Structural Flight Testing

By John W. Thorp

The ever increasing amount of structural flight testing by EAA members on airplanes of their own design and construction gives pause to consider the risks that are being incurred and what can be done to minimize them.

The movie concept of a dive test requires the pilot to roll into an inverted position and then split-ess into a vertical dive from which he recovers by super human effort with both hands on the stick and both feet on the dash. It is a good day, the company is saved from financial ruin and the pilot makes an honest woman of the boss's daughter. If followed carefully, this technique is guaranteed to thin the ranks of homebuilt airplanes and EAA members.

Actually the dive test has two principle functions: (1) structural substantiation, and (2) establishment of speeds safe from flutter.

This piece will deal solely with structural flight testing and a later effort will cover flight flutter testing.

Actually **no dive** at all is required for the major portion of the structural flight test for most airplanes. What diving may be required is quite shallow and is obtained by a gentle push-over. If this sounds too tame and you elect the movie version, please do it over open country so that the splatter won't endanger other people or their property.

Any structural flight testing is dangerous and must be approached with utmost care. It is not unusual to make a number of flights to get the prescribed load factor and it is inviting suicide to rush this phase of the flight test program.

The prescribed load factors for homebuilt airplanes usually sound insignificant in comparison to the 9 "G" movie pull-out, but it is a considered opinion that some structural damage will be incurred in most amateur built aircraft without greatly exceeding the usually prescribed 3.8 "G's". This is in spite of the tendency of the amateur builder to "make them stout". Even professional designers frequently miss getting a uniformly strong structure and no matter how strong one part is—if the next one to it is weaker, the whole structure is no stronger than the weakest part.

The best insurance for a structural flight test program is to precede it with a static test program. This, however, is very time consuming and most "homebuilders" will want to pass up this exercise. Also, if the new airplant has been carefully built to a proven design, there is little point in static testing. In any case, a structural flight test can be conducted with reasonable safety if approached intelligently and cautiously. To this end, the following points are worthy of consideration:

1. Instrumentation

There isn't much that can go wrong with an accelerometer. However, most of the instruments in use are surplus and, at some juncture, they could have been roughly handled. Be sure that yours is in good working condition and is free from friction. It should show one "G" normal and when inverted should show minus one "G".

Since air speed is the key to being able to pull high "G's", be sure that your air speed meter and pitot-static system give a good calibration throughout the normal operating range (up to maximum level flight speed).

2. Load Factors

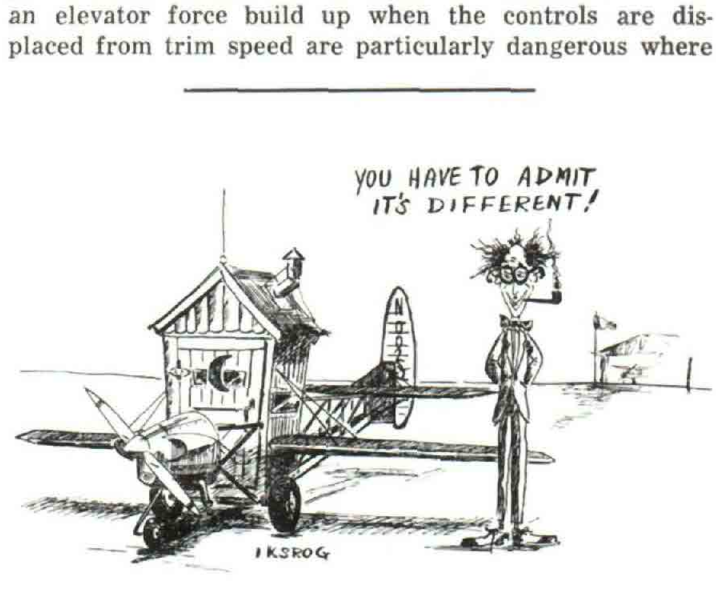
Maneuvering load factors are arbitrary for different classes of airplanes. 3.8 "G's" are usually sufficient to demonstrate structural integrity of airplanes which are not intended for aerobatic flight. 4.4 "G's" is sufficient for utility aircraft which may perform under aerobatics. 6 "G's" is minimum for an aerobatic category airplane. You should not attempt to demonstrate higher maneuvering load factors than the purpose of the airplane dictates. Don't be bold with dive tests.

3. Structural Deformation

All structures deflect under load. It is not unusual for airplane structures to deflect appreciably under static load test or structural flight test. This is to be expected, but what is to be avoided is permanent deformation after the load has been removed. The prescribed maneuvering load factors must be sustained without failure or **permanent deformation.** Most structural materials will have a breaking strength in tension of about 1.5 times the load that may be sustained without permanent set. Shear and compression also have failing values which are somewhat greater than those which first produce permanent set, but the ratios for most aircraft materials will not be as great as the 1.5 ratio in tension. An airplane structure will have parts under tension, compression and shear at the same time for any loading condition. It is probably reasonable to assume that any aircraft structure will take 10-20 percent more load before failing than it took at the first evidence of permanent set. If the airplane structure is carefully inspected at each increment of loading for evidence of permanent set (wrinkles, loose wires, sloppy fittings, etc.), before a higher load is applied, it should be possible to reduce the risk of an in-flight failure due to overloading to the point of insignificance.

4. Longitudinal Stability

The greater the longitudinal stability of the airplane, the easier it will be to avoid exceeding the load factor planned for any maneuver. Airplanes that do not exhibit an elevator force build up when the controls are displaced from trim speed are particularly dangerous where



maneuvered at high speeds and require extreme caution in a structural flight test program.

Longitudinal stability usually increases with forward movement of the CG. If any doubt exists as to the longitudinal stability characteristics of an airplane being structurally flight tested, the flights should be conducted with the CG as far forward as is practical for the intended use of the airplane.

5. **Pull Up Speeds**

Speed planning is the real key to conducting a safe structural flight test program. It is obvious that no greater load can be applied to an airplane structure than is required to **stall** the **wings** at a **given speed.** Since lift varies as the square of speed, so will the load factor for a given control displacement. The speed at which full and instantaneous control motion will produce stall is known as V_p (pull-up speed)

$V_p=\sqrt{h} \times V_s$ where:

h=prescribed load factor

Vs=unaccelerated stalling speed

If your prescribed maneuvering load factor is 4 "G's" and the flaps up stalling speed at design gross weight is 60 M/H

$V_p=\sqrt{4} \times 60=2 \times 60=$ **120** M/H

You should therefore be able to pull the stick back against the stop at 120 M/H without exceeding 4 "G's". Since it is impossible to pull the stick back instantly, the experienced load factor will actually be something less than 4 "G's". To demonstrate 4 "G's" this airplane would need to be flown at slightly more than 120 M/H. In any case, this is **not** the movie's screaming dive. Even if 6 "G's" was to be required, the speed would only be $\sqrt{6} \times 60=2.45 \times 60=$ **147** M/H.

6. **Summary**

a) Be sure of your instrumentation.

b) Pick a load factor reasonable for the purpose of the airplane.

c) Sneak up on your prescribed load factor in small increments and inspect structure for evidence of permanent set. Stop tests if permanent set is found.

d) Conduct test at a CG position as far forward as is practical for the airplane's intended use.

e) Determine maximum maneuvering speeds for several load factors up to that prescribed. Inspect for evidence of structural weakness at lower speeds before getting to high speeds. If you have no permanent set at one load factor and speed based upon a ratio of 1.1 of breaking strength to yield, you should be able to increase your speed by $\sqrt{1.1}=1.05$ or about 5 percent for the next test without incurring too great a risk of structural collapse.

f) Wear a properly inspected parachute for all structural flight tests and be sure that you know how to use it. Be sure that you can get out of your airplane tumbling as it will with a wing or tail missing. If you need jettisonable doors be sure that you can jettison them in an emergency.

Do your flight testing over open country and start your tests high enough that you will have a chance to get out if something goes wrong.

This is a serious flight testing job, so be serious about it and you will have a good chance of keeping everything in one piece—including you.

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Wing Ribs—Wood, metal, etc. One of each type in serviceable condition to be used in preparing an airfoil type and structure display.

Landing Gears—One of each type in serviceable condition (right hand preferably) to be used in preparing a display of landing gear development of the light plane. Early types especially needed.

Fuselage (Sections)—Wood, tube, or metal.

1. Fuselage sections—tail post forward to a point 24" forward of the foremost vertical fin and stabilizer attachment fittings.
2. Wing attach clusters.
3. Landing gear attach clusters.
4. Complete fuselages.

Fuel Tanks—Metal and fiberglas.

1. Fuselage.
2. Wing.

Propellers—Wood and metal.

1. Serviceable.
2. Damaged—can be prepared to display.
3. Cross sections of propellers.

Control Surfaces—Wood, steel tube and metal.

1. Ailerons; 2. Flaps; 3. Stabilizers; 4. Elevators; 5. Vertical Fin; 6. Rudder.

All of the above mentioned items should be of the sport or light plane category. This would include such early aircraft as Waco, American Eagle, Fleet, etc. Samples of World War I or earlier construction encouraged.

To avoid duplication, National Headquarters should be contacted prior to shipment of any items. To aid in reducing the work load of the restoration committee, if at all possible, items should be in serviceable condition. If metal, a primer coat will do.

Items listed below will also add to the value of your Air Education Museum.

1. Aircraft instruments.
2. Aircraft drawings — plans.
3. Photographs or negatives. (Negatives can be returned after photos are made).
4. Wheels and brakes.
5. Engine mounts.
6. Control sticks, rudder pedals, brake pedals.
7. Books, magazines, early aircraft literature.
8. Complete aircraft.
9. Wing spars and/or fittings.
10. Wing panels.

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