NEi Nastran Progressive Ply Failure Analysis (PPFA™)

Formula 1 race team Minardi relies on NEi Nastran composite analysis software to achieve the ultimate in performance and safety.

Composite Analysis Tool for the Design Stage

PPFA is the perfect tool for composite part advanced design. With composites being used increasingly in general public applications in all forms of products from transportation to sports, designers seek greater understanding of the nature and mitigation of catastrophic failures.

In many practical cases, the residual strength of a laminated composite part after the first-ply-failure (FPF) is still high enough to prevent the rupture of a component. So applying FPF criteria for the design may lead to excessively conservative sizing. This is not desirable in high performance applications where the weight penalty is a serious factor.

PPFA allows engineers to examine structural behavior beyond first ply failure (FPF) and understand post FPF events of the composite material in the nonlinear field. PPFA can be used to perform:

- Risk mitigation studies
- Comparison of design alternatives
- What – if analysis and sensitivity studies
- Conceptual understanding of events beyond FPF

Common Design Questions and PPFA

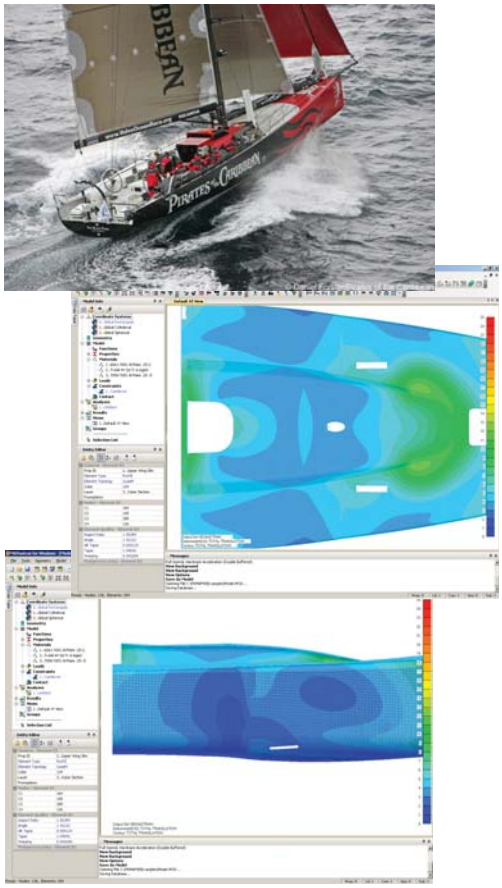
Engineers involved in composite design are typically faced with questions and issues like:

- What happens after FPF?
- How much of a separation is there between FPF and ultimate strength?
- How much time does it take to go from FPF to ultimate failure?
- What design modifications are effective in altering structural properties subsequent to FPF?
- Do certain types of local damage compromise the overall structure?
- How do variations in temperature affect performance?
- Where does damage occur and what is the effect on structural properties?

Benefits of NEi Nastran PPFA

PPFA provides the main tools and benefits of ply failure analysis without requiring the user to employ special elements and time consuming analysis techniques. PPFA benefits are:

- Simple, easy to set up and use
- No additional material data is required
- Accurate and robust with failure direction sensitive criteria not found in tools that don't incorporate LaRC02 and Puck
- Examination of damage propagation and effects on structural performance
- Captures the highly nonlinear discontinuous type failure typical in composites
- PPFA can be used with advanced solutions such as nonlinear transient response and nonlinear static analysis including all advanced modeling tools in NEi Nastran like Automated Impact Analysis (AIA™) and Automated Contact Generation



Farr Yacht Design, known for impressive wins in America's Cup and Volvo Ocean Race uses NEi Nastran for advanced composite design.

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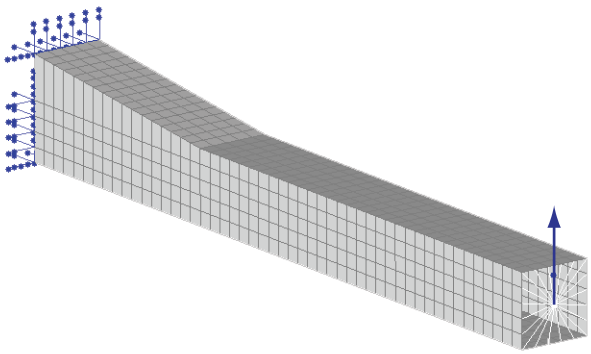
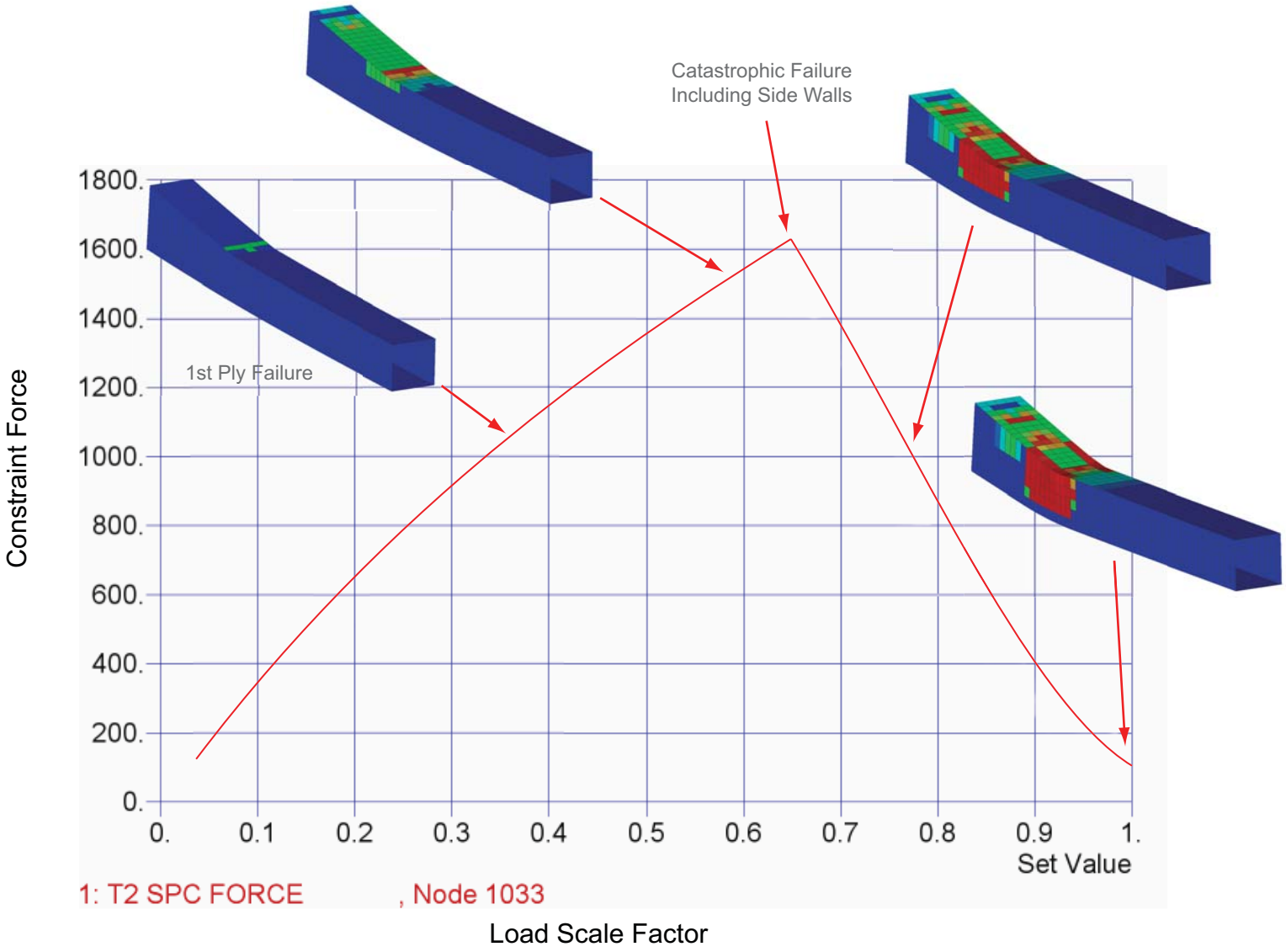


Cantilever box beam example. Beam is fixed at one end and loaded with an enforced displacement at the free end.

Progressive Ply Failure Analysis (PPFA)

- Allows plies to degrade or undergo a complete loss of strength during the progression of a nonlinear static or transient analysis
- Input consists of standard composite material properties and material stiffness reduction factors (E1, E2, G12, G1z, and G2z)
- Uses specified composite failure theories to determine failure (Hill, Hoffman, Tsai-Wu, LaRC02, Puck, Max Stress, Max Strain)
- Integration with the Helius:MCT product from Firehole Technologies for micromechanics based damage degradation
- Multiple failures are permitted:
  - Failure can occur in one ply direction with load still carried in the other
  - Both ply and inter-laminar shear failures supported



The above plot shows load scale factor vs. constraint force. At approximately 65% of the applied load, the structure fails catastrophically.