ATTENTION: ALL STEPHENS-TYPE MONOPLANE PILOTS

By Kermit Weeks
Photos by John Ford

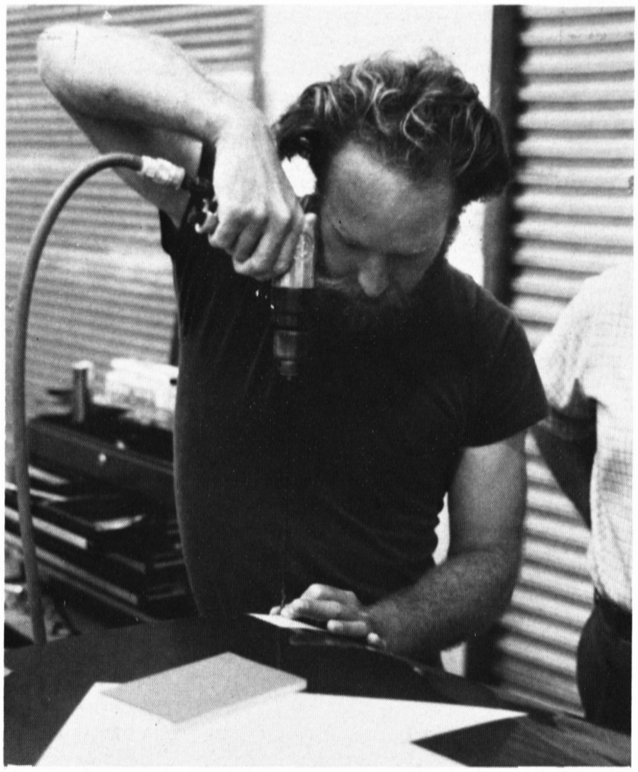
As most of you know, Jerry Thomas, one of our top Unlimited competitors, lost his life last year in the crash of his Stephens-type monoplane. It was a tradgedy for all of us who knew him well, as Jerry was a fun-loving guy and a very dedicated pilot-builder and aerobatic enthusiast. This article is to present some background to the accident and to share what we have learned from it.

The day of the accident Jerry climbed into his monoplane and took off for a routine practice flight. The weather was good with a light breeze as he headed for the box. We practice over a X-roads in the very edge of the Everglades about 10 miles SW of Tamiami Airport. It is uninhabited, other than an occasional target shooter who comes out to practice. An eyewitness, who himself was a charter pilot, watched Jerry practice for about five minutes, and then returned to shooting his gun. With his ear muffs on he heard what he described as "a loud resonant sound, similar to a snap-roll but 10-times as loud". He looked up and observed the aircraft in a near vertical dive at around 700 feet. Pieces of wood and fabric were fluttering down as if the wing had "exploded". The right aileron was in trail and the aircraft hit at an angle of about 60 degrees, wings level. Jerry was killed instantly.

At first we all had suspected that the prop, a 3-bladed Hoffmann, had slung a blade and hit the wing. Leo Loudenslager had lost a blade on his 2-bladed Hoffmann several months earlier (see *Sport Aerobatics*, March '82). After investigation, there was found no indication of wear between the engine and the mounts, cowling, baffles etc. as would have been the case with an unbalanced engine. No blade pieces were found, other than at the crash site.

The left wing and tail were intact other than impact damage and the right wing main spar was intact. Most of the right wing structure was gone except for the aileron, which was still attached to the fuselage by the torque tube. Pieces were found for ½ mile downwind.

Strong indications showed that the aileron had fluttered. The aileron hinges had torn themselves out of the rear spar and were intact with the portion of rear spar to which they were bolted. Pieces of the rest of the spar were found with the furthestmost pieces from the wreck, indicating departure from the wing early in its destruction. The balance weight pieces were found at the crash site, so flutter due to imbalance was ruled out. Almost all of the right wing leading edge strip was found intact which indicated even more that the prop had not separated. No prop pieces other than at the crash site were found.


Jim Roberts virgin wingtip about to be drilled to attach "shaker".

From all the studying of the evidence and discussing the pros and cons of our theories we still didn't have a concrete answer. The wing had fluttered at some point in its destruction, but we didn't know if the flutter had caused a structural failure or a structural failure had caused the flutter.

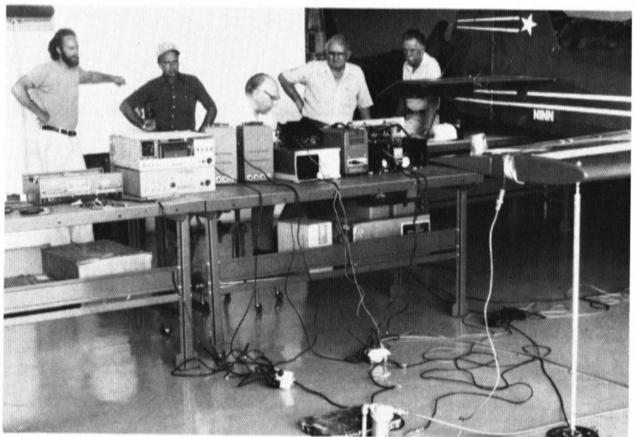
To help understand what had happened, the idea of running flutter tests on the monoplanes was brought up. In talking with Curtis Pitts we were refered to a man who had done testing for the factory and was well reputed in his field. This man was Leon Tolve from Atlanta, Georgia.

Leon is probably the World's most leading authority on Flutter. He was in on the beginning of the science, back when airplanes were venturing into new speed realms and encountering these new problems. He has done flutter tests on almost every aircraft that has been in the Air Force inventory, from the P-38, P-51 and B-17 to the F-86, F-104 and C-5A. He worked for Lockheed for 16 years and now still consults for them and other aircraft manufacturers.

We had the opportunity to bring him to Miami and have him look at the wreck and other Stephen-type aircraft. During this first meeting we, of course, had many questions about flutter: If a blade had come off, could the resulting vibration induce flutter? No, there would be no correlation between the engine vibrating frequency and the natural frequency of the wing. Does it help to flutter test your airplane at different speed increments and "hit the stick" to prove that your aircraft is flutterproof? No, a certain condition or conditions may be needed that these type tests may never show up. Does 100% or more balancing prevent control surface flutter? No, as we shall see in the case of the Stephens-type wing. Our questions were endless and the more we asked the more we realized how little we knew and how much there was to learn.

We concluded that the tests should be done and arranged for a date to start. One concern we had expressed was the difference in the construction of the different Stephens-type wings now flying; some have stringers while others do not, some have different aileron sizes, some have different skin thickness etc. After discussing the possibilities, we decided to arrange for two different aircraft with dissimilar wing constructions.

The first aircraft was built by Norm Nielsen, N1NN. It was built literally side by side to Jerry's in my shop and was, for all practical purposes, identical. The second aircraft was Jim Roberts, N20JJ, and is a sister ship to Leo Loudenslager's (N10LL), Jim's wing has different rib construction and also has span-wise stringers while Norm's does not. Soon both aircraft were at my new shop and we were helping Leon set up his equipment.

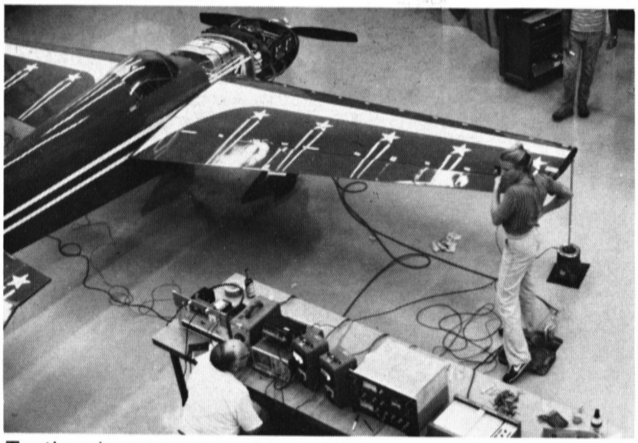


Leon setting up his equipment. Note: the shaker on the floor and accelerometer in place on wing.

After having taken all the root fairings off, the aircraft were set up in a level attitude. A "shaker" was set under each wing-tip on the floor. After a small hole was drilled in each wingtip, a rod was attached between the tip and the shaker. The shakers were used to induce vibration to the wing which could be measured by a small accelerometer placed at various fixed positions on the wing. Leon could change the frequency (amount of shakes or cycles per second) and the amplitude (the distance the wing moved through each cycle). This was used to determine the wing's natural frequencies.

All wings and ailerons have certain natural frequencies at which they will flutter. The speed at which they will flutter changes with different constructions and design techniques. Certain precautions and design considerations can be taken to increase the speed range beyond which the aircraft flies. The frequency at which they will flutter is related to the speed at which they will flutter.

There are two modes of flutter that the wing has. A torsional mode, where the wing rotates around a lateral axis, and a bending mode where the wing bends around a longitudinal axis. These modes occur at different natural frequencies of the wing. The axis of rotation, which doesn't necessarily have to be a straight line, is called the "node" line. Our concern, was to plot these node lines and the different natural frequencies, and note their relationship to how the aileron should be balanced.

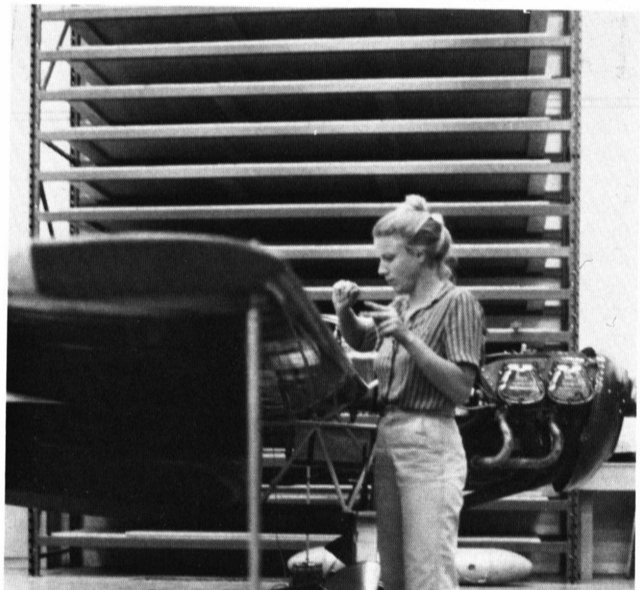


Testing in progress with cowling and fairings removed for wing freedom. Note: the tape locations on the wing where accelerometer was placed for different readings.

Within five minutes of shaking the wing, Leon said that we had a problem. For proper flutter dampening the aileron counterweight had to fall outside the bending mode node lines and behind the torsional mode node lines. The torsional mode node lines on both airplanes tested fell behind the balance weight at the tip (Fig. 1). The bending mode node lines were obviously well inside the tip counterweight an were not a factor.

While both airplanes tested the same in the torsional mode, the span-wise stringers in Jim's wing gave him a higher frequency in the bending mode, but this was not a problem area. The builder who thought he was doing himself a favor by over-balancing his aileron at the tip was making things worse. Any extra weight at the tip was like adding it directly to the trailing edge of the aileron!

For me to try to explain about something which I don't totally understand would not be appropriate. Leon



Linda Meyers helping by moving accelerometer to the different positions.

Author looks on as Leon records data.

Leon explains data with interested onlookers.

has agreed to write an article at a later date that would explain the concepts of flutter and how they relate to us. For now he states that the "aileron was not adequately dynamically balanced to preclude flutter in a wing torsional aileron-rotation mode. The aileron was statically balanced but was not adequately dynamically balanced." He also feels that "the wing is not tied into the fuselage as good as it should be." While not a structural problem, the wing would have a higher frequency (hence higher flutter speed) if it were more securely attached.

After several weeks of sorting out his data and running computer programs, Leon came up with the attached data (Fig. 2). Realizing the difference in certain aileron sizes, several weights are given for a particular aileron case. Unless you plan to red-line your Stephens-type monoplane below 160 mph, this is a MANDATORY modification!

Basically all ailerons should be balanced with 1.75 lbs. at the tip and with a "spade" type balance 42" in from the tip. This inboard weight will depend on the size of your aileron but **must** be located 8⅜" from the hinge centerline. Conforming to these changes should give your aircraft a flutter speed in excess of 300 mph.

Another problem that has arisen is the construction of nose-ribs in certain wings. Henry Haigh recently sent his wing back for re-skinning after noticing small cracks in his leading edge and small slivers of wood coming out of his drain holes. When they de-skinned the wing they found that every nose-rib, other than at the tip and root, was broken. Henry's wing had 160 hrs. on it.

Apparently, early in the design, the nose-ribs were constructed with a single hole cut out of the plywood for lightning. Later, after a redesign, a larger cut-out was noted in the plans, following the same shape as the nose section (Fig. 3). Henry's ribs were all cracked in the corners as shown. Jerry's ribs were of the same construction and may have contributed to the accident. As the ridgidity of the wing is lost, the speed at which it will flutter will be lower.

I would strongly suggest to anyone with a Stephens-type monoplane to determine what type of rib construction your wing has and make sure that it is properly designed. While not a flutter consideration, Leon suggested that the span-wise stringers are of good design technique and should be installed during construction or re-skinning. In talking with Leo Loudenslager, he stated that he had the original nose-rib design and stringers installed. With over 700 hrs. on his wing he has had no apparent leading edge problems.

I'm saddened that it took the life of a close friend to realize a problem about which we were unaware. At times it seems that sacrifices are made so that others may learn. As back in the 30's, our homebuilt designs are going faster and faster into higher speed realms and problem areas. I can't help but wonder how many of the faster homebuilts are flying today without the testing for flutter tendencies. I can only hope that we can benefit from a science that has already made it's mistakes.

Fig. 1

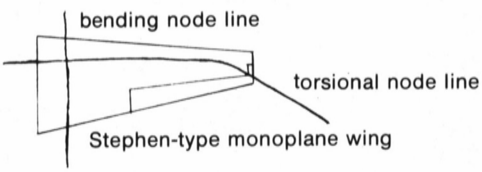
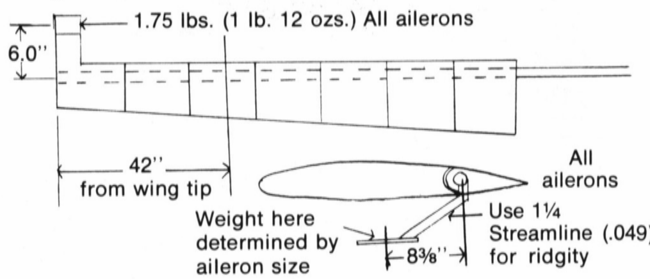


Fig. 2



Aileron Size	Weight at Tip	Weight at 42" Station
Standard Length (83")	1.75 lbs.	2 lbs. 8 oz.
One bay longer (95" approx.)	1.75 lbs.	3 lbs. 1 oz.
Two bays longer (107" approx.)	1.75 lbs.	3 lbs. 6 oz.

1. All weights are in addition to supporting arms.
2. Measurements are from aileron hinge centerline to C.G. of weight.
3. 42" Station Weight may be in the form of spades, ball, tear-drop etc. but C.G. of weight **MUST BE** 8⅜" from hinge centerline. It **may not** be moved for or aft and be compensated for by more or less weight.
4. Tip Weight **MUST BE** 6" from hinge centerline.

Fig. 3.

Original type — Re-designed type