Aircraft Landing Gear Drop Test Simulation and Design Evolution

NAFEMS invited several software vendors to a roundtable to demonstrate their best processes in an aircraft landing gear drop test example. The emphasis was on simulation processes that can make problem solving innovative, accurate and efficient. Altair was the only participant who could solve all three problems, thanks to the power of the HyperWorks software suite. This article explains the process followed by Altair engineers and should help increase awareness among HyperWorks users regarding the powerful tools available for solving realistic design problems.
**Problem Definition:**

Landing gear design considers an aircraft landing and a taxiing event. In the landing event, energy of the descending aircraft must be absorbed by the landing gear without generating reaction loads that exceed the design limit loads. This reaction load, as a function of landing gear stroke, is referred to as the Dynamic Load/Stroke Curve. The taxiing event is simulated as two discrete static events: braking and turning. These events generate high stresses in the torsion links and lugs. The objectives of landing gear design for these two events can be grouped into three categories:

1. **Determination of damping profile:** Design the damping profile to ensure that the Dynamic Load/Stroke Curve always stays within the Dynamic Loads Envelope during the landing simulation.

2. **Concept design and optimization of torsion links:** Design the torsion links, which are critical for fatigue as a result of braking and turning while taxiing, such that they meet the stress and manufacturing requirements.

3. **Shape optimization of lugs:** Evolve the design of the integrated lug on the lower outer cylinder, which is also critical for fatigue as a result of the taxiing event. NAFEMS provided the scope of this project in order to enclose and simplify the problem. It also provided all the necessary design information such as applied loads and allowable stresses. As explained above, only the lugs and the torsion links can be changed, all other parts must remain unchanged.
Solution:
To efficiently satisfy the above three objectives in a final design, a software suite must have the following capabilities:

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<th>Capability</th>
<th>Enabler with Hyperworks Products</th>
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<td>Multi Body Dynamics tools to perform a system level analysis</td>
<td>Altair MotionSolve, Altair MotionView, Altair HyperMesh, Altair RADIOSS</td>
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<td>Design optimization of a system level multi-body model through a design study and optimization tool</td>
<td>Altair HyperStudy</td>
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<td>Tools to transfer results from system level results (loads, positions) for component level optimization</td>
<td>Load mapper, Altair HyperMesh- RADIOSS for mesh repositioning</td>
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<td>State-of-the-art concept design and optimization capabilities to find the optimum design</td>
<td>Altair OptiStruct</td>
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<td>Seamless integration with third party software packages</td>
<td>HyperShape/CATIA, HyperMesh-T-addons for mesh repositioning</td>
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<td>An integrated approach to perform component level optimization based on system level analysis</td>
<td>Equivalent Static Load Method in Altair OptiStruct</td>
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Problem 1: Optimization of damping curve
Generic problem: System Level Optimization
Tools used: MotionView, MotionSolve, HyperStudy or HyperMesh, RADIOSS, and HyperStudy

A MotionView model was built by importing the CATIA model. The deformable components were modeled as flexible bodies. IMPACT type of contact was used to model the contact between the tires and the ground. MotionSolve was used to solve the problem.
As shown in Figure 3, 10 coefficients on the damping curve were used as design variables in HyperStudy. The direct link between MotionView and HyperStudy makes the optimization setup of the damping curve extremely straightforward. The run converged in 19 iterations and as shown in Figure 5, damping characteristics were achieved to have vertical load under the load envelope.
Figure 4, Optimization solution convergence history
Figure 5, Vertical reaction load at strut vs. strut stroke

Note: In HyperWorks 8.0, HyperMesh can be used to build MBD models to run through RADIOSS. This interface is targeted towards HyperMesh users. It allows not only MBD analysis but also helps reposition FE mesh with ease.

Problem 2: Concept design and optimization of torsion links
Generic problem: Component level topology and shape optimization
Tools used: OptiStruct, HyperMesh, or HyperShape/CATIA
The landing gear is modeled with tetrahedral elements. Nonlinear gap elements are used for interfacing components. Landing events do not create high stresses, therefore only the braking and turning conditions are considered in this process.

Design space is defined for topology optimization (top left image in Figure 7). Mass or weighted compliance is used as the objective along with stress constraints. Manufacturing constraints (draw direction and extrusion) are used to guarantee a manufacturable and interpretable design proposal. From the interpretations of several topology optimization runs, two designs are proposed: one is a heavier more conservative design, the other is a lighter more risky design. To further reduce weight in the conservative proposal or to meet the stress requirements in the lighter proposal, shape optimization is used. Several shape changes are defined as design variables. The link proposals are optimized to minimize the mass and meet the stress constraint. As shown in Figure 8, the total mass of upper and lower links without the pins is reduced from 240 lbs to 176 lbs, a 27% reduction while satisfying the stress requirements.
Mass reduced from 120 lbs to 88 lbs. (27% reduction) per link while meeting stress requirements

Figure 8, Mass reduction through topology optimization

Concept design of torsion links can also be performed in the CATIA V5 environment using HyperShape/CATIA. The steps of this process are:

1. Starting with CATIA geometry (CATParts + CATProduct), geometry was defined.
2. Constraints were modeled to capture behavior of the landing gear.
3. Using these constraints, the landing gear was positioned in the stroked configuration very quickly.
4. Unnecessary parts, such as tires, were removed from the model.
5. Following analysis connections were defined:
   - Rigid virtual meshes to model connection to the plane
   - Rigid virtual mesh to model connection to the wheels
   - Rigid meshes to model connection between struts and outer cylinder
   - Contact connection elsewhere
6. A HyperShape/CATIA case was defined and the topology optimization was performed on the torsion links.
Problem 3: Lug redesign using shape optimization

Generic problem: Component level shape optimization

Tools used: OptiStruct, HyperMesh, MotionSolve, and Equivalent Static Load Method in OptiStruct

Designing for static loading: Several shape changes were defined as design variables. Free shape was also used to change some contours. The lug was optimized to minimize the lug mass and to satisfy the allowable stress constraint. Optimization reduced the stress from 294 ksi to the allowable stress level of 120 ksi (Fig. 10) with a small penalty on the lug mass; lug mass increased by 5.2 lbs.
Designing for dynamic loading with Equivalent Static Load Method (ESLM):

ESL method is used for the optimization of structures subjected to transient loads. This method converts dynamic loading to a series of static loads calculated at each time step such that the displacement fields are the same. ESL is calculated from deformation from MBD analysis or transient analysis. Stress comparison of designs before and after optimization are shown in Fig. 11. As there was no stress violations in the baseline design under the dynamic loading, optimization reduced the lug mass by 4.6 lbs.
Figure 11, Stress contours before and after optimization for dynamic loading

**Conclusion:** Altair HyperWorks is an integrated simulation platform offering complete CAE solutions including concept design, optimization, best-in-class solvers, and reusable models. Through this robust integration, innovative solutions to both system and component level design problems can be efficiently found.

For more information, contact your local support office.
SPECIAL ANNOUNCEMENT

Altair is happy to announce the release of HWupdate-80SR1-SA1-035-UG and will be on our website by the end of January. This SA updates the v8.0SR1 UG reader to be able to read UG NX5 and earlier models with .prt and .asm extensions. The update can be installed on top of v8.0SR1 release and does not require any other packages. HyperMesh v9.0 will come “out of the box” with UG NX5 support. Please remember that in order for the UG reader to work; the proper environment variables must be set and pointing to a valid UG NX5 installation. See online documentation from HyperMesh for complete details.

SUPPORT TIPS & TRICKS

KB #1: 684
Contour the thickness change of components in gauge optimization. Download

KB #2: 761
Generating mesh transition from large mesh size to substantially smaller mesh size. Download

ADDITIONAL HYPERWORKS MACROS

trueView.zip: This HyperView macro allows users to visualize the model in true view mode based upon the user defined view plane. Download

reverse_mask.zip: This HyperView macro is used to reverse mask the state of all elements using the function key F2. Download

UPCOMING EVENTS

In the near future, Altair is participating in the following events:

Pacific Design & Manufacturing Show
January 29-31, 2008
Anaheim, CA
pacdesignshow.com

The 2008 International Transport Packaging Forum
March 17 - 20
Orlando, FL
transportpackagingforum.com

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- **Interfacing HyperWorks with ABAQUS**
  Jan. 31
- **Introduction to RADIOSS**
  Feb. 11-13
- **Intro. FEA Modeling & Results Visualization**
  Feb. 18-20
- **Intro. Concept Design & Fine Tuning with OptiStruct**
  Feb. 27-28
- **Intro. MBD Modeling & Results Visualization**
  Feb. 28-29

California training classes (Mountain View)

- **Intro. Concept Design & Fine Tuning with OptiStruct**
  Feb. 19-20

Washington training classes (Bothell)

- **Intro. FEA Modeling & Results Visualization**
  Feb. 12-14

Canada training classes (Toronto, Ont.)

- **Intro. FEA Modeling & Results Visualization**
  Jan. 15-17
- **Introduction to Radioss Linear**
  OptiStruct Analysis class has been renamed to Radioss Linear. This is an introductory course for using Radioss Linear.
  Jan. 28
- **Intro. DOE, Optimization & Stochastic Studies**
  Jan. 31
- **Intro. MBD Modeling & Results Visualization**
  Feb. 25-26

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