Evaluation Code for Composite Joints in General Aviation Structures

September 17, 2003

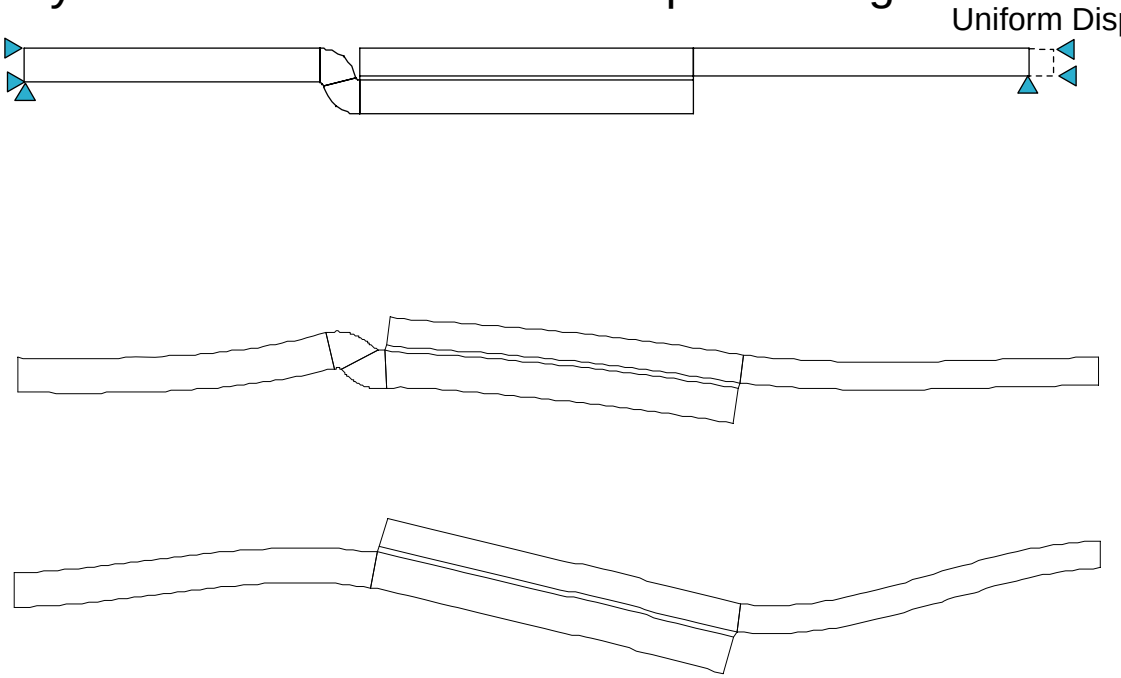
Rachael Andrulonis

Introduction

- Phase II SBIR program through the FAA Technical Center
  - P. Shyprykevich, Technical Monitor
- Goal is to create a flexible bonded analysis system that can be used for a wide range of aircraft structures
- Study and apply rigorous mechanics for constrained adhesive layer
- Release a commercial code

Joggled Joint Models Using MSC Analysis Code

- General end boundary conditions
- Generalized plane-strain
- Bending
- Cylindrically curved elements allow complex configurations to be modeled



Major Goals

- Create a new bonded joint analysis standard
  - Replace A4EI as a referenced standard
  - Much broader class of problems
  - Handle bending, peel, and general adhesive nonlinearity
- Handle adhesive mechanics in a rigorous fashion
  - Adhesive as a 3D material
  - Thickness effects, including thickness variability
- Provide intelligent failure criteria
  - Adhesive and adherents
  - Stress/strain based and fracture mechanics capability
- Release a commercial quality code
  - Modern, Windows based GUI
  - Documentation
- Provide initial validation tests

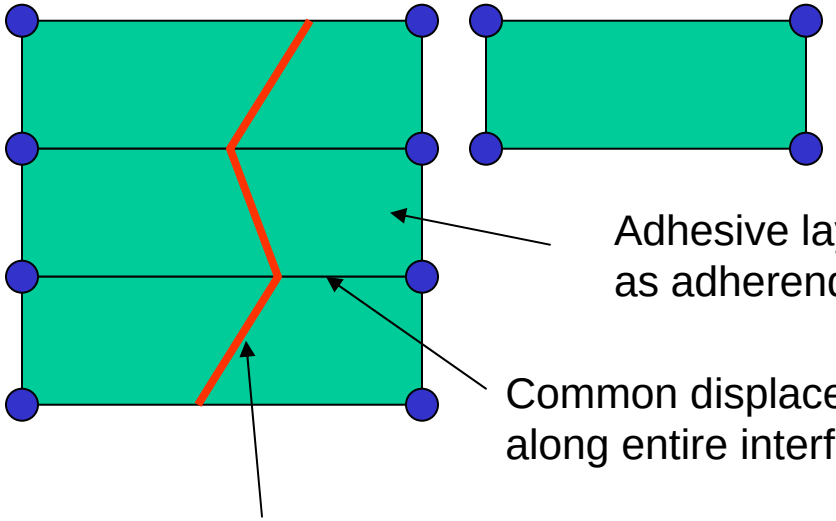
Analysis Approach

- Modify an existing code that handles interlaminar stress and fracture for composite laminates
- Wrap a graphical user interface around analysis code
  - Parametric models for most possible joint topologies
  - Database management for material properties and user models
  - Graphical display of output
  - VB.net based
- Build failure models on top of analysis code
  - Highly modular system
  - User customization

Existing Code: SUBLAM

- Originally developed by G. Flanagan under NASA funding
- Continued development by MSC and Navy
- Modern, well documented FORTRAN 95 code
- Allows for general, finite-element-like modeling, but is designed to yield accurate interlaminar stress components with extremely coarse models
- Phase I program used to add material nonlinearity to code

Some Concepts from SUBLAM



"Elements" may be joined at nodes

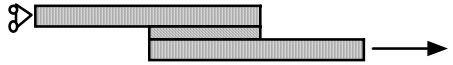
Force and displacement boundary conditions applied at nodes

Adhesive layer treated with same mechanics as adherend plates

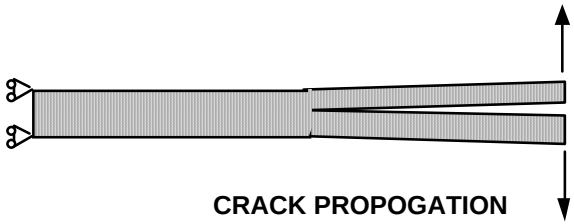
Common displacement and tractions along entire interface

Zig-Zag type theory
Linear distribution for u & v
Quadratic for w

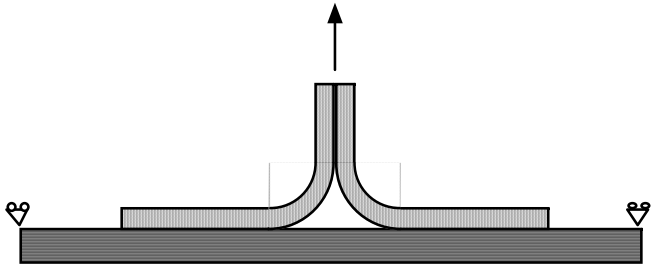
Classes of Problems Solved by SUBLAM



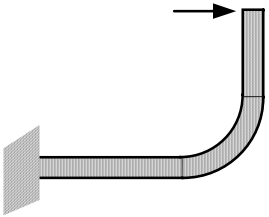
BONDED JOINT



CRACK PROPOGATION

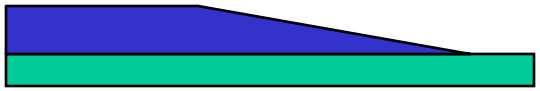


STIFFENER ELEMENT



CURVED BEAM

Shear Loading



Tapered Elements

SUBLAM Approach

- Stacked, high-order plates
  - Plates are laminated, with full material distribution information captured
  - For uniform plates, governing differential equations solved in closed-form
  - Plate equilibrium equations used to compute interfacial tractions
- Plates can be joined end-to-end to form complex built-up structures
- Tapered and nonlinear elements handled using P-element approach
  - Legendre polynomial series
  - Equilibrium equations used as with exact solution
- Generalized plane-strain
  - Prismatic structures

Graphical User Interface

- Standard Microsoft Windows features
- Extensive use of database concepts
  - Storage of material properties
  - Store user models
- Interactive parametric modeling
- Graphical output and report generation

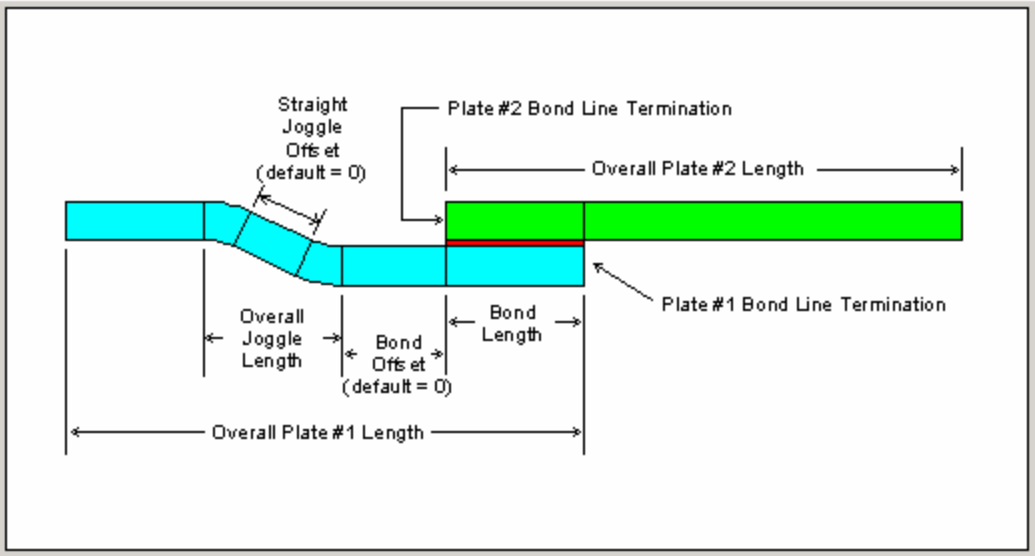
Joggle Single Lap Joint with Flat Exterior Model Definition

Model ID: 5

Model Name:

Model Comments:

Geometry | Forces, Displacements, and Moments | Input File



The Joggle Single Lap Joint with Flat Exterior has a joggle in Plate #1 in order to flatten the exterior of the (overall) bonded joint.

About... | Plate #1 (Joggled) | Bond + Termination Geometries | Plate #2 (Flat)

Save | Cancel

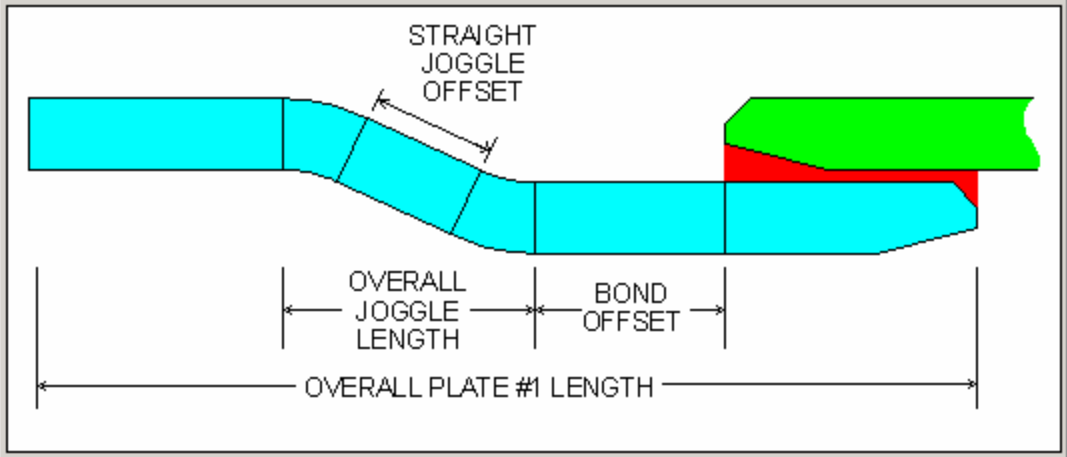
Joggle Single Lap Joint with Flat Exterior Model Definition

Model ID: 5

Model Name:

Model Comments:

Geometry | Forces, Displacements, and Moments | Input File



Overall Plate Length:

Overall Joggle Length:

☐ Straight Joggle Offset:

☐ Bond Offset:

About... | Plate #1 (Joggled) | Bond + Termination Geometries | Plate #2 (Flat)

Save | Cancel

Joggle Single Lap Joint with Flat Exterior Model Definition

Model ID: 5

Model Name:

Model Comments:

Geometry | Forces, Displacements, and Moments | Input File

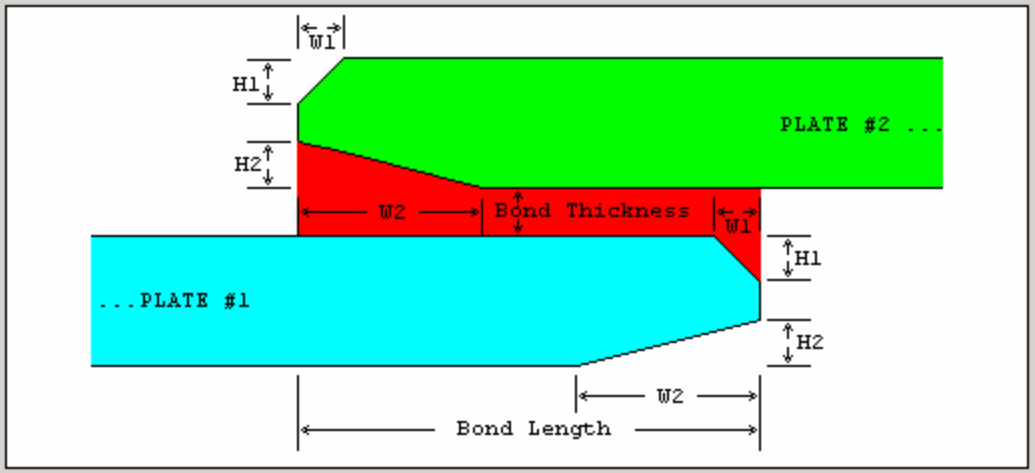


Plate #1 Termination Geometry

H1: W1:

H2: W2:

Plate #2 Termination Geometry

H1: W1:

H2: W2:

Bond Length: Bond Thickness:

About... | Plate #1 (Joggled) | Bond + Termination Geometries | Plate #2 (Flat)

Save Cancel

Summary

- A commercial quality, very general bonded joint analysis code is being created
  - Built on a proven, accurate, analysis engine
  - Graphical interface for productivity and ease-of-introduction
- Code is being combined with advanced mechanics concepts for adhesive behavior
- Beta testing planned in 6 months
- Technical Contact at MSC
  - Gerry Flanagan, flanagan@materials-sciences.com