How Many G's?

A Brief Look at the Hatz CB-1 Wing Spar

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This engineering analysis of the CB-1 Wing Spar using modern computing methods gives us an exciting first look at the structural capability of the main wing spar.

Under direction from the Hatz Biplane Association, the Hatz CB-1 upper and lower wing spars were analyzed for structurally limiting conditions. Information from the Association web site and known airfoil characteristics were used to select several flight conditions to be examined. Loads for these particular flight conditions were calculated and then applied to a computer model of the wing structure. These models take into account the material properties of Sitka Spruce used for the spars, as well as mechanical attachment (fixity) of members one to another, and load path redundancies which exist in most frame-type aircraft. The outputs of the model include reaction loads, internal loads, stresses, and strains in the various aircraft components. These outputs are then compared to the assumed material properties to determine safety factor, or structural capability. In general, the rear spar of the center section is the limiting location when subjected to loads in a 4g dive pull out.

CB-1 Spar Strength: Model Assumptions

Several assumptions were made in order to answer the question, "to how many g's is the spar structure capable?" These assumptions include:

- how the wing responds to flight loads
- inclusion of selected components which are thought to drive the result: wing spars, compression tubes, tension tubes, tension wires, roll, fly, and landing wires, cabane and interplane struts.
- thoughtful selection of the material properties of Sitka Spruce.
- Unmodified *stock* plans with 1400 lb gross weight.

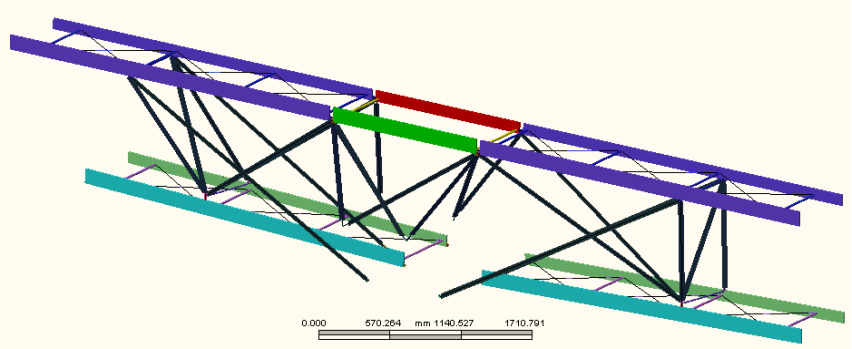
Results: An Exciting First Look

The analysis results were tabulated by major area and limiting flight condition. The results include two perspectives on structural capability: Safety Margin to Failure assuming a 4g maneuver; and Predicted Maneuver Load when a 1.5 Safety Factor is assumed.

The Safety Margin to Failure (with a value of 0 indicating that

the ultimate loads are reached) may be thought of as remaining Safety Margin in a particular location for a particular flight condition if a +4g / -2g flight envelope is assumed. For example, the Center Section Rear Spar shows a critical maneuver of a dive pull out with a Safety Margin to Failure of 0.3. This means that the model predicts that an additional 30% of the maximum calculated loads can be added to the component until predicted ultimate failure.

The next column, Predicted Maneuver Load, assumes a Safety Factor of 1.5 on all structural members, and then shows the number of g's of structural capability for each location and critical condition. For example, the Lower Wing Rear Spar in a dive pull out shows a Predicted Maneuver Load of 4.1 g's. This can also be correlated to the Safety Margin shown in the previous column of 0.6, as the member shows slight Safety Margin to Failure above 0.5, indicating a slightly higher g-capability than the assumed 4g maneuver.



This schematic view of the computer model shows the 65 parts of the wing structure that were included in the analysis.

From the tabulated results, the rear spars seem to be somewhat under designed and front spars slightly over designed (the design target being +5 g's). These results are an exciting first look a the spar structure and its mating parts for a stock CB-1.

Spar	Safety Margin [4g Maneuver]		Predicted Maneuver Load [g's]	
	Accel Stall	Dive Pull Out	Accel Stall	Dive Pull Out
Center Front	1.1	2.3	5.6	8.7
Center Rear	1.2	0.3	5.8	3.5
Lower Front	0.9	5.4	5.1	18.2
Lower Rear	0.9	0.6	5.0	4.1
Upper Front	0.9	1.4	5.0	6.5
Upper Rear	0.6	0.5	4.3	3.9

What's Next?

Financial constraints prevented a closer and more thorough look at the CB-1 structure in general, although the wing spar analysis provided some evidence behind some of the claims on the airframe. Streamline Designs recommends that when financially possible, additional follow-on work be completed, including, but not limited to:

- A broader look at more of the airframe, just in case a different component is the "weakest link" in the system.
- The inclusion of plywood fuel tank mounting plates in the model is recommended, since the maximum loads occur in the area of attachment of these plates.
- Skin effects and the transfer of force from aerodynamic forces to the wing structure.

Resources

1. "Hatz CB-1 Spar Analysis," report conducted by Streamline Designs, LLC. Report number SD-2008-005-01, July 20, 2009.
2. Mueller, Juerg. "Structural Analysis of a Hatz CB-1 Biplane," March 24, 1997.
3. "Design of Wood Aircraft Structures," Munitions Board Aircraft Committee. ANC-18, June, 1951.
4. "Wood Handbook: Wood as an Engineering Material," Forest Products Laboratory, USDA Forest Service, FPL-GTR-113. March 1999.