Strain Rate Characterization of Advanced High Strength Steels

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Acknowledgements

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Purpose of Work

- **Support weight reduction in vehicles by more efficient use of high strength materials**
  - **Improve material characterization methods for loading conditions characteristic of automotive crash**
  - **Improve predictive capability of computational models and tools for automotive crash**
  - **Validate developments for structures of increased complexity**

Supporting Goals of the Office of Vehicle Technologies

- **Improve fuel efficiency of vehicles by weight reduction**
- **Weight reduction is enabled by increased use of high strength materials and design optimization**
  - **Reduction in structural redundancy (i.e. mass) requires more aggressive use of the available structural materials**
- **Understanding of material and structural performance is essential for efficient design**
  - **Crash performance is the limiting design factor**
  - **New materials do not have design history available for conventional automotive materials (e.g. mild steel)**
  - **This lack of knowledge is compensated by increasing safety margins (e.g. cross section) which increases vehicle weight**

Barriers

- **Industry Consensus**
  - **The AHSS performance in crash cannot be determined based on conventional, quasi-static tests**
  - **Characterization of material for impact is not standardized**
  - **Modeling technology is not adequate for aggressive weight reduction**
- **Gap exists in the fundamental understanding and the predicting capability for AHSS in crash**
  - **This gap is shared by other high strength materials, as well**
  - **What is the range of strain rates in impact?**
  - **What kinds of tests do we need?**
  - **What are the limitations of current modeling and testing technologies?**

Approach

- **To improve crash properties characterization and validation**
  - **Focus on advanced high strength steels**
  - **Develop tests to assist in development of better material and structural models**
  - **Provide instrumented crush testing of increasingly complicated structures to validate/refine model improvements**

- **To improve modeling**
  - **Determine high strain rate properties for steels currently used or anticipated to be used in automotive structures**
  - **Refine material models to better represent material behavior**
  - **Refine FEA modeling approaches**
  - **Develop advanced analytical tools to compare FEM simulations and experiments**

Performance Measures and Accomplishments

- **Developed tests on three different length scales of crash**

  A: Uniaxial tension in intermediate strain rate regime

  - Base material properties

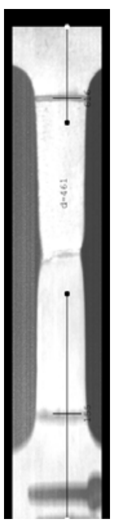
  B: Off-axis compression test for crash bending

  - Basic energy absorption mechanism in crash

  C: Constant velocity component crush test

  - Structural performance

Length scale



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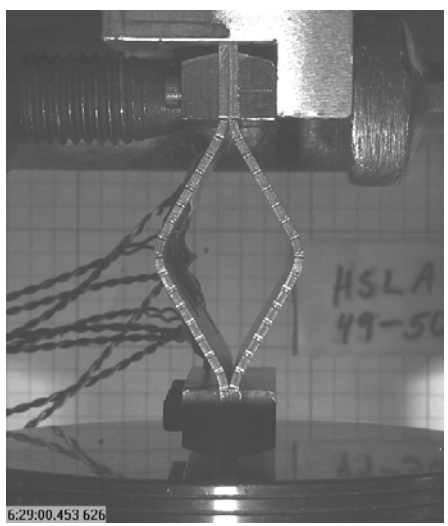

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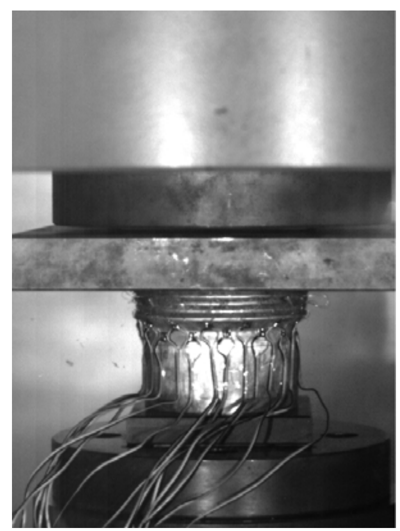

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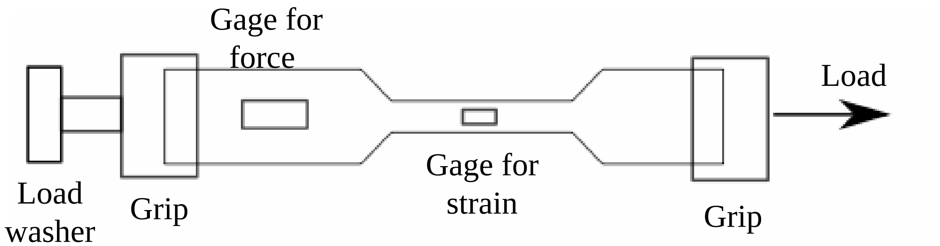
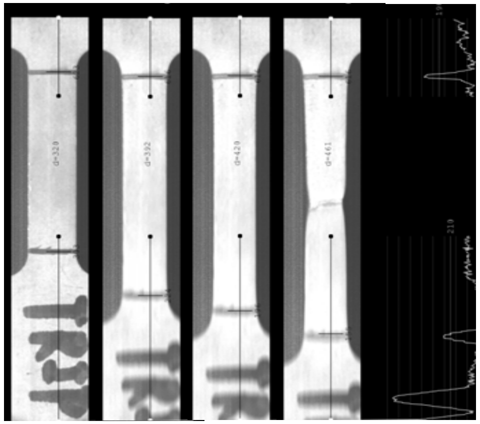
Tension Test Development for Sub-Hopkinson Rates Regime

- **Elimination of ringing in the system is the most challenging task**
- **Strain gage in extended specimen tab section is used as one force data measurement source**

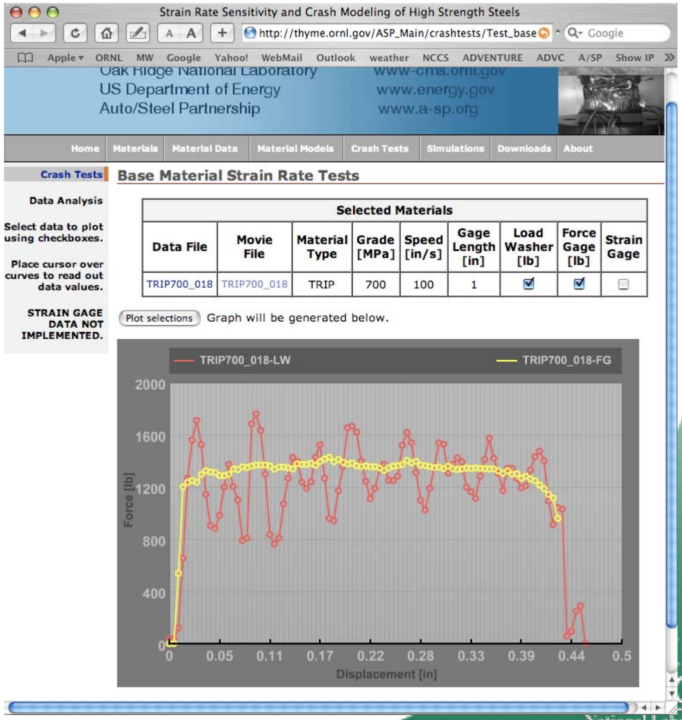


- **Data is measured from multiple sources and shared with project participants over www**

Optical strain measurement

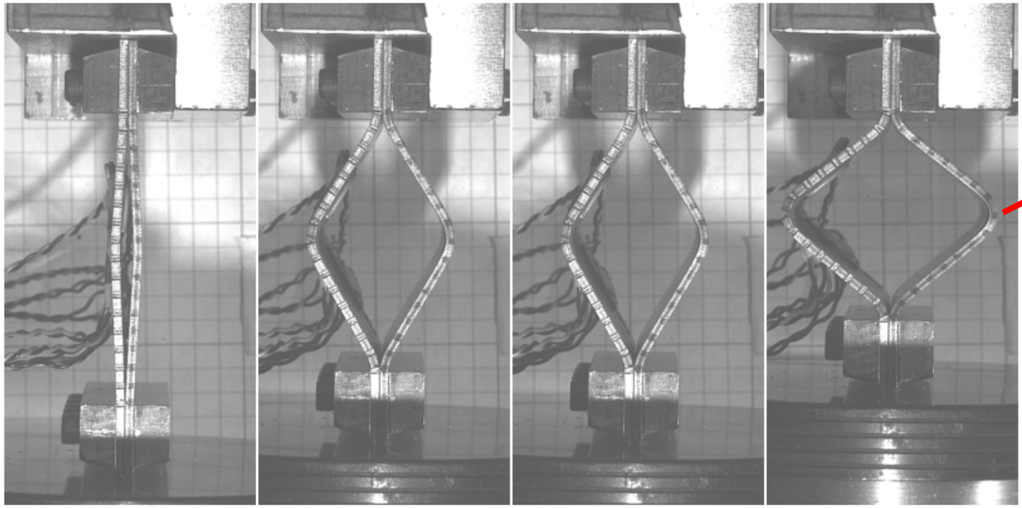


Data analysis and distribution

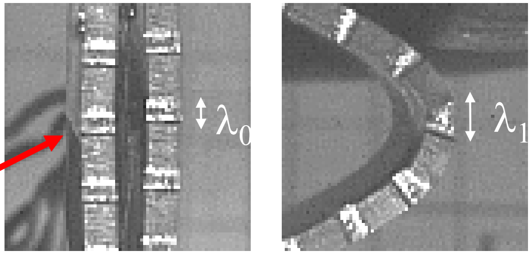


Double Plate Crush Test for Plastic Compression Bending

- **Plastic fold formation is the basic crash energy dissipation mechanism**



Multiple measurements for verification of data

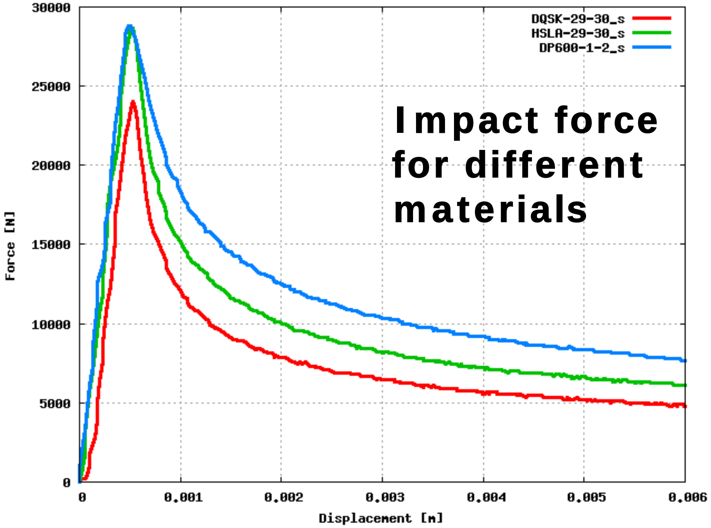


Contact measurements:

- – **Force, Displacement, Strain**

Optical measurements:

- – **Moment, Curvature, Strain**

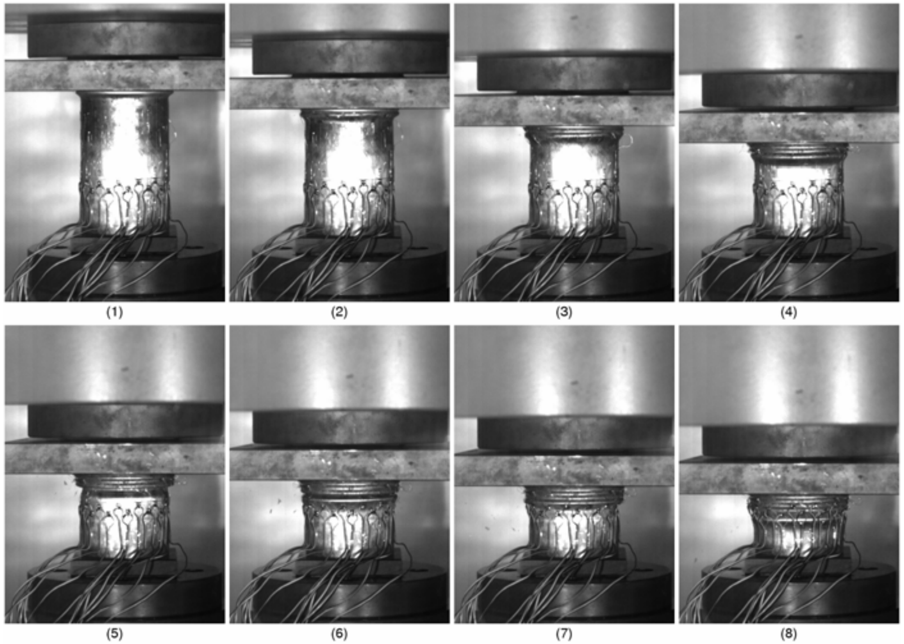


Advantages:

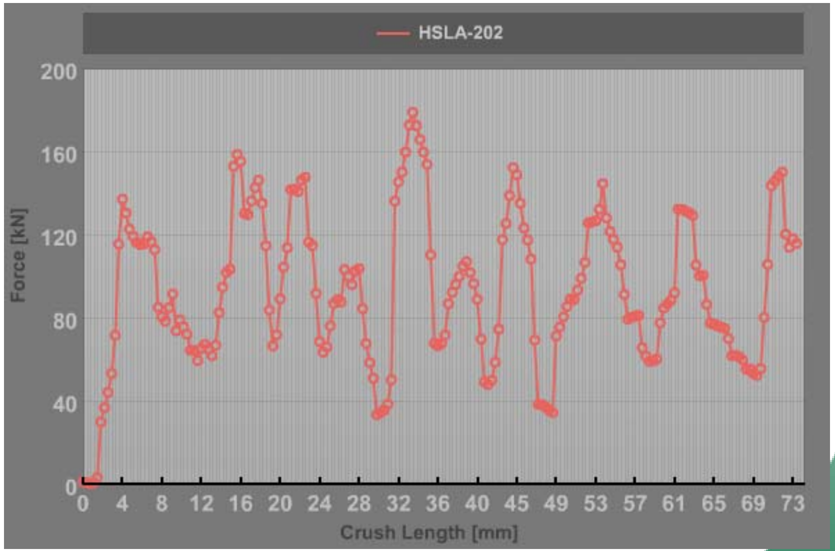
- **Low force**
- **Stable gage**
- **Semi-analytical model**

Constant Velocity Crush Test

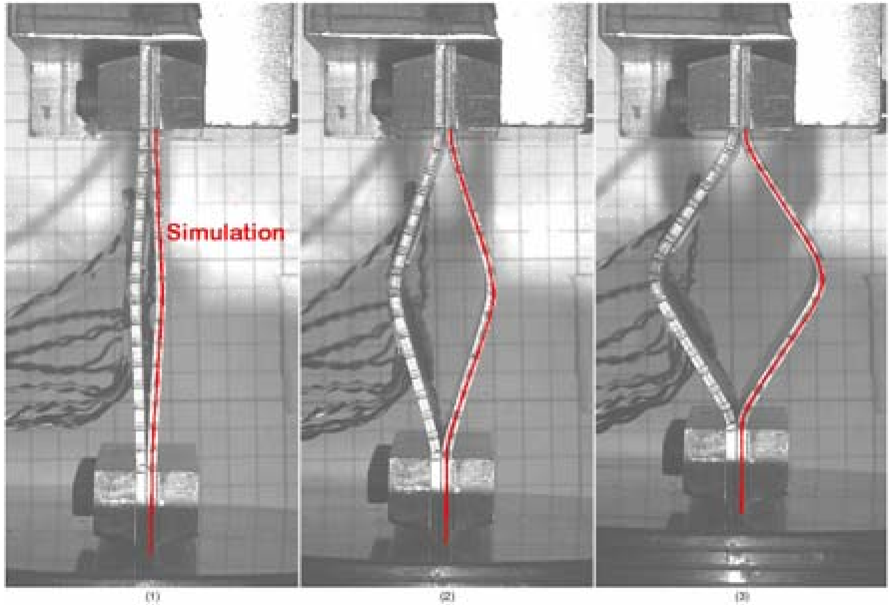
- **Objective: Investigate crush folding formation during crush at different speeds**
  - **Multiple strain gages around folds used to investigate fold geometry**
  - **Results used for crashworthiness characterization of materials and macro-scale crash model verification**



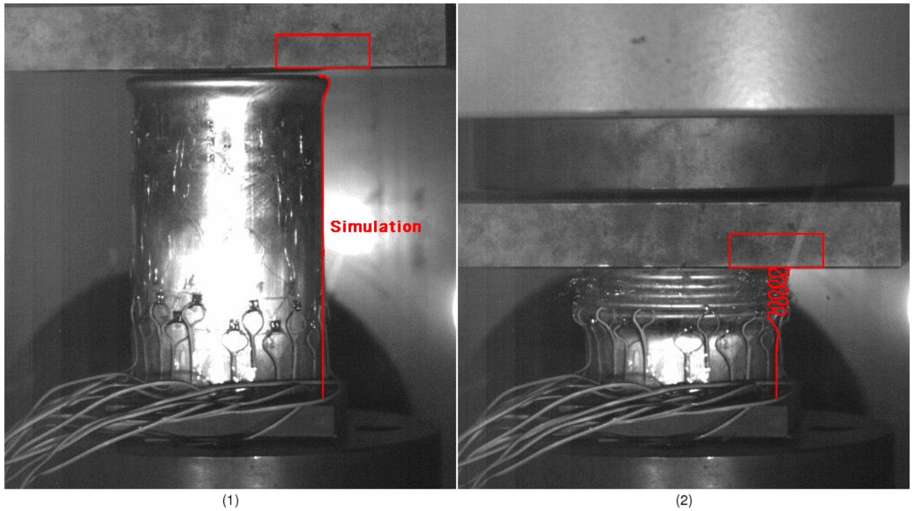
HSLA 340 4m/s crush

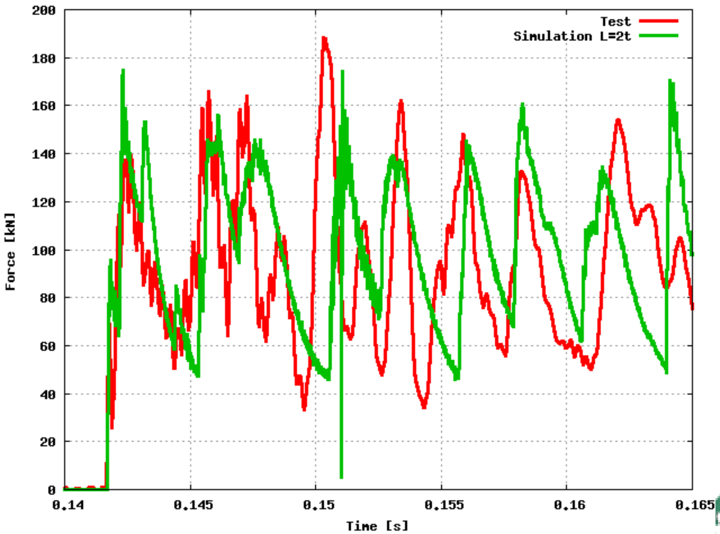


Modeling of Impact in AHSS Structures



- **Optimal modeling approaches are determined at the scale of single fold (double plate test) and component (tube) tests**
- **Accuracy for different modeling approaches is verified against experiments**
- **Local (fold) and global (force) characteristics are compared**

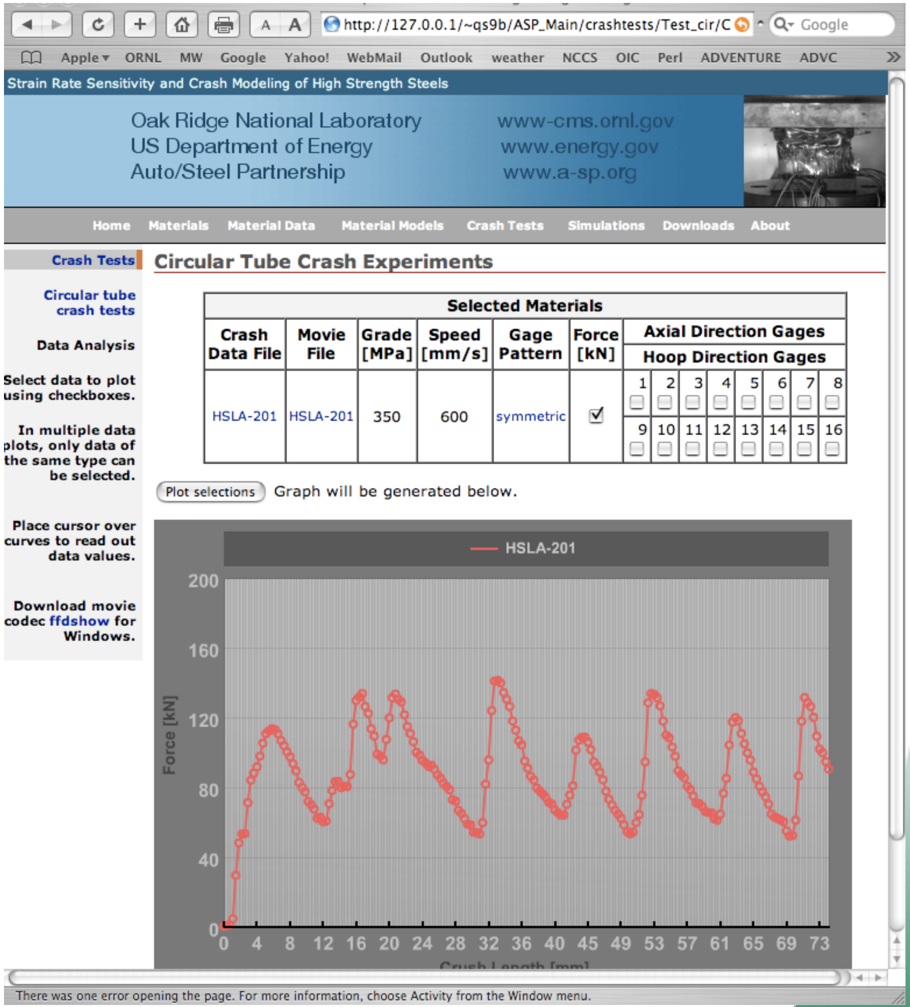




Comparison with experiment for element size = 2*thickness

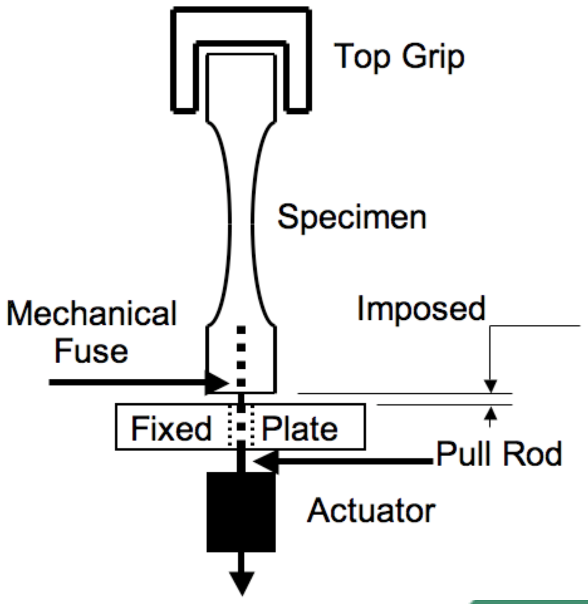
Technology Transfer

- **Experiments and modeling reported monthly to A/SP Strain Rate Characterization group every month**
- **The web site has been developed for reporting and analysis**
- **Findings from the project have been implemented in crash simulations at OEMs**



Activities for Next Fiscal Year

- **Initiate project on characterization and modeling of fracture in AHSS during impact**
- **Fracture during impact in AHSS has different character than conventional automotive steels**
  - **No significant strain preceding fracture**
  - **Little experience with AHSS in fracture**
- **Research challenges**
  - **Interrupted deformation high speed tests**
  - **Modeling of fracture (failure criteria, FEM technology)**



Summary

- **New methods have been developed for crush characterization of AHSS.**
- **Modeling guidelines have been developed for modeling of strain rate sensitivity and progressive crush of automotive structures.**
- **Methods are applicable to other automotive materials.**
- **Project developments are constantly communicated and evaluated by industry project participants (A/SP and OEM)**
- **Activities for the next fiscal year are planned for development of methods for characterization and modeling of impact fracture in AHSS**

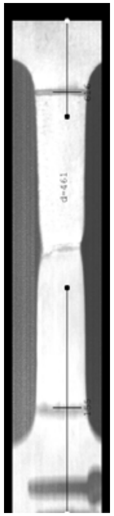
Changed Slides

Barriers

- **Industry Consensus**
  - **The material performance of AHSS in crash cannot be determined based on conventional, quasi-static tests**
  - **Technology for material characterization for loadings characteristic of automotive crash is not standardized and is fraught with problems**
  - **Conventional structural and material models for automotive crashworthiness have to be improved in order to enable increased use of AHSS and achieve desired weight reduction**
- **Gap exists in both the fundamental understanding and the practical capability of predicting the behavior in AHSS in crash**
  - **This gap is shared by other high strength materials, as well**
  - **What is the range of strain rates important for characterization and modeling?**
  - **What are the loading configurations needed for characterization of performance? What kinds of tests?**
  - **What are the limitations of current modeling and testing technologies?**
  - **What are the practical combinations of material models and FEM formulations needed for accurate crash modeling?**

Performance Measures and Accomplishments

- **Developed tests on three different length scales of automotive crash process**
  - **A: Uniaxial tension in intermediate (sub-Hopkinson) strain rate regime**
  - **B: Off-axis compression test for crash bending mechanism**
  - **C: Constant velocity component crush test**



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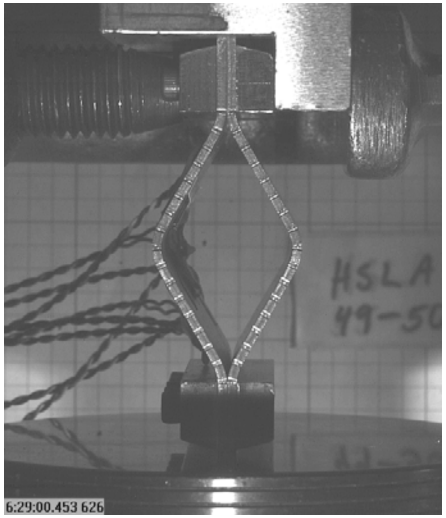

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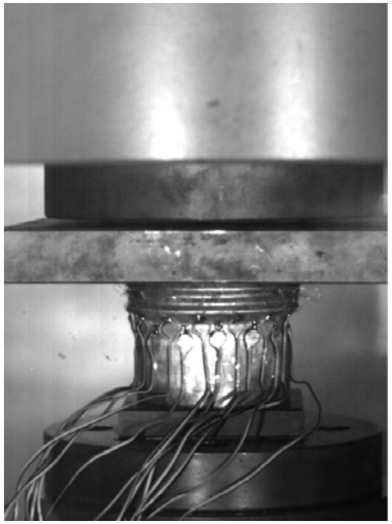

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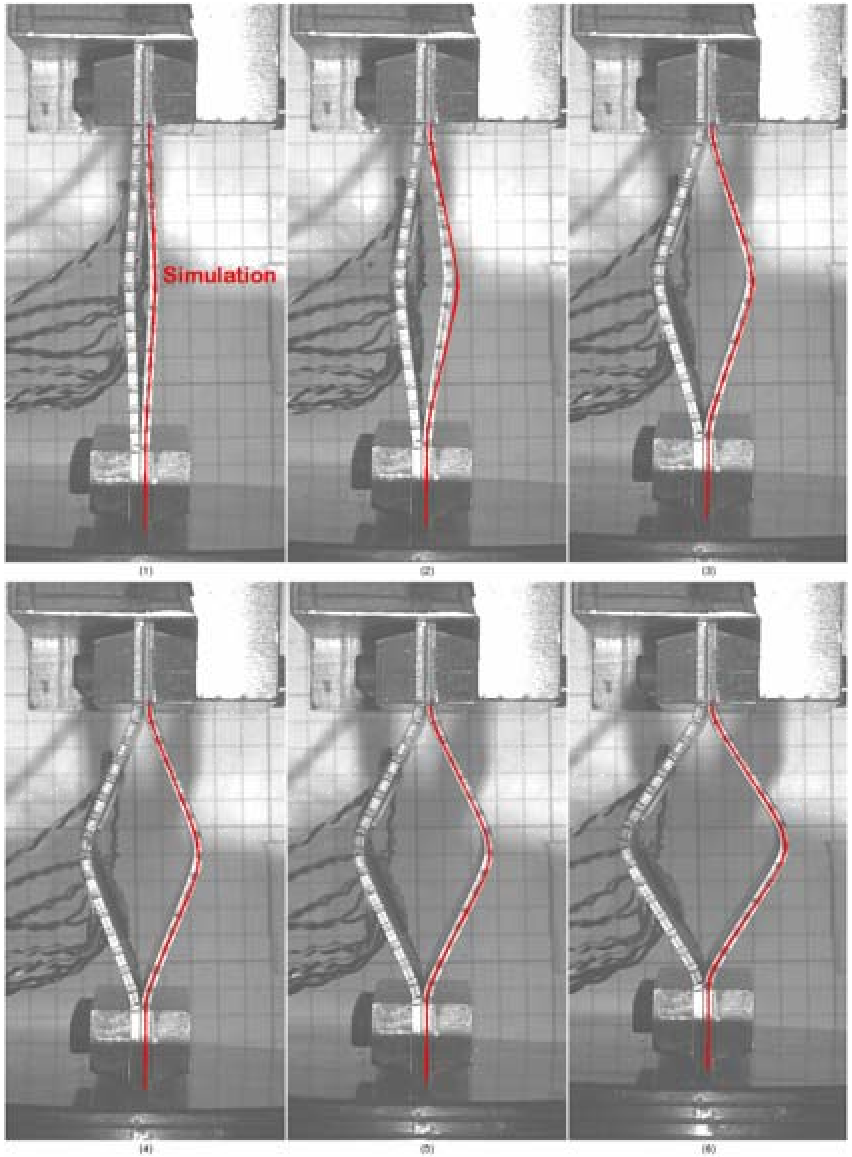
Modeling of Impact in AHSS Structures



- **Modeling of crush process starts at material properties**
- **Optimal modeling approaches are determined at the scale of single fold (double plate test) and component test**
- **The developed modeling guidelines are transferred to industry through A/SP**
- **New material model has been developed to account for strain rate history and transients in crash**