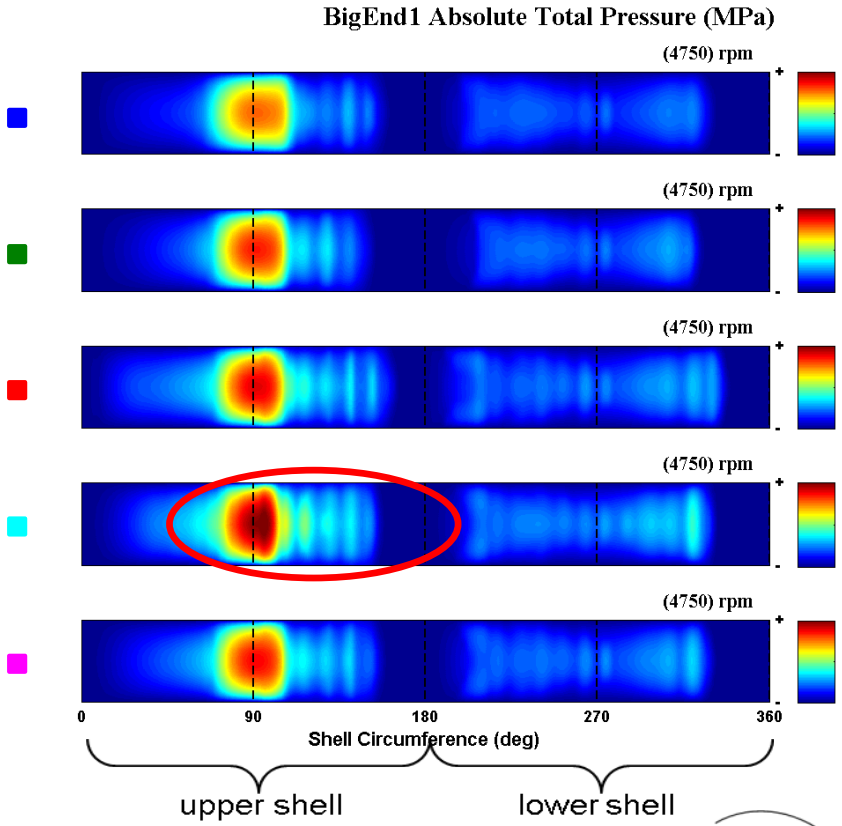
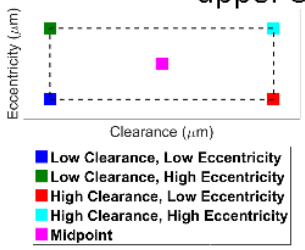


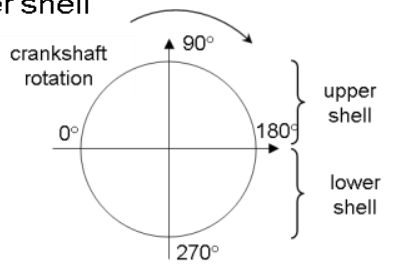




2000rpm

4750rpm

Total pressure increasing with speed



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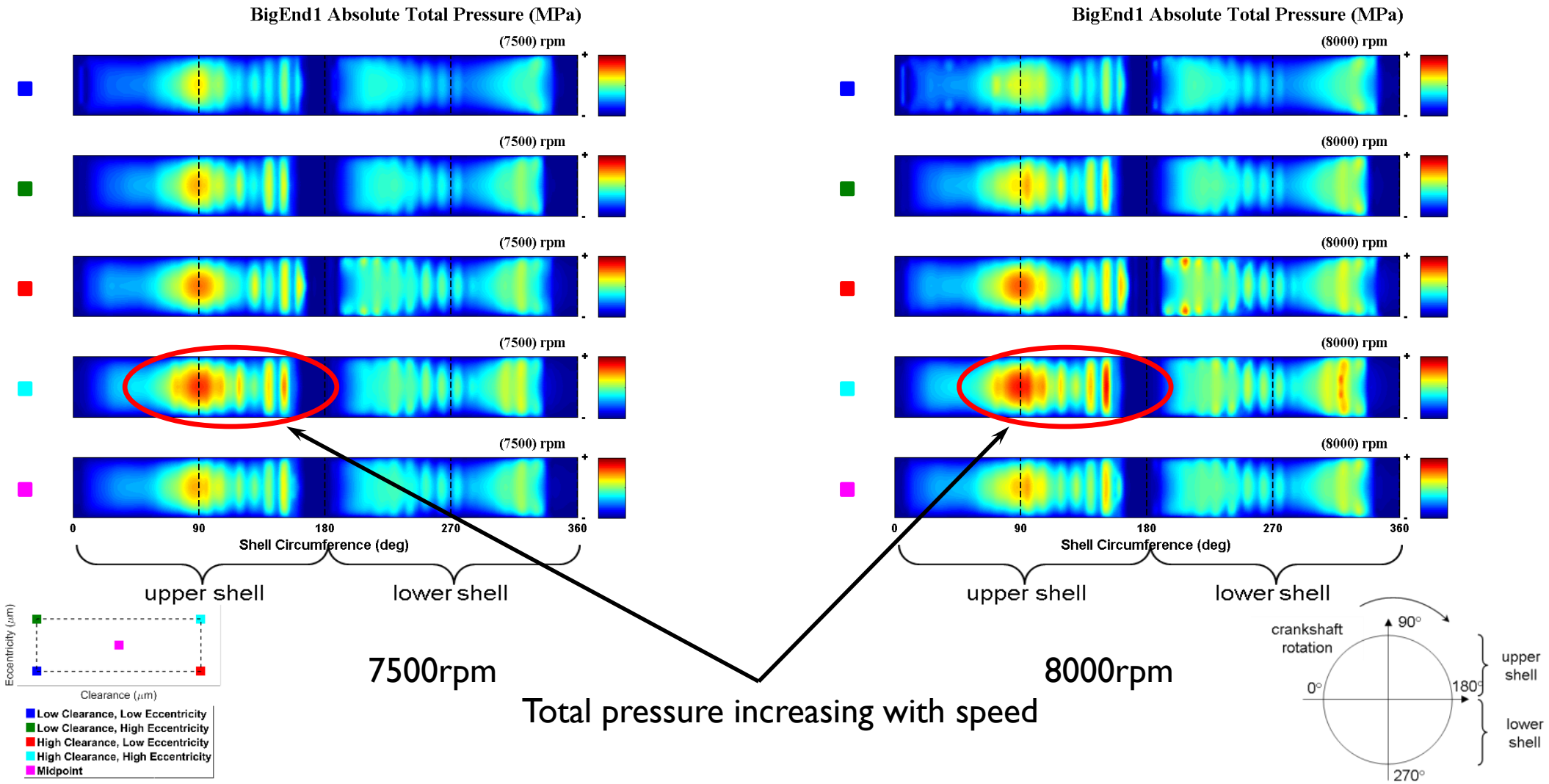

Conclusions

- EXCITE™ Designer and Powerunit are used during the design and development cycle
  - To evaluate design options
  - To evaluate fatigue life and bearing performance
  - To evaluate solutions if problems arise
- EXCITE™ Designer and Powerunit are used to analyze different components and systems
  - Bearing performance
  - Connecting rod performance
  - Crankshaft durability
  - Loads for cylinder block durability
- EXCITE™ Designer and Powerunit are integral to our design and development process both for production and high performance programs