AI-Driven Innovations for Steel Vehicle Structural Design

Reducing Weight, Enhancing Performance, and Lowering Costs with Advanced AI Solutions

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GREAT DESIGNS IN STEEL™

Why AI for Steel Automotive Structures?

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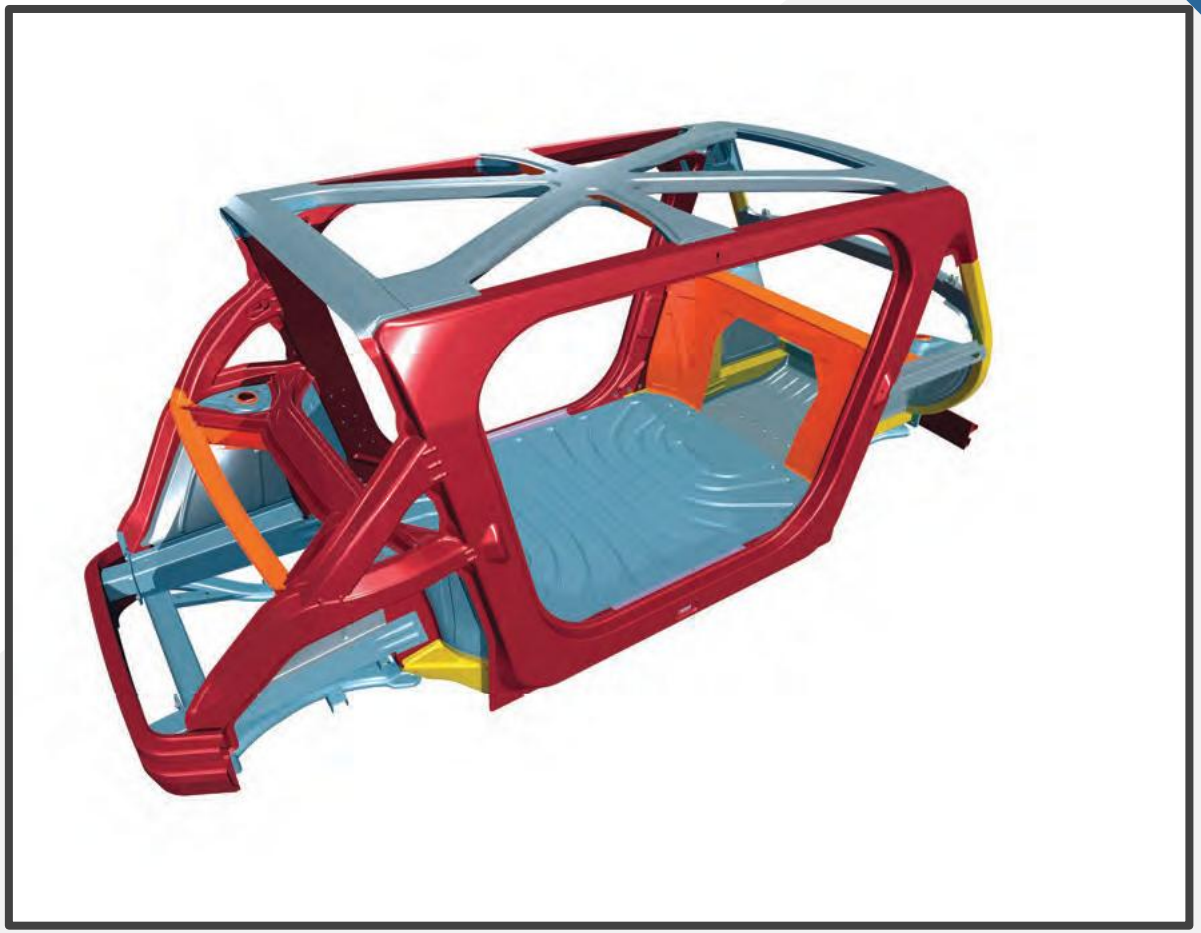
- Traditional steel design approach:
  - Labor-intensive manual iterations
  - High cost, lengthy cycles
  - Error-prone process and simplified models
  - Limited utilization of historical data
- AI-driven steel design approach:
  - Rapid automated optimization
  - Reduced design cycles and costs
  - High reliability and real-time adjustments
  - Maximized utilization of historical data



What can AI Achieve in Steel Design?

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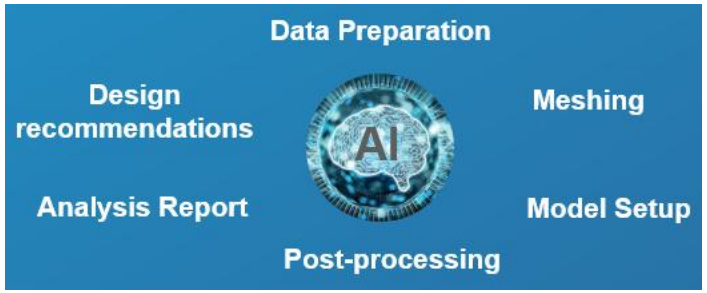
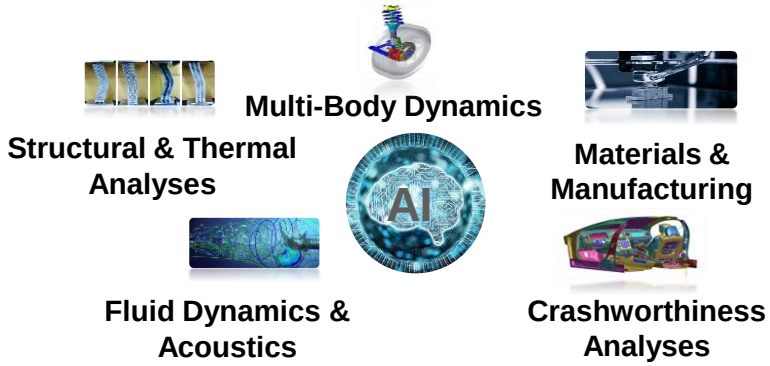
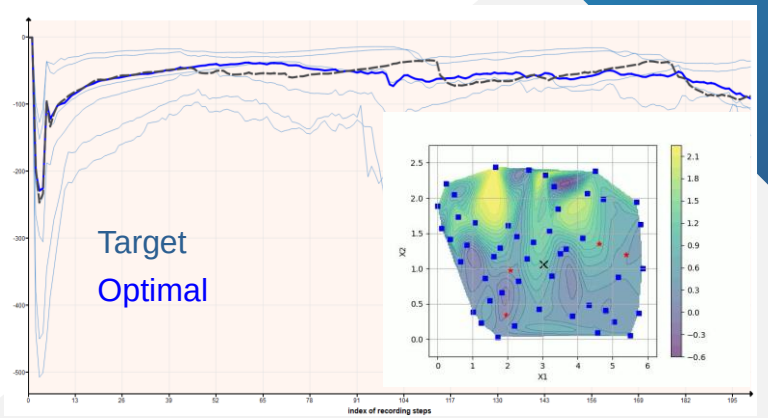
Automation of Design Process



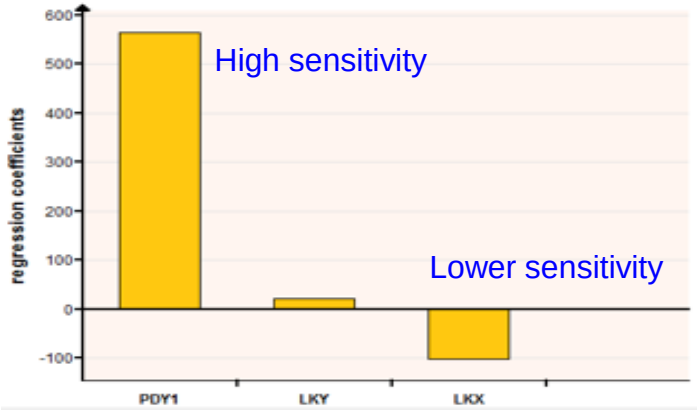
Integration of Multi-Domain Physics



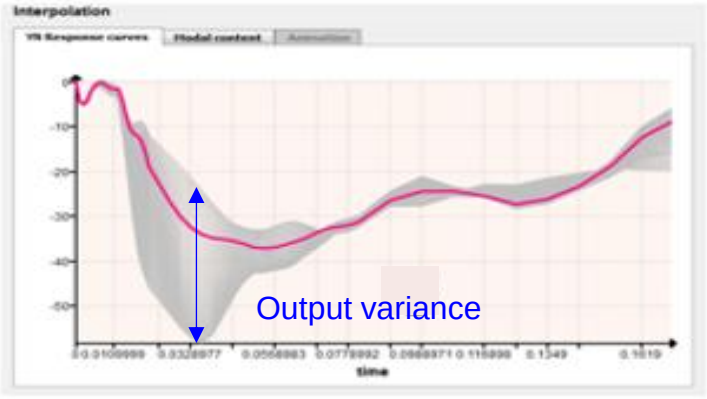
Adaptive DOE & Optimizations



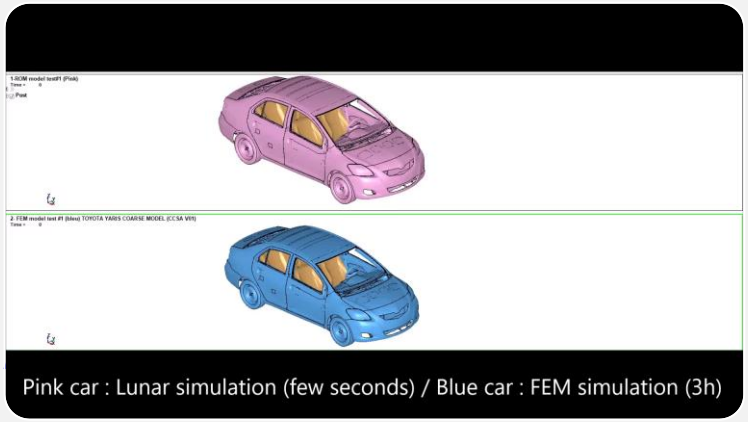
Enhanced Sensitivity Analysis



Reliability & Corridor Studies



Real-time Transient Animations and Predictions



Real-World Application Example – Safety Optimization

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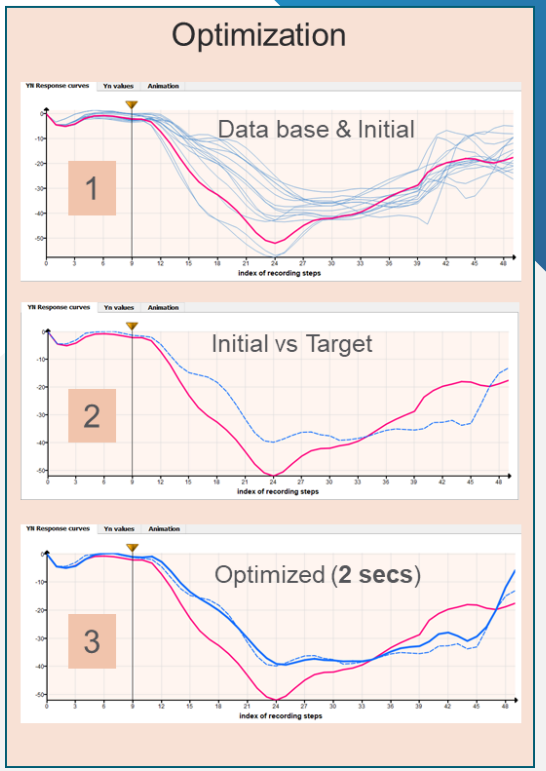
Challenge: Predict vehicle safety metrics (Thorax Compression and Pelvis Acceleration)

Input design variables:
- Deceleration
- Braking speed
- Airbag properties

Output:
- Safety performance metrics

→ AI Trained ML model →

Predict / optimize:
- Thorax compression
- Pelvis acceleration
- Animation prediction with field data

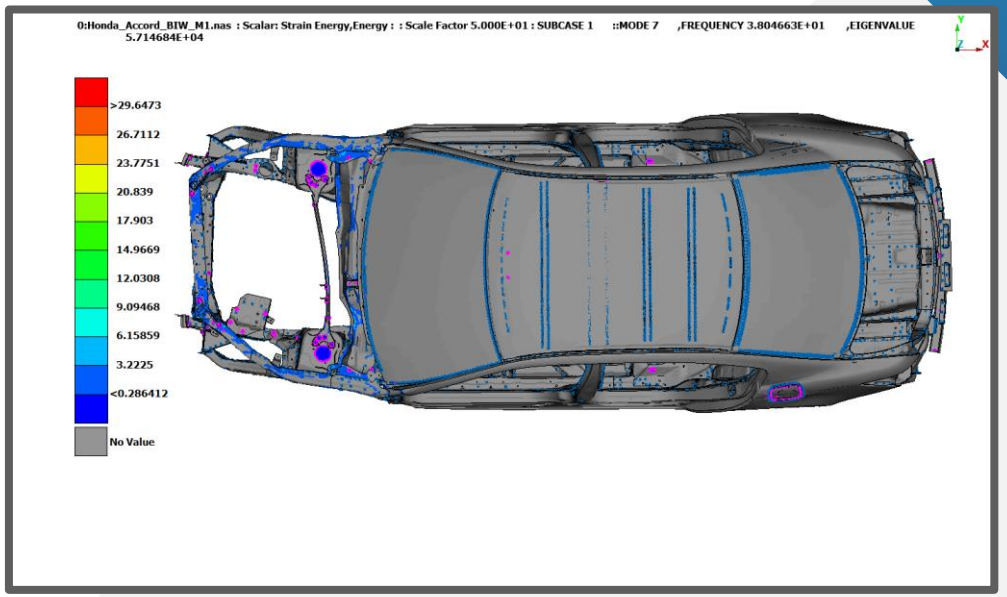


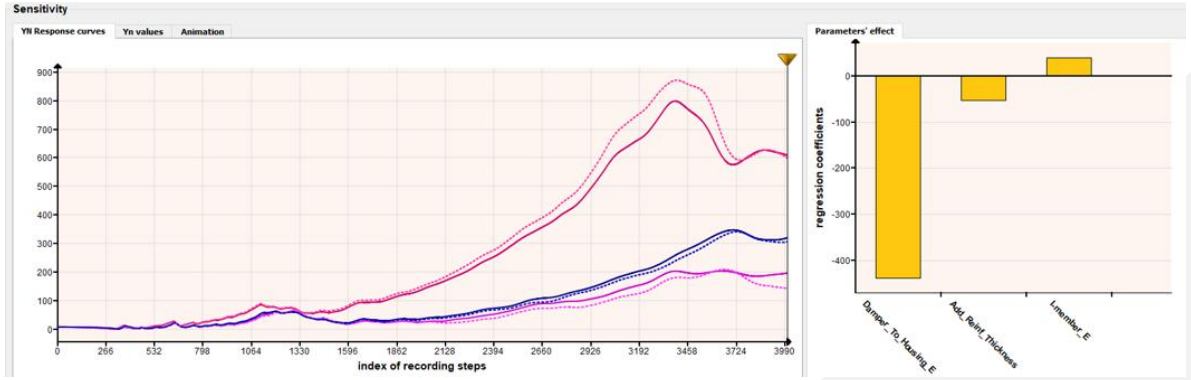
- AI Approach:
  - Reduced-order modeling (ROM) with limited simulation runs (15 training runs)
  - Drastic reduction in prediction times (from 1 hour to 1 second)
- Benefit:
  - Rapid iteration leads to superior safety performance optimization, significantly reducing cost and design time

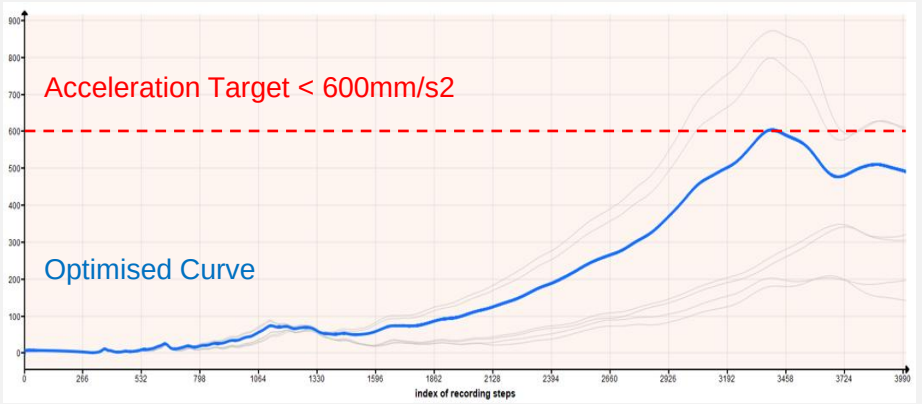
Real-World Application Example – Structural NVH Optimization

Challenge: Optimize front-end lateral bending and point mobility to reduce acceleration peaks

- AI Solution:
  - ROM developed from 10 Nastran simulations
  - Parametric sensitivity analysis and design optimization in 5 minutes
- Results:
  - Accurate predictions within seconds; optimal design performance achieved rapidly







Key Takeaways & Summary

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- **AI Transforms Structural Design:** AI accelerates design, reduces costs, and improves quality by automating tasks, enabling faster, more reliable results.
- **Improved Efficiency:** AI speeds up iterations and optimizations, shortening development cycles and cutting costs—essential in the fast-moving automotive industry.
- **Data-Driven Decisions:** Real-time data and design learnings ensure higher accuracy and better decision-making throughout the design process.
- **The Future of Engineering:** AI is reshaping structural engineering, turning engineers into AI application specialists, and pushing performance and sustainability.
- **Stay Competitive with AI:** Adopting AI isn't just about keeping up—it's about leading the way in innovation, competitiveness, and sustainability.

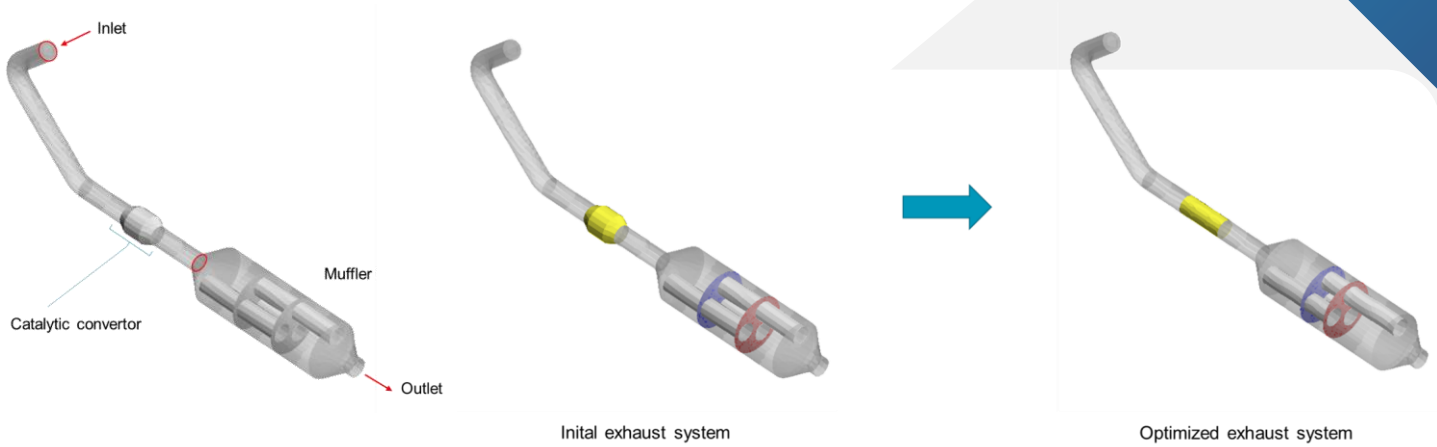
Act Now: Embrace AI-driven solutions to revolutionize your vehicle structural designs

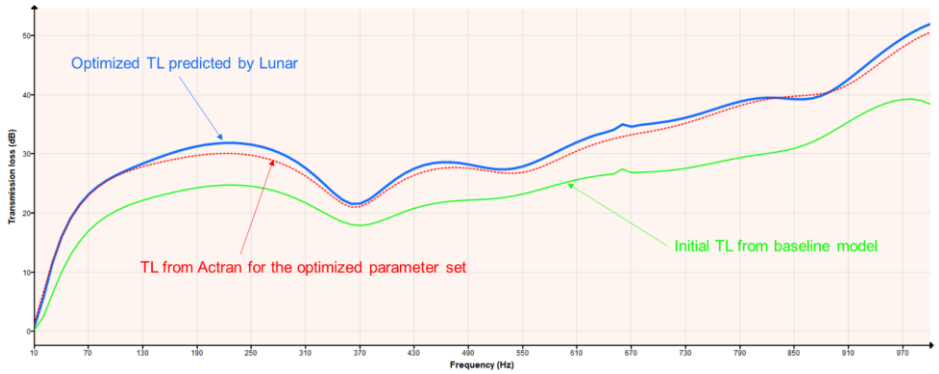
Backup slides

Real-World Application Example – Geometric Optimization

Challenge: Maximizing sound transmission loss across the frequency spectrum ensures quieter operation

- AI Solution:
  - Utilized acoustic simulations combined with Reduced-Order Modeling (ROM) for rapid evaluation.
  - AI rapidly identifies optimal geometric configurations for mufflers and catalytic converters without extensive physical trials.
- Benefits:
  - Accelerated optimization cycle, significantly cutting design time.
  - Achieved enhanced sound attenuation and compliance with noise standards efficiently.





Real-World Application Example – Crash Structure Optimization

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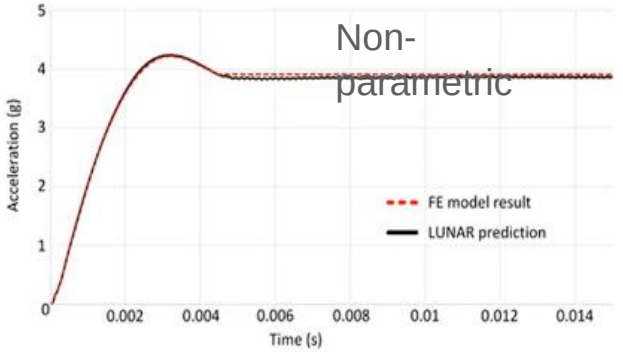
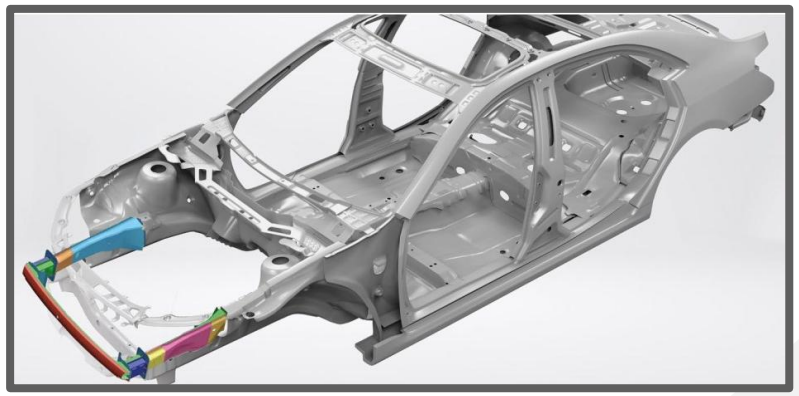
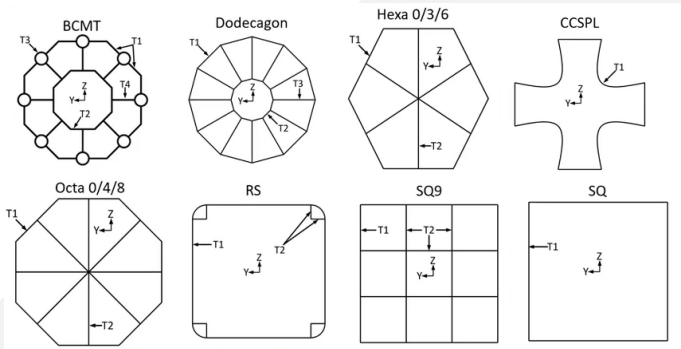
Challenge: Identifying optimal designs for occupant safety by controlling structural deformation, acceleration, and impact forces

- AI Solution:
  - Developed Reduced-Order Models (ROM) to analyze 12 complex structural geometries.
  - Automated optimization evaluated thousands of design scenarios, requiring only 1,500 simulations instead of the typical 15,000 for full FEM optimizations.
  - Enabled accurate predictions of critical performance metrics like maximum structural loading and acceleration with less than 5% average error.
- Benefits:
  - Quickly pinpointed optimal crash structure designs, significantly reducing analysis time and cost.
  - Demonstrated clear performance advantages of innovative hexagonal crash can designs.

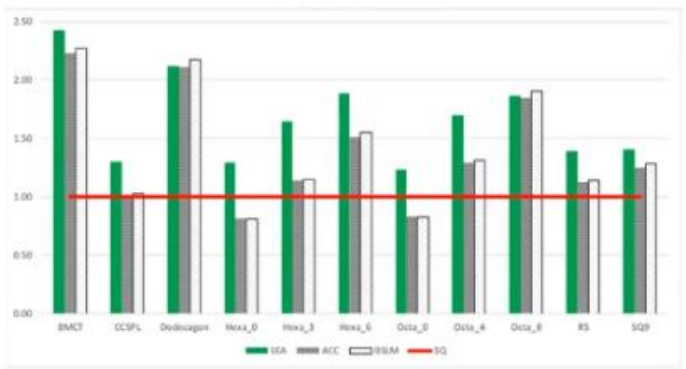


AI Predicted and FEA calculated acceleration curves





Cross section designs



Comparison of structural designs to the standard squared design (red line)

Real-World Application Example – Multibody Dynamics

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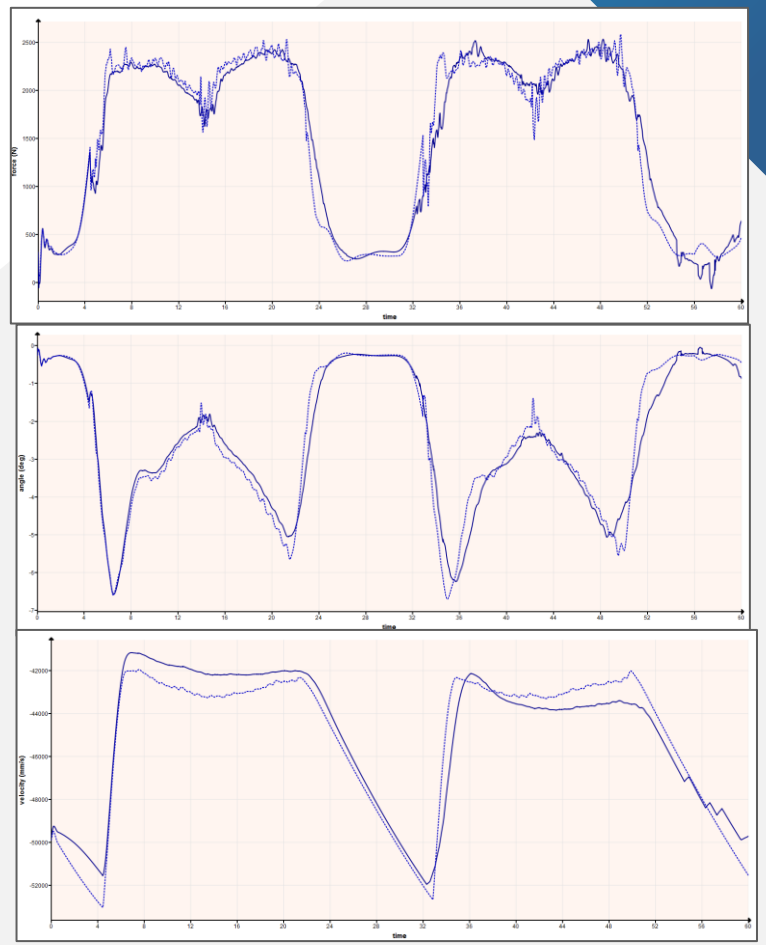
Challenge: Quickly predict handling metrics for different tire properties

Input design variables:
- Tire-road lateral friction coefficient
- Stiffness scale factors

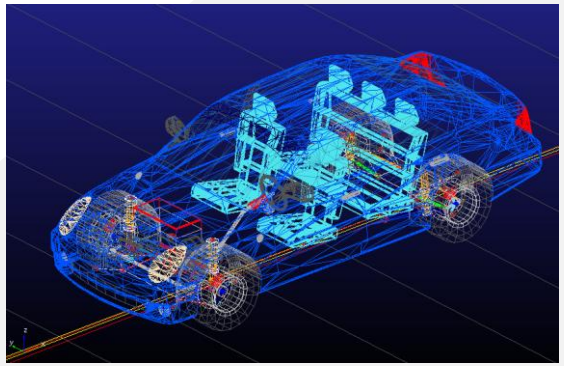
Output:
- Full-vehicle handling metrics

→ Trained ML model →

Predict / optimize:
- Front tire lateral slip, force
- Longitudinal velocity



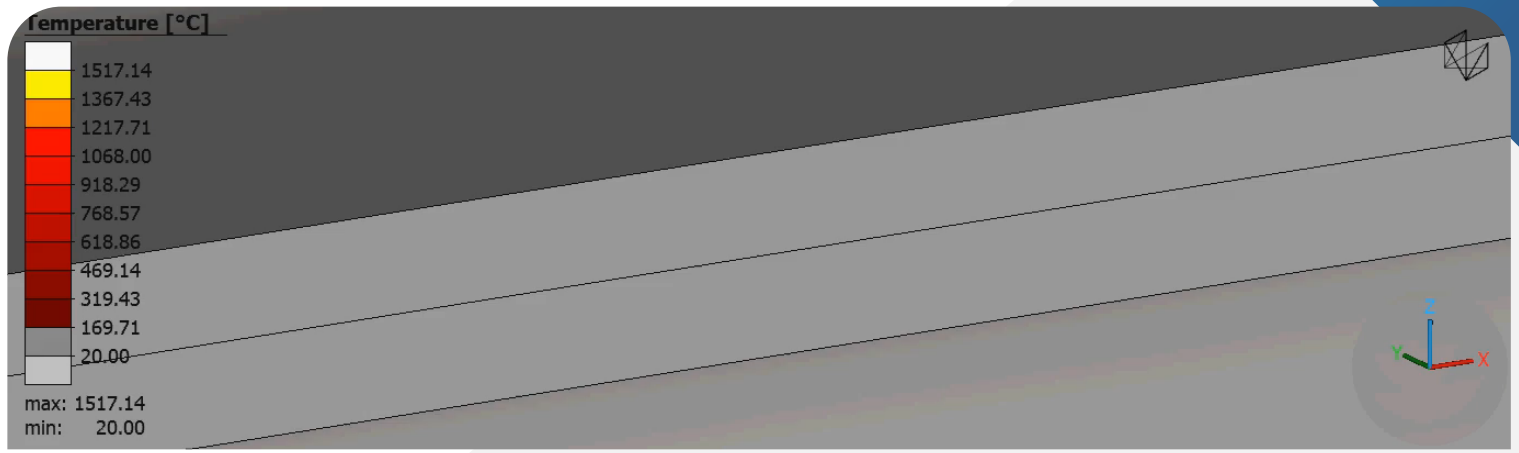
- AI Approach:
  - Reduced-order modeling (ROM) with limited Adams runs (15 training runs)
  - Drastic reduction in prediction times (from 1 hour to 1 second)
- Benefit:
  - Accurate prediction of the lap times.
  - Optimization of the tire properties in 5 minutes

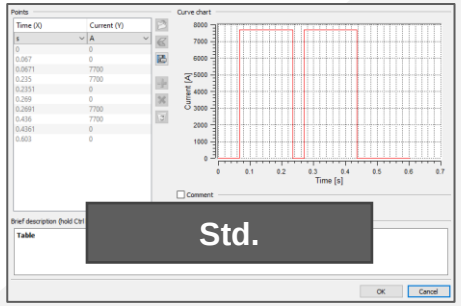


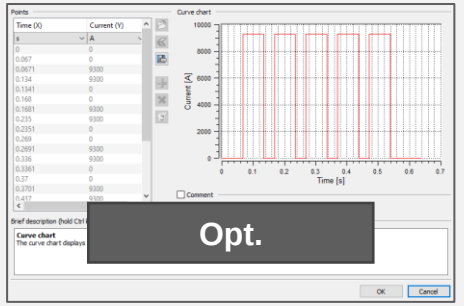
Real-World Application Example: Resistance Spot Welding Optimization

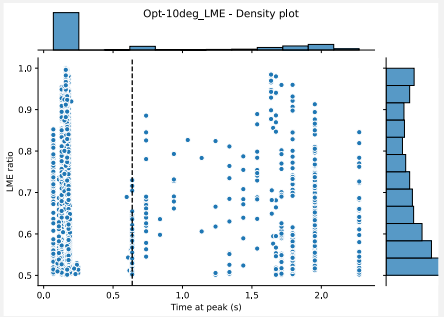
Challenge: Extensive manual testing for RSW schedules (material compatibility, weld quality)

- AI Solution:
  - Predictive simulations to create optimal welding schedules
  - Reduced physical testing, automated optimization of welding parameters
- Outcome:
  - Improved weld reliability and substantial reduction in testing costs and time.









Real-World Application Example – Defect Detectio

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Objective: Quickly and accurately verify cast metal parts to detect defects such as blowholes, pinholes, and burrs

Source: https://www.kaggle.com/ravirajsinh45/real-life-industrial-dataset-of-casting-product

- AI-Based Approach:
  - Implemented image processing on a small database (<500 images).
  - AI algorithms automatically extract critical image features and classify parts as "valid" or "defective.“
- Benefits:
  - Achieved 100% inspection accuracy with minimal image samples (as few as 123 images).
  - Dramatically reduced human inspection effort and time, significantly enhancing manufacturing efficiency.