RV-10 Modal Impact Testing

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A critical aspect of Sky Designs' development of ER fuel tanks for RV-10 and RV-14 has been substantiating that the addition of fuel forward of the spar and at approximately mid semi-span would not increase susceptibility to flutter.

While it would be ideal to perform a full ground vibration test (GVT) and subsequent flutter analysis on an “ER” tank equipped RV-10, the cost of such testing is beyond the financial means of Sky Designs. See note 1.

Substantiation of flutter avoidance was instead made via study of technical reports stating directly or whose conclusions demonstrate that mass forward of the elastic axis is stabilizing to wing flutter. Reports cited are: NACA-TN-1594, NACA-TN-1848, and NACA-RM-L54I1. Further substantiation was made via comparison to aircraft having similar size, configuration, and speed range - PA-28 and PA-32 - that carry extended range fuel in the leading edge yet without any changes in Vne or known cases of wing flutter.

Additional substantiation was made via comparison to an aircraft having similar size, configuration, and speed range - Polen Special - where fuel was to be placed aft of the leading edge, but analysis and testing indicated a danger of wing flutter.

Recalling the words of Wernher von Braun, “One test is worth a thousand expert opinions”, when Aeronautical Engineering colleague and RV-10ER customer David Sanchez offered his own RV-10 aircraft, test equipment, and expertise to perform GVT modal impact testing, Sky Designs jumped at the opportunity.

Another example of the caliber of people we work with, David is the owner of Streamline Aerospace - https://www.streamline.aero/ - an R&D engineering consulting firm that specializes in the design, testing, and development of milestone aerospace vehicles and advanced manufacturing technologies.

So, what exactly is a "modal impact" test? The test procedure consists of measuring the “modes” of vibration which result from an “impact” to the wing, hence the name “modal impact” testing. The impact is delivered by a calibrated hammer and a tiny 3-axis accelerometer allows for measurement of acceleration in the X, Y, and Z directions. A plot of acceleration versus time shows the different frequencies at which the wing is vibrating.

The plot below shows acceleration in the Z (vertical) direction for the 20th impact test. The first photo below shows the hammer alongside the 4-channel signal analyzer and laptop used during the tests. The second photo shows the accelerometer mounted on the wing of the test aircraft.

By varying the chordwise and spanwise location of the accelerometer, it is possible to infer the frequencies of first-mode bending and first mode torsion as well as the location of the elastic axis.

A total of 31 individual “modal impact” tests were made, all on the left wing of the test aircraft. Knowing that one incorrectly placed hammer impact could damage the aircraft, it felt strange to be repeatedly delivering hammer blows to the wing of a beautifully finished RV-10. See the third photo below. Beware of engineers wielding hammers!

The goals of the modal impact testing were:

1. Determine the location of the elastic axis of the RV-10 & RV-14 wing. (A shear force acting at the elastic axis results in bending deflections and no twist, and a torque acting at the elastic axis causes twist but no lateral deflection of the elastic axis due to bending)

2. Determine if the fuel tank front attach contributes significantly to the torsional stiffness of the RV-10 & RV-14 wing. (The front tank attach was eliminated in all kits subsequent to the issuance of Van’s SL-00003 in February 2021.)

3. Determine the change in torsional frequency of the RV-10 wing as the amount of fuel in the tank is increased.

So, what was learned about the RV-10 wing as a result of the modal impact testing?

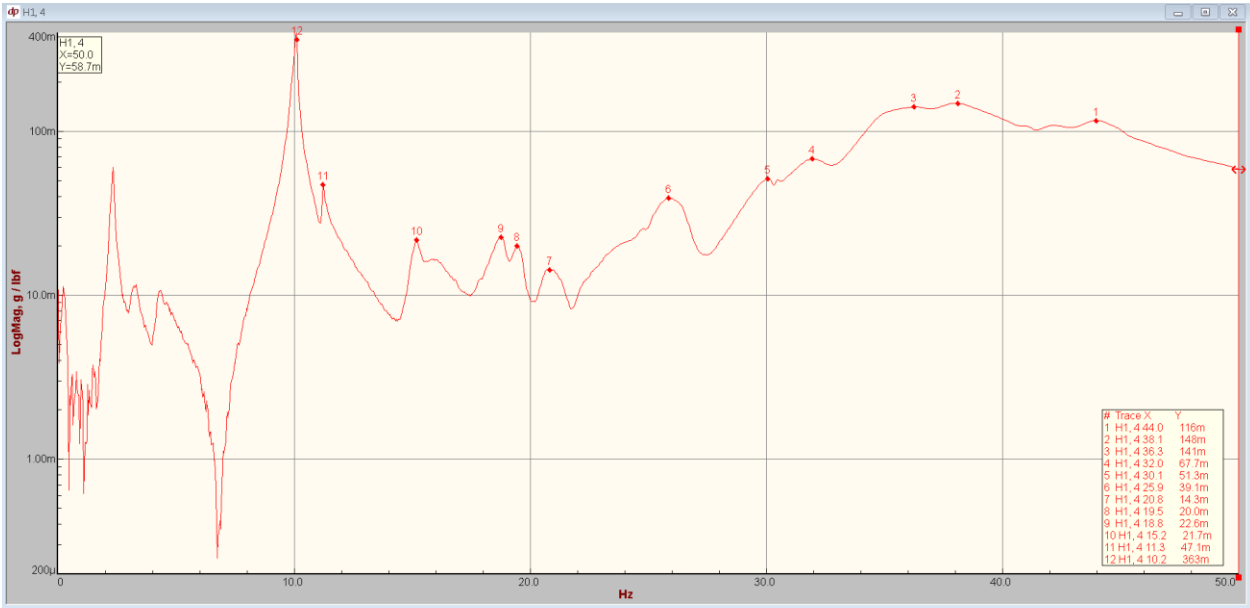
1. The elastic axis is located roughly 8 inches aft of the main spar.

2. The fuel tank front attach does not contribute significantly to torsional stiffness.

3. The torsional frequency with "standard" (30-gallon capacity) fuel tanks full is 36.3 Hz whereas with zero fuel, the torsional frequency is 39 Hz, a reduction of 2.7 Hz.

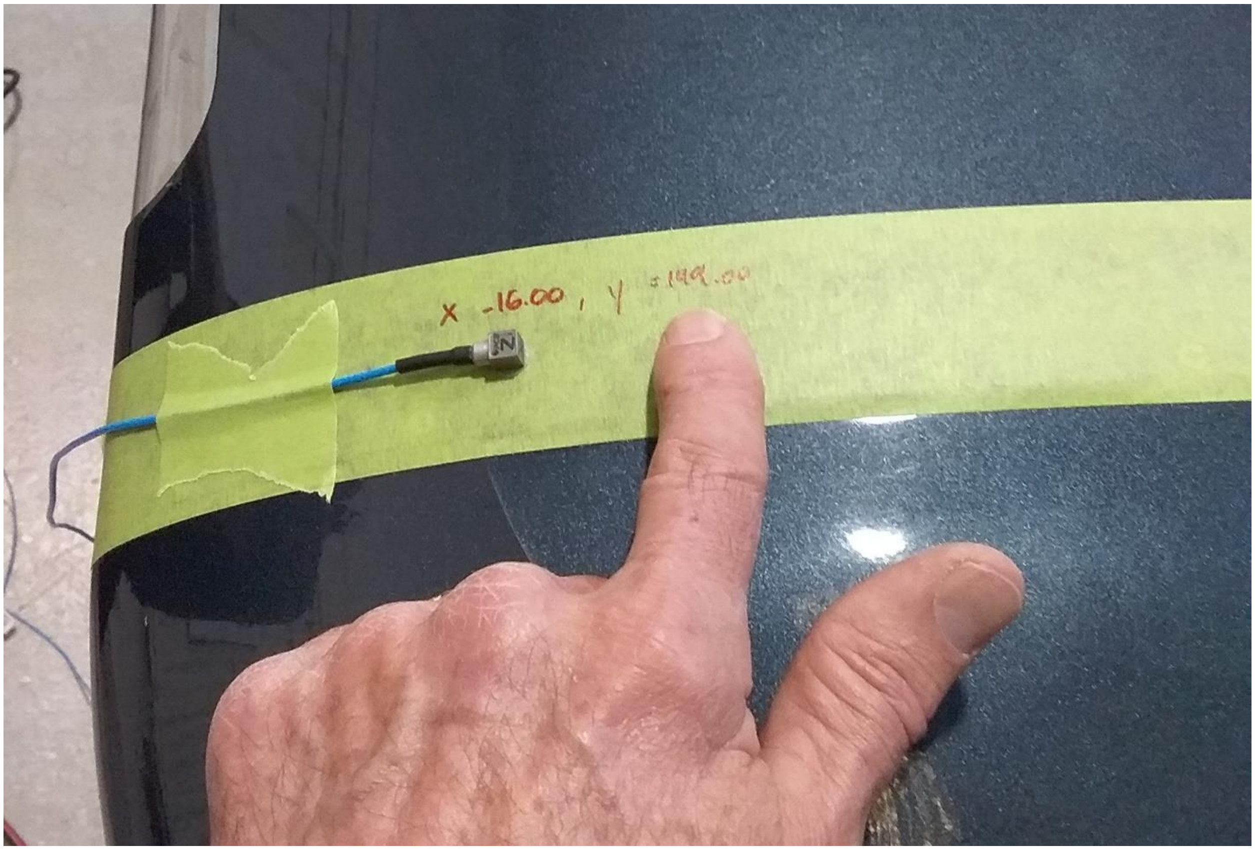
Overall, the modal impact testing revealed no surprises and confirms that there is no justification for reducing the never exceed speed of RV-10 or RV-14 when equipped with Sky Designs ER tanks.

Note 1. This is the norm among kit-built aircraft as only a small number of designs have had GVT & flutter analysis performed on them.



Acceleration in the Z (vertical) direction for the 20th impact test.

Calibrated hammer alongside the 4-channel signal analyzer and laptop used during the tests.



Accelerometer mounted on the wing of the test aircraft.

The author preparing for tests on a beautiful RV-10ER.