"Delamination/Disbond Arrest Features in Aircraft Composite Structures"

AMTAS FALL MEETING

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University of Washington
November 4, 2015

Sponsored Project Information

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  - **Toray**: Kenichi Yoshioka, Dongyeon Lee, Masahiro Hashimoto, Felix Nguyen
- **Industry Sponsors: Toray and Boeing**

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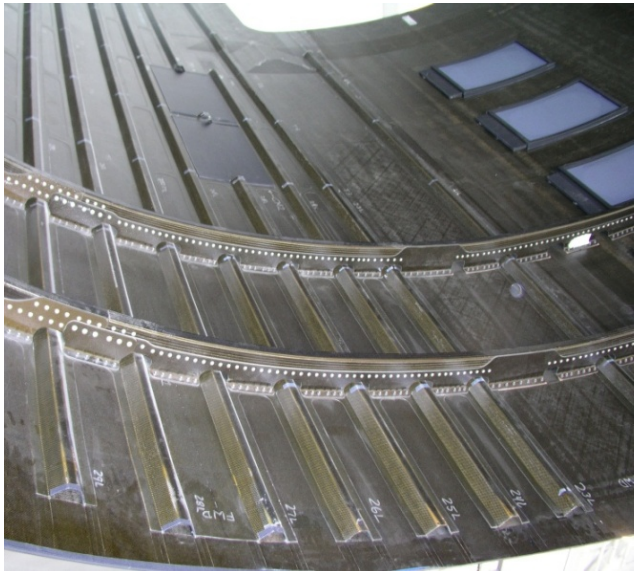
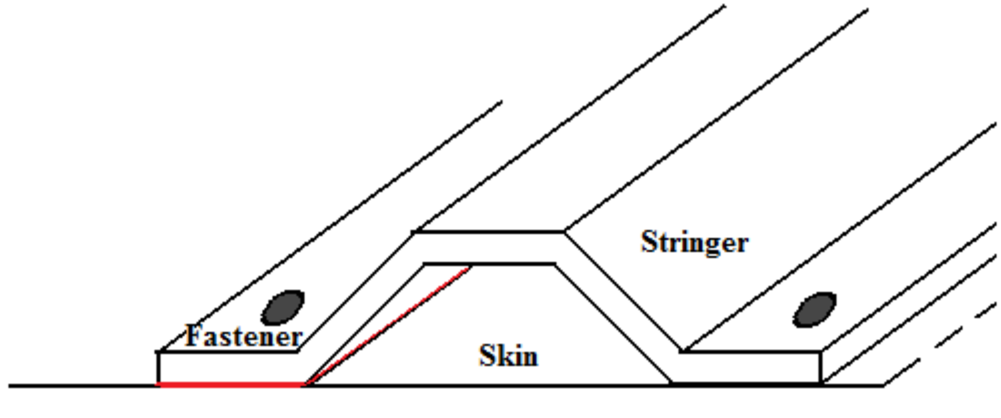
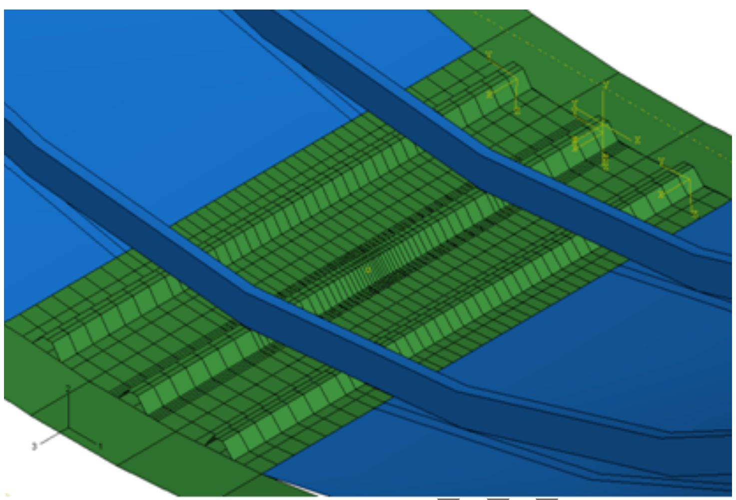
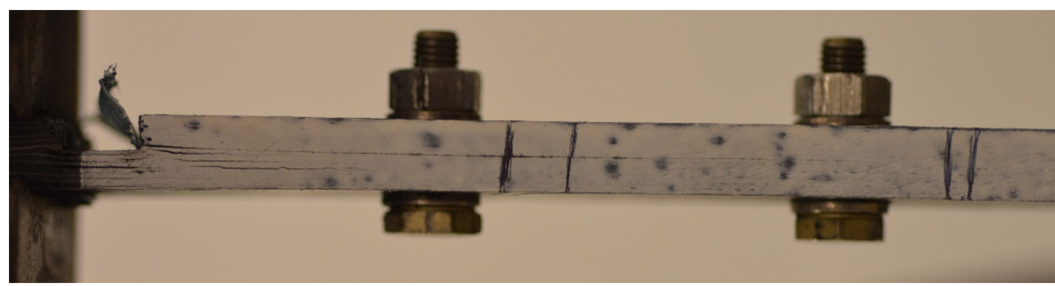
Crack Arrest Mechanism by Fastener









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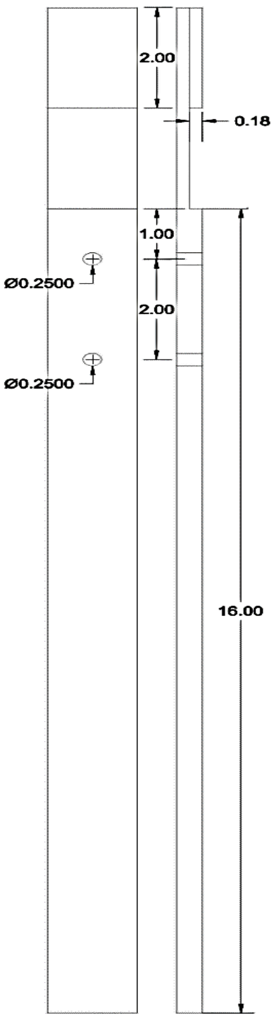
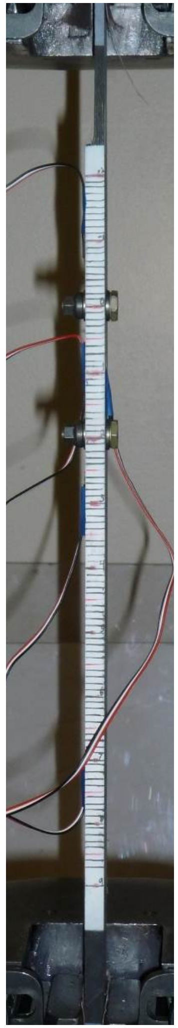
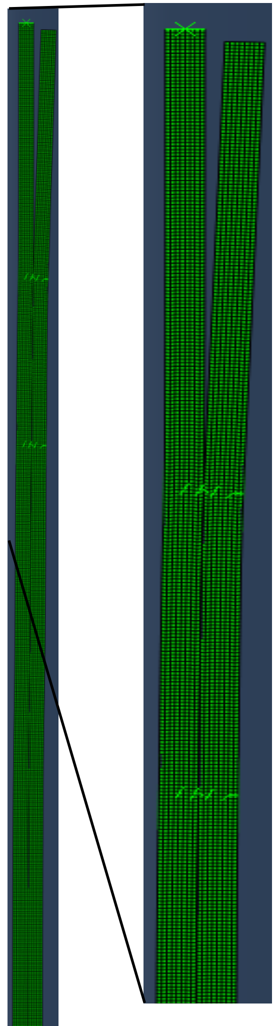
Research Objectives

- Accurately predict crack arrest capability for varying laminate and fastener configurations
  - Understand driving parameters of crack propagation and arrest by multiple fasteners under static and fatigue loading
  - Develop modeling techniques which can be employed for design, certification and optimization

Two Fastener Experimental Work

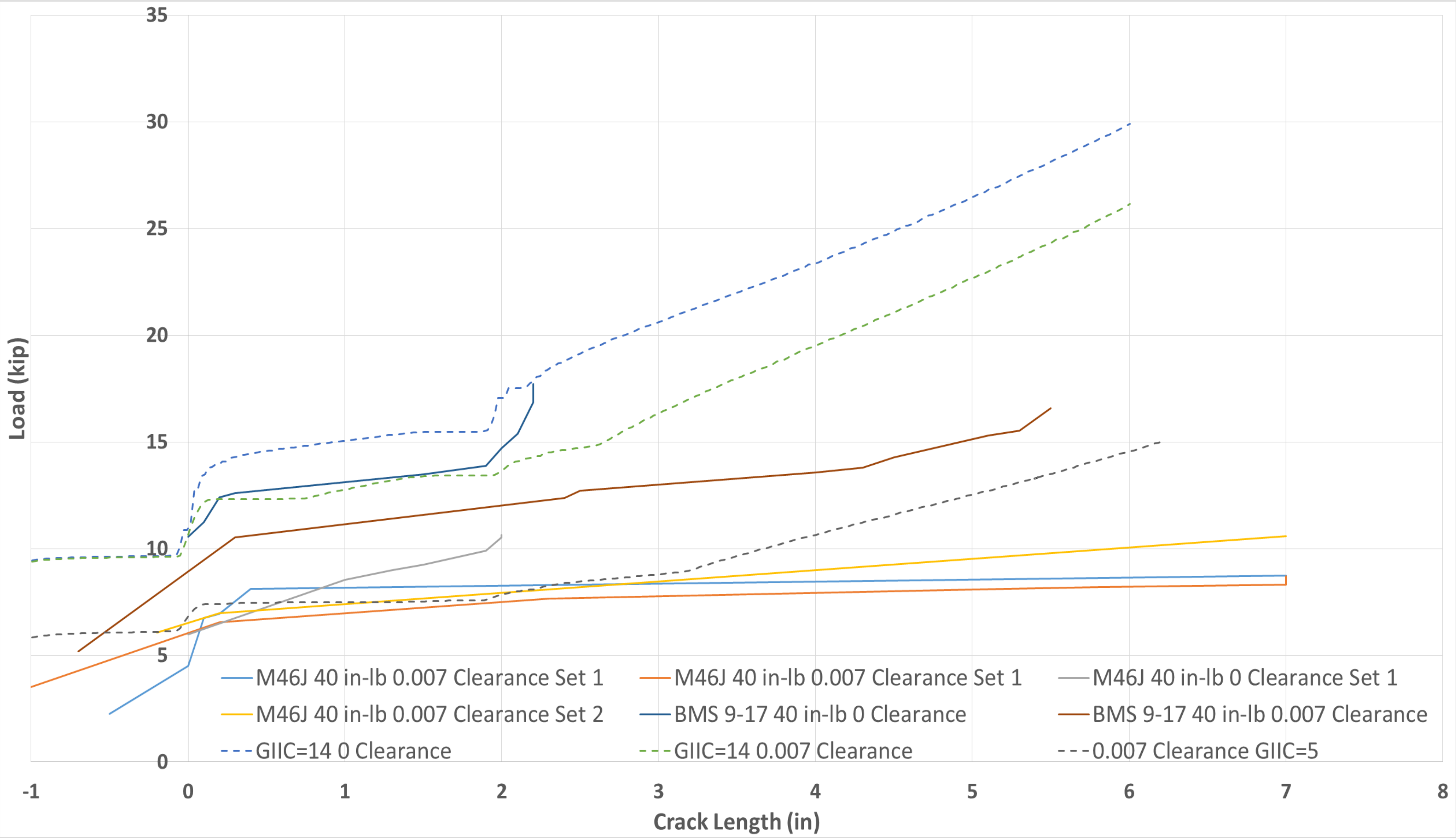






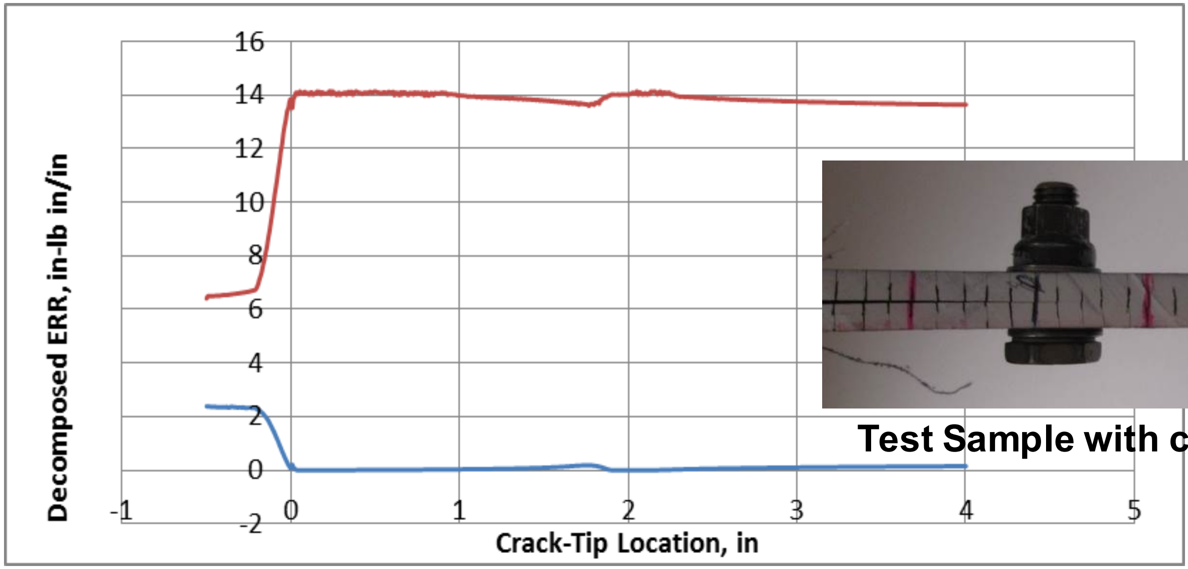
- T800S/3900-2B unidirectional pre-preg tape
- BMS 9-17 surplus unidirectional pre-preg tape
- 0.25 Inch titanium fasteners
- $(0/45/90/-45)_{3S}$ and 50% 0
- Load rate 0.1 mm/min (Static)
- 20 Hz (Fatigue)
- Crack tip tracked visually

Static Test Results



Mode I Suppression

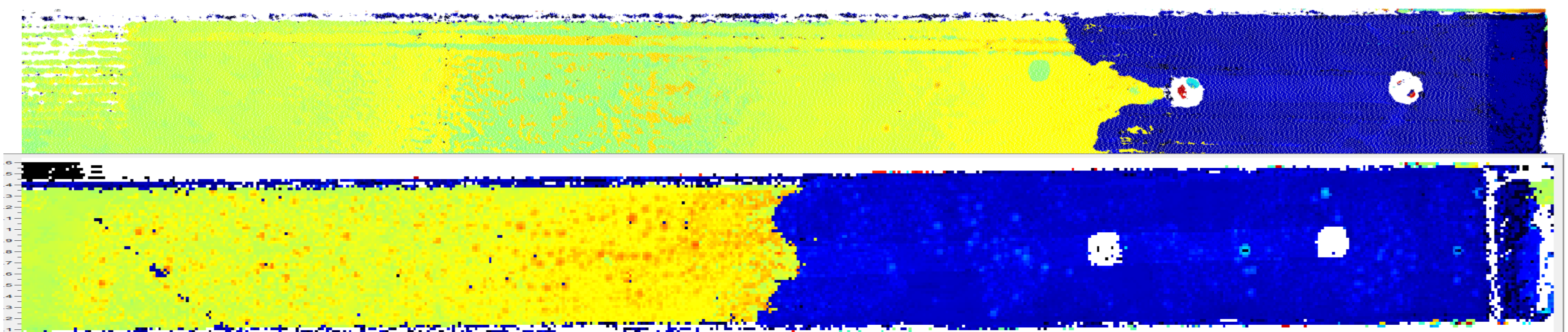
- First fastener effectively suppresses Mode I
  - Mode I suppression regardless of clearance value
    - Propagation load increases as $G_{IIC} > G_{IC}$
  - Fastener size excessive for Mode I suppression
    - 6-32 fasteners (D=0.1380) found to suppress mode I



Test Sample with crack forced into Mode II

Friction and Crack Curvature

- 0/0 interface has minimum coefficient of static friction: 0.25
- Load transfer through friction is small compared to through fastener for static loading
  - 1000 lb preload results in 250 lb load transfer
  - Load transfer is non-negligible in fatigue loading
- Crack Curvature is extensive near fasteners but minimal outside the influenced zone



Fatigue Modeling

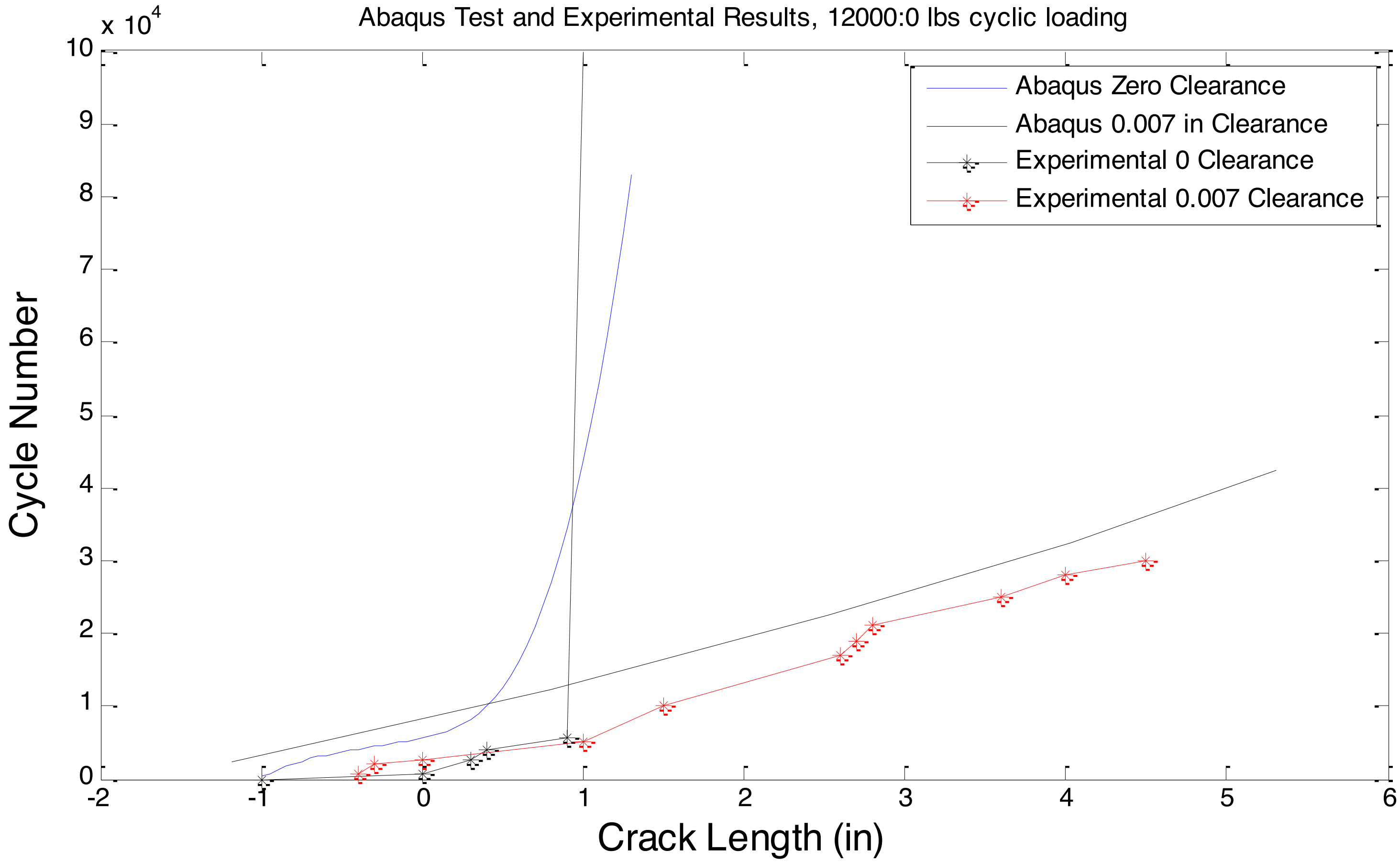
- Identical two and one dimensional models
  - Fatigue properties derived from initial testing and sourced from literature
  - Constant amplitude loading simulated
  - Zero and positive clearance simulated
  - Hole damage not currently modeled
- Dramatic fatigue life difference due to clearance
  - Consistent result both in tension-tension and tension-compression loading
- Hole damage may be critical factor
  - Even 0.001 in clearance results in lower fatigue life

Fatigue Testing

- Below fatigue threshold, fastener has no effect
- Fastener hole treatment has significant effect on low cycle fatigue
  - Crack arrest capability greatly reduced by the inclusion of clearance
- Loss of fastener clamping has arisen
- Hole damage may be critical factor
  - Not always visible on tested samples

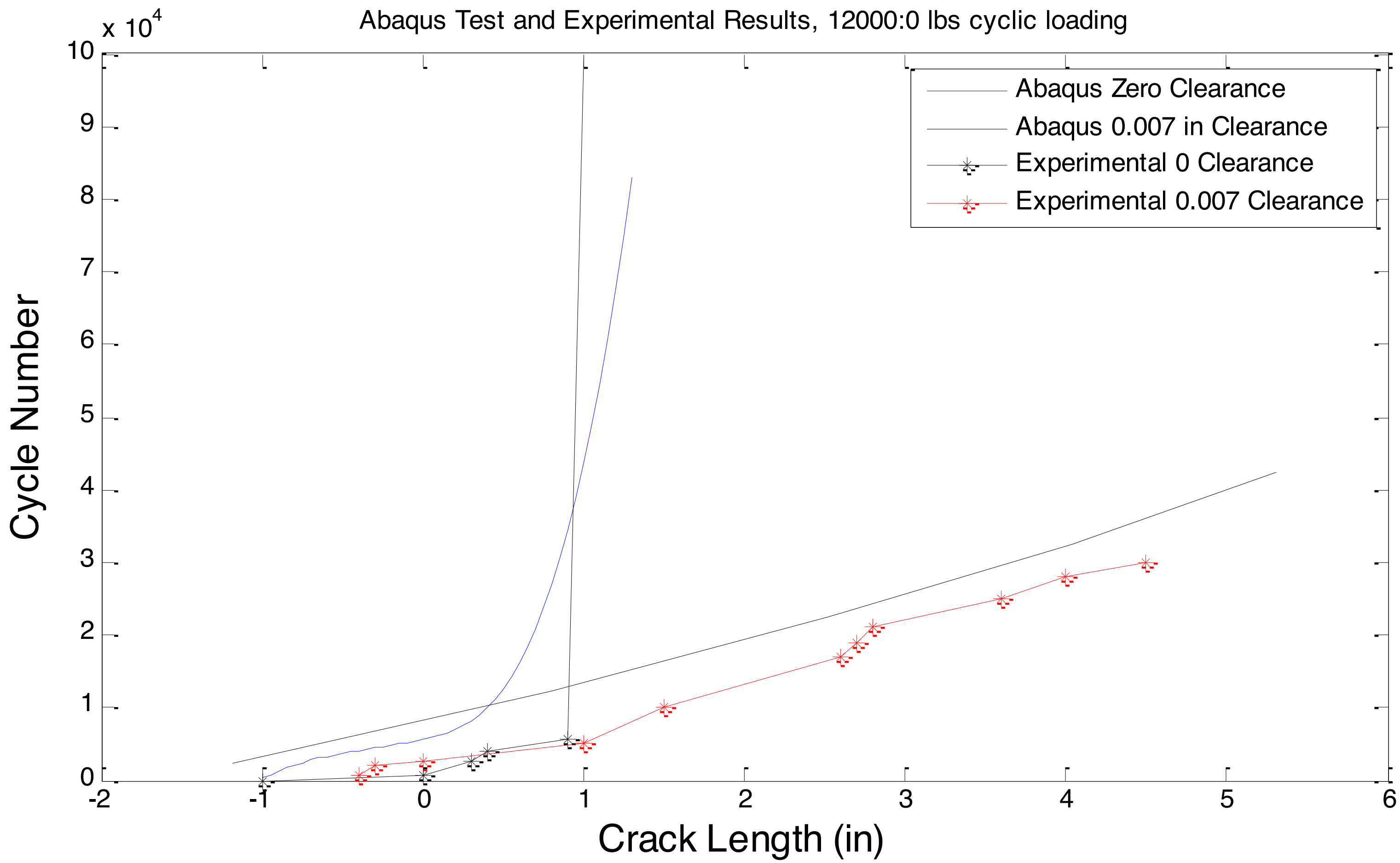
Fatigue Results (high loading)

- Loads equal to or greater than static crack initiation load (9000 lbs)
- Distinct knee in zero-clearance hole
  - Fastener provides sufficient load alleviation so as to eliminate further crack propagation (below threshold)



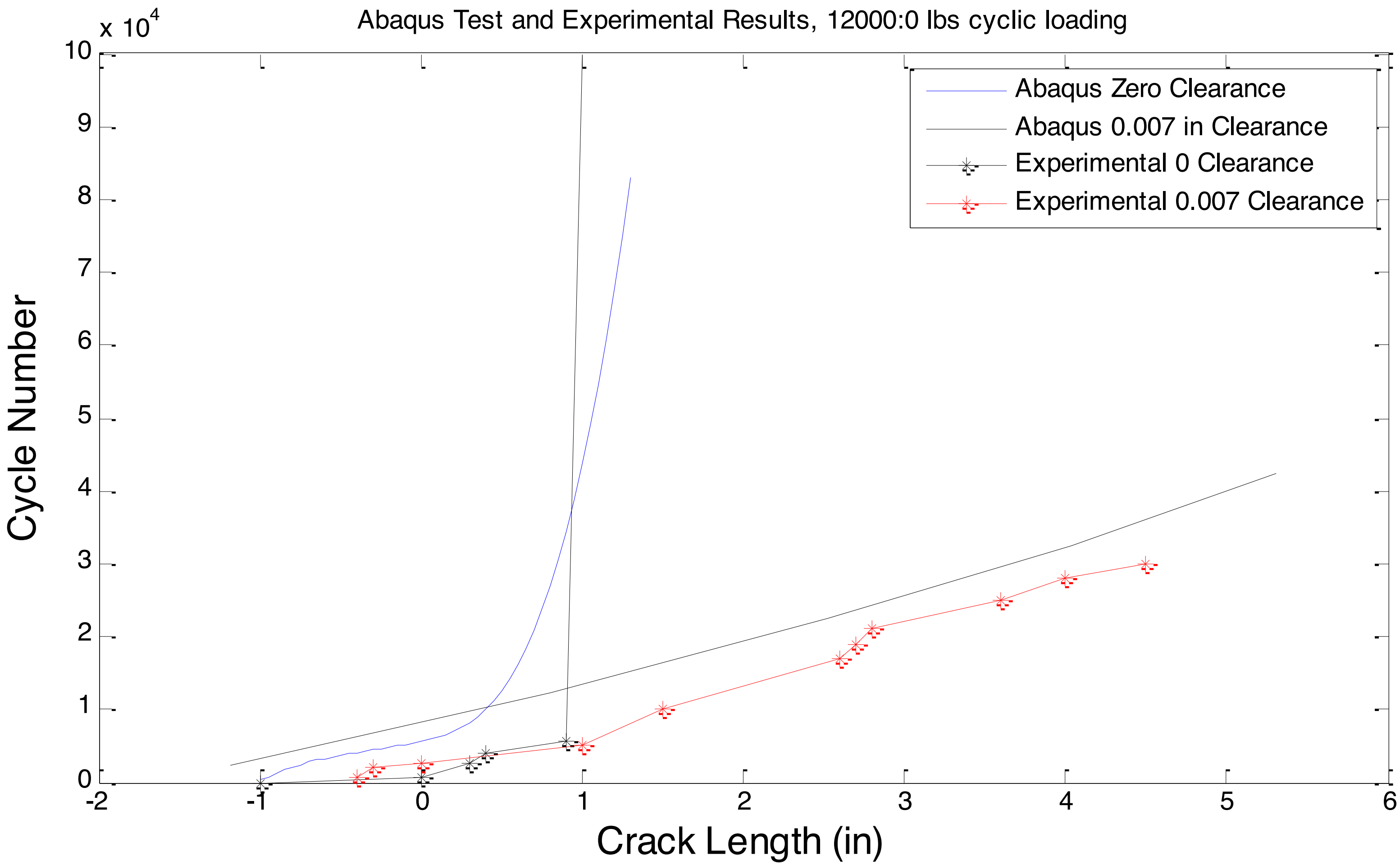
Fatigue Results (high loading)

- Run-out (10^7 cycles) did not occur
- Clearance drilled hole did not experience this, crack propagation is only slowed



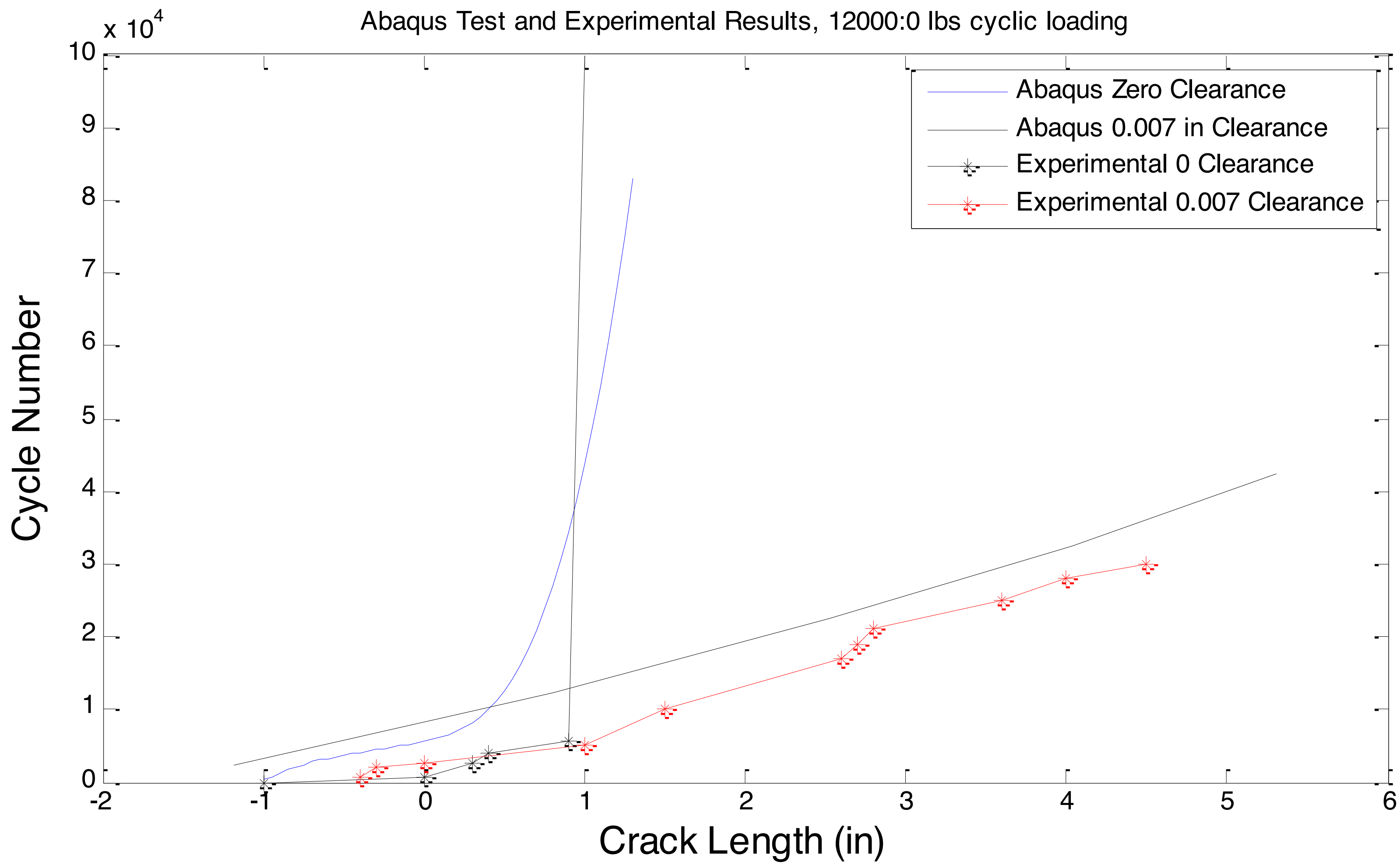
Fatigue Results (high loading)

- Fatigue model and test results agree better when identical (quasi-isotropic) layup used for fatigue properties



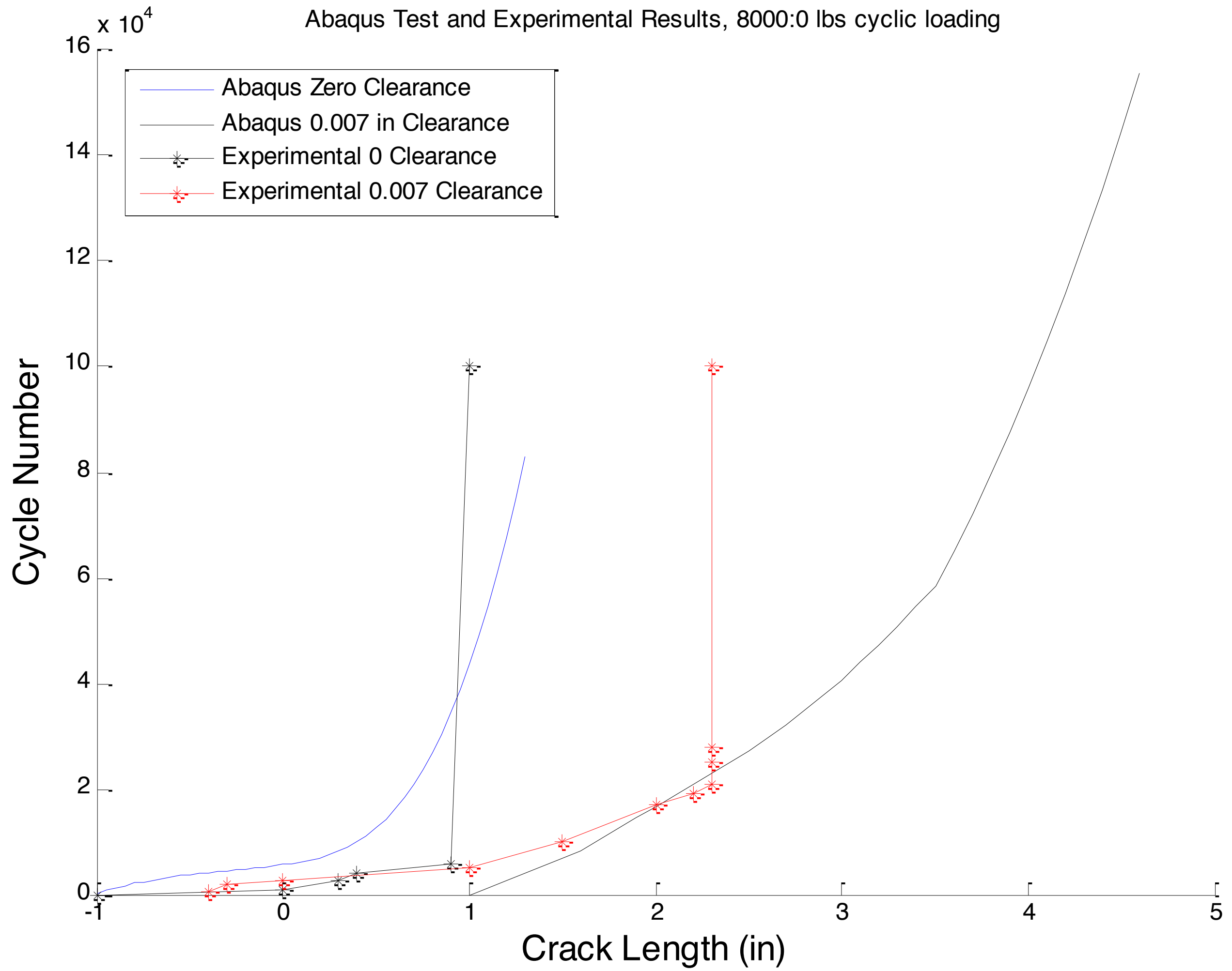
Fatigue Results (high loading)

- 1D modeling provided better agreement
  - Fastener modeling becomes increasingly important



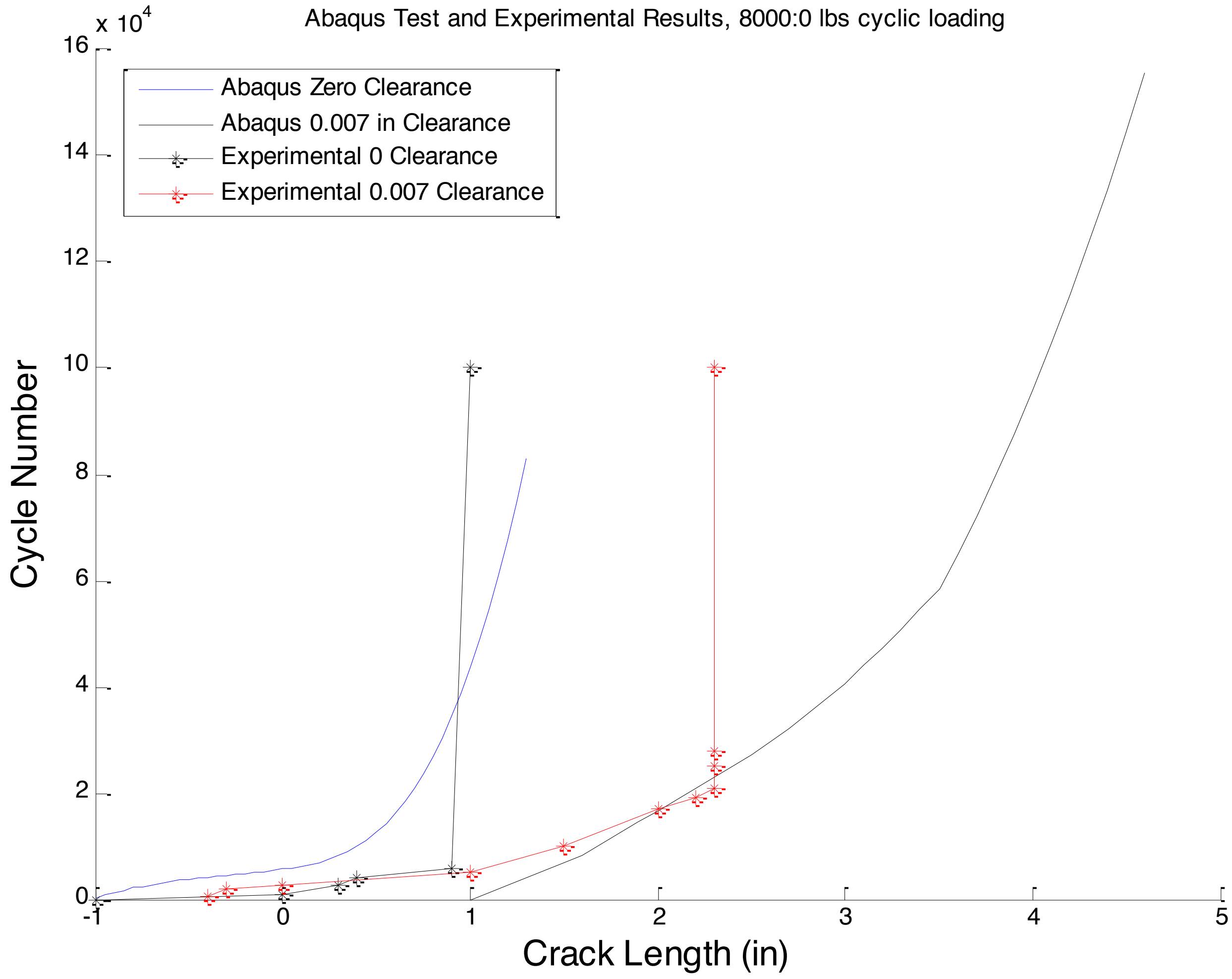
Fatigue Results (low loading)

- Loads equal to or less than crack initiation loading (9000 lbs)



Fatigue Results (low loading)

- Fastener friction clearly important
  - Modeling of friction in this scenario needs work



Future Work

- Friction Modeling
  - Lower load testing indicates critical influence of fastener friction
  - Removal of second fastener permits crack to continue to grow
- Establish conditions which create hole damage
  - Reversed and high loading both tend to increase the visibility of hole damage
- Determine critical load conditions
  - Establish scenarios where fastener is least effective
- Test with spectrum loading

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Looking Forward

- Benefit to Aviation
  - Tackle a crucial weakness of laminate composite structures
  - Improve analysis to prevent changes in schedule/cost due to a re-design associated with the delamination/disbond mode of failure in large integrated structures
  - Enhance structural safety by building a methodology for designing fail-safe co-cured/bonded structures
- Future needs
  - Further fatigue testing to establish parameters
  - Initiate investigation of crack propagation through fastener arrays
  - Industry/regulatory agency inputs related to the application, design, and certification of this type of crack arrest feature

Question and comments?

Thank you.

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