Product Development Excellence through Modeling & Simulation

Machine-Ground Interaction Consortium

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Agenda

• The Product Development Challenge
• Caterpillar “Virtual Product Development”
• A Future Vision
From our Chairman & CEO

“Our customers are diverse, but all have something in common — they all expect the best from Caterpillar. They expect the best quality, the best performance, the best productivity and more than anything, they expect the best value for the price they pay. We've got our work cut out for us to deliver on these expectations. That’s why we have to set the bar high.”

Doug Oberhelman, Chairman & CEO

The Product Development Challenge

Time
- Product Introduction Rate

Cost
- Manufacturer
  - Development Cost
  - Production Cost
- Customer
  - Owning & Operating

Quality
- Customer Perception:
  - Performance
  - Reliability
  - Durability

Simulation at Caterpillar... Virtual Product Development

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Simulation at Caterpillar... Virtual Product Development

Insight Before Iron

VPD Applications – Machine Performance

Engine Speed

Metal plate

Time next

Worksite Productivity

Machine Performance

Manufacturing Quality

Component Durability

System Efficiency

Assembly Reliability
System Efficiency – Engine

Component Durability – Topology Optimization

Simulation at Caterpillar... Virtual Product Development

Insight Before Iron

- Manufacturing Quality
- Assemble Reliability
- Machine Performance
- Workplace Productivity
- System Efficiency

Oil Filter Support Bracket
- Original: welded fabrication
- Proposed: casting based on original

797F Mining Truck
C175-20 Engine

Final Castings
Durability Comparison
Simulation algorithm allowed Caterpillar to eliminate a “historic” need to straighten Medium Wheel Loader rear frame rails.

Optimal sequence – 3 rollers
15-10-9/1-3-2/11-16-12-13-14/5-6-7-8-4
Out-of-flat: 0.9 mm
Leg opening: 0.6 mm

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Virtual Validation

Optimize Design

Simulation Data Management

Core Model - Model Validation

Most Designs are Derivatives of Previous Designs
Simulation in Product Development

- Model Build
- Model Validation
- Optimize Design
- Virtual Validation
- Updated Model for New Content
- Simulation Data Management

Actionable Results...

- Rapid Quantitative Directional
- Fully Explore

- Accurate Physics
- Validated Simulation Model
- Correct Representation of Real Product Application

Min Performance Target

Predicted Performance for application population

Our Vocabulary Changes...
- We'll now record BFP, which stands for the 95% of our
  current values, and that 95% range, based on the
  simulation, will replace our performance target. We need a
  new design decision!
Simulation in Product Development

- Seamless
- Rapid
- Quantitative
- Directional
- Fully Explore

- 1x Single Simulation
- 10-100x Variability / UQ
- 1000x+ Multiple Design Alternatives

Porting is “Easy”
Weak Scaling is Challenging
Strong Scaling is REALLY HARD

Expert Analysts in weeks
Core Analysts in days
Designers in hours/min

Predictive Simulation
- Proper Physics
- Model Validation
- Model Realism
- Variability / UQ
- HPC

Simulation Embedded in Product Development
- Automatic Pre/Post Processing for everything that is not analyst “high-value add”
- Model Validation
- Variability / UQ
- HPC

Automated Design Evaluation with Real Time Feedback
- “Physics packaged for the designer”
- Runs automatically in real time as design is modified
- Highly robust simulation processes
- Automated error proofing
- Real time feedback on design alternatives ability to meet design requirements
- Leverage “Internet of Things” to achieve virtual verification / validation

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• Model Validation
• Model Realism
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Questions