FLIGHT TESTING OF ZENAIR XL G-EXLL WITH AILERON MASS BALANCES AND STRUCTURAL REINFORCEMENTS

Contents

1. Summary

In October 2008 Zenair issued a service bulletin ZE-2008-01 which revealed that aileron flutter could occur on CH601-XL aircraft if the aileron cable tensions were insufficient, and calling for the cable tension to be set to 25-35 Lbs to prevent aileron flutter. Bearing in mind the number of in-flight break-ups involving wing failures which had occurred overseas with these aircraft, the LAA did not consider it satisfactory to rely on aileron cable tension to avoid aileron flutter because the manner in which these aircraft are maintained and operated means that cable tension might not be preserved in service. CAA subsequently issued an MPD 2008-006 which grounded the UK fleet of Zenair CH601 XL aircraft pending actions to restore the structural integrity of the wing.

LAA, working with the kit manufacturer Zenair have developed discrete internal aileron mass balances, and also additional reinforcements to the wing root attachments and centre section spar web to address low reserve factors identified in these areas during a re-evaluation of the aircraft structure by the LAA.

This report describes the flight tests carried out to evaluate the first aircraft fitted with these modifications, which included checks on the wing/aileron damping, freedom from flutter, longitudinal stability, elevator trim system and ASI position error throughout the speed range. The wing/aileron responses were found to be heavily damped over a wide range of aileron cable tensions and between 98 and 100% static mass balance. The aircraft was found to be longitudinally unstable at the previously recommended aft cg limit particularly with the elevator trim bias spring connected. The elevator trim sensitivity and range also raised concerns about the risk of overstressing / overspeeding the aircraft in the event of a trim runaway, particularly in the nose down sense.

The tests amounted to eight hours flying in 17 flights. A summary table of the individual flight conditions is shown in Appendix A.

2. Aircraft Tested

The aircraft tested was a standard amateur-built Zenair CH601 XL G-EXLL, built from a kit supplied by CZAW, with a Rotax 912-ULS engine and Woodcomp 3 bladed SR3000 variable pitch propeller. The aircraft is the standard nosewheel undercarriage variant with standard front-hinged canopy retained by two cable-operated latches. The aircraft was fitted with the standard optional servo-operated aileron trim tab on the starboard aileron, and the standard optional wing lockers. The ailerons were hinged using the standard optional piano wire hinges rather than ‘flexible skin’ type hinges. The aircraft was fitted with a single ‘Y’ configuration control column. The pitch trim servo was not fitted with the optional speed reducer. Wheel spats were fitted to all three wheels.

3. Condition of Aircraft

The aircraft was in excellent aerodynamic and mechanical condition, having accumulated only approximately 200 hours flying hours since newly completed in 2004.

The aircraft contains various features standard on the UK-built aircraft as supplied by CZAW which are understood to differ from earlier examples, and early US kits and LSAs, as follows:

- Full-span elevator trim tab on port elevator (drg 6-T-6 dated 08/05)
- Elevator trim bias spring connected to flap system to reduce the nose-down trim change when flaps are lowered (drg 6-BO-4CZ)
- More positive wing setting angle on fuselage

In addition, prior to this test program the aircraft had been modified as follows:

- Additional aluminium alloy vertical reinforcement angles fitted to wing root attachments and centre section main spar web.
- Discrete aileron mass balances fitted at outboard ends of ailerons, internal to wing, mounted on aluminium alloy ¾” square box-section tubes sandwiched between additional ribs fitted to ailerons.

- An emergency canopy jettison system was fitted.
- It was checked that flap up-stops were fitted per Zenair service letter ZE-2009-01 and drawing 6-S-3.

4. Test Equipment

- The aircraft was equipped with a typical instrument fit consisting of a Dynon D10A EFIS and EIS 4000/6000 engine monitoring system, with mechanical back-up ASI, altimeter and compass. The Dynon D10A included a ‘g’ meter display including a ‘max recorded g’ bug.

- In addition to the standard flight instrumentation the aircraft was fitted with four accelerometers, aligned vertically, mounted on brackets riveted to the extreme outboard ends of the wing front and rear spars. The accelerometers were connected to a data logger mounted in the cockpit, powered by an internal battery. The accelerometer wiring was taped along the aileron and flap shrouds and up the fuselage sides to enter the cockpit under the canopy seal. The logged data was downloaded onto a laptop after each flight for processing.

- A hand-held GPS 12XL was used to measure ground speed during the ASI position error testing.

- Spring-balance ‘meat hook’ type force gauges used to measure stick forces, 0-6 Lbs and 0-50 Lbs range

- A conventional aircraft cable tension gauge was used to measure aileron cable tensions

5. Personnel

The aircraft was flown by F.Donaldson, the flight test engineer was N.Bamber, the flight test observer was A.Draper. Inspection coverage was provided by G.Johnson and M.McBride. The wiring of the accelerometers to the data-logger was carried out by J.Viner.

6. Weight and Balance

The aircraft was re-weighed immediately prior to the test program to establish an up-to-date weight and balance. The aircraft had an empty weight of 314 Kg and empty cg of 313.3 mm AOD, datum being the leading edge of the wing at the root. This results in the max loaded forward cg position of 342mm AOD with a solo 55 Kg pilot and maximum fuel, and a typical aft cg case of 508mm AOD with two 86 Kg crew and no fuel, with 20 Kg baggage in the rear, or 455mm AOD with just 3 Kg baggage in the rear baggage bay.

The cg limits for the type were originally 300-455mm AOD, but were extended later by CZAW to 300 – 520mm AOD.

Most examples of the CH601-XL (including G-EXLL) incorporate baggage bays in the wings which can be used instead of the rear fuselage baggage bay when it is necessary to carry weighty baggage. As the wing baggage bays are very close to the loaded cg of the aircraft, baggage placed in the wing baggage bays has no significant effect on the loaded cg.

In order to allow loaded cg positions to be achieved back to the furthermost rear cg limit during the tests, two 20 litre plastic containers were anchored into the extreme rear of the rear baggage compartment using rope, and filled with water as required for each loading condition.

7. Ground Checks

The aircraft was flown initially with aileron cable tension set at 20 Lbs, which seemed appropriate by ‘feel’. This was less than the Zenair recommended range of 25-35 Lbs as promulgated in their service bulletin. It was noted that raising the aileron cable tension to 35 Lbs and above resulted in distortion of the wing rib which the aileron bellcrank is mounted on, which in turn caused local distortion of the wing skins. This raised concerns about the implications for this area of operating with high control cable tensions, in particular the rivets loaded in tension attaching the stiffeners to the ribs where the ailerons bellcranks are mounted, where the prizing action caused by rib flexure could lead to early cracking in the ribs from the rivet holes.

It was noted that irrespective of the cable tension set, the drive cable to the starboard aileron was consistently reading 2 lbs higher tension than that in the port aileron cable, despite this being a closed-loop system. It has been suggested that this is due to the asymmetric design of the ‘y’ shaped control column, making the control column assembly tend to ‘fall over sideways’ when ‘stick-free’. No other explanation could be found for this effect. The cable tensions referred to henceforth in this report refer to those in the port aileron drive cable ie the lesser of the two.

It was checked that with both aileron drive cables disconnected, each aileron was 100% statically mass balanced as installed ie was balanced about the hinge line with no tendency for the trailing edge to rise or fall from the neutral position when released, or to overshoot more in the upwards or downwards direction when nudged up and down.

It was checked that with this aileron cable tension there was no undue friction in the aileron controls or aileron hinges. The break-out force measured at the stick grip was 0.3 kg (0.7 Lbs) with negligible free-play.

It was checked that with the aircraft standing static on its wheels, when the wing main spar was tapped vertically at ether wing tip using a steel crowbar impacting on a protective wood block, the accelerometers on both wing tips recorded a 10 Hz symmetric (ie in-phase) oscillation which is reasonably consistent with the predicted primary wing bending frequency of 8 Hz produced by 2D FEA (ZBAG report CH601XL/RPT/80-006).

It was checked that the pitot-static system was the standard one shown on the Zenair drawings, with a combined pitot-static mast mounted under the port wing per drawing 6-W-9.

It was checked that the elevator trim tab range of movement was 22 degrees up and 23 down. The up travel (ie down trim) stated on the drawings is 20 degrees while the down travel (ie up trim) is stated to be 40 degrees on the drawing. It was not possible to determine why the deflections on the drawing had not been achieved. The time taken to motor the electric trim from full up to full down, and vice-versa, was 11 seconds.

8. General Handling

As with other examples of the Zenair CH601XL tested previously, G-EXLL was found to have straightforward handling characteristics with a forward cg, the main issues being the poor control harmony due to relatively heavier aileron control forces than elevator forces, significant nose down pitch trim change with flap deployment, and the relatively low flap limiting speed of 65 KIAS.

Considerable right rudder force was required to keep straight during the take off roll, as is normal with the Rotax 912 series engines. At aft cg the aircraft has weak longitudinal stability and a tendency to over-rotate on take-off and leap into the air rather than unsticking progressively.

All the flying controls are powerful and easy to operate. The cockpit seating position is excellent and the view from the cockpit very good thanks to the bubble canopy. The forward view on approach is adequate with flaps up but much improved with flaps lowered due to the more nose-down pitch attitude generated. The flaps give a significantly steeper approach path allowing easier approach speed control and shorter landings. Landing characteristics were straightforward.

The aircraft was found to have good stall characteristics, being reluctant to drop a wing, and significant natural pre-stall warning was provided by buffeting / rattling of the rear fuselage and tail at 3-4 kts above the stall.

The lateral stability was positive as indicated by the lower wing rising on releasing the stick in a sideslip, and turns on rudder alone. The directional stability was strong with rudder fixed. When feet-off, the rudder tended to ‘stay where it was put’ in flight, feeling as though there was a great deal of friction in the nosewheel steering, despite the fact that when parked on the ground, with the nosewheel lifted off the surface the rudder centering springs easily overcame the static friction in the nosewheel steering and rudder circuit. This may be due to the effect of mild aerodynamic overbalance on the nosewheel spat which is bathed in the propeller slipstream, and might be improved by adding a nosewheel spat finlet.

Nevertheless, in normal flight the strong rudder-fixed directional stability and relatively small degree of adverse yaw generated by aileron inputs meant that directional control was straightforward and it was not difficult to maintain the aircraft in balanced flight or to kick on and off the drift in a cross wind landing. The lateral / directional characteristics were considered satisfactory.

9. Wing/Aileron Flutter

The aircraft was flown initially at speeds of 80, 100, 120, 140 and 147 KIAS with 100% aileron static balance and 20 Lbs aileron cable tension, inputting stick jerks and shakes and then first releasing the stick and then restraining it to test stick-free and stick-fixed behaviours respectively. In separate tests, stick inputs were made in roll and pitch to attempt to induce asymmetric and symmetric aileron motion. The tests were flown at around 6000 ft, light weight and aft cg. A marking pulse was used to identify each successive test on the logger output, operated by a push button on the logger which was pressed prior to the commencement of each test.

The outputs from the accelerometers were examined between flights to check that there were no signs of reducing damping with speed.

At all speeds tested, the aileron response appeared heavily damped in flight with no more than one or two overshoots following cessation of the control input excitation.

The tests were then repeated with the aileron cable tension slackened off to 5 Lbs, which was considered to be the lowest conceivable tension that might occur in service. With this tension, the control system felt decidedly sloppy in roll and rocking the aircraft on the ground led to the cables slapping on the wing skins. Due to stretch in the control system, the amount of aileron movement available in flight was reduced by approximately 30% at high speeds. There was no noticeable reduction in the damping of the wing/aileron response with the slack aileron cables, either as observed in flight or from the accelerometer outputs, although it was noted that the amount of excitation was reduced due to the lesser aileron deflections that could be achieved.

The tests were then repeated with the aileron cable tension raised to 30 Lbs and lumps of plasticene weighing 20 grams attached to the port and starboard aileron trailing edges in line with the spanwise position of the aileron mass balance arms, to simulate the effect of the ailerons being only 98% mass balanced. There was no noticeable reduction in the damping of the wing/aileron response with the plasticene weighted ailerons, either as observed in flight or from the accelerometer outputs.

The final series of tests was carried out with the plasticene weights on the ailerons and the aileron cable tension reduced to 10 Lbs, to establish an adequate safety margin on cable tension exists with the ailerons 90% balanced. There was no noticeable reduction in the damping of the wing/aileron response with the slack aileron cables and underbalanced ailerons, either as observed in flight or from the accelerometer outputs.

A more detailed description and results from the aileron flutter investigation are provided in the associated report ‘Zenair CH601-XL G-EXLL Flutter Flight Tests’ by N.Bamber dated 30.7.09.

10. Longitudinal Static Stability

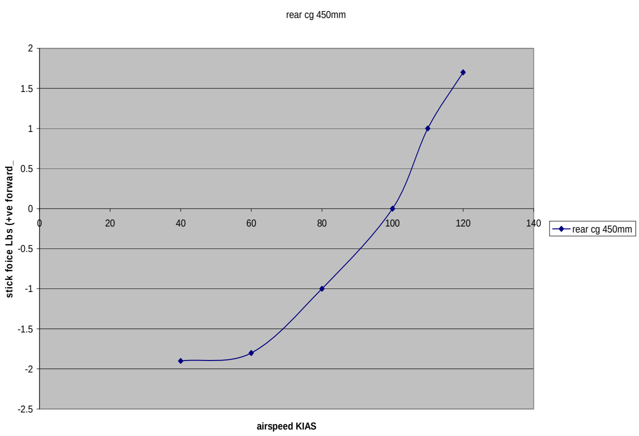
The static longitudinal stability was measured over a range of centre of gravity positions by trimming for a mid-range airspeed and then noting the stick force required to hold an airspeed displaced from the trim speed.

With the trim bias spring connected, the aircraft was mildly statically unstable with the cg at 500 mm AOD, flap up (flight 2). The aircraft needed a rearward stick force to maintain a speed above a trim speed of 100 KIAS and a forward stick force to maintain a speed below the trim speed. The aircraft could be trimmed with flap down at 60 KIAS but was also statically unstable in this configuration, although this was difficult to measure because of the aircraft’s low flap limiting speed which results in a narrow useable speed range of only about 30 KIAS with flaps down.

With the trim bias spring disconnected,(flight 15) the aircraft was neutrally to marginally positively statically stable with the cg at 503 mm aft of datum, flaps up, at speeds above a 100 KIAS trim speed, but became increasingly statically unstable at speeds below the trim speed. With hands off, if the speed was displaced below the trim speed, the aircraft would eventually pitch up markedly into the stall and from below 40 KIAS would require significant forward stick movement to arrest the nose-up pitching tendency and regain a level attitude.

With the trim bias spring disconnected, flap up, the aircraft was just positively statically stable with a cg at 450 mm AOD, (flight 16). From a 100 KIAS trim speed in level flight, the following results were recorded:

IAS KTS	Stick force
40	1.9 Lbs back
60	1.8 Lbs back
80	1 Lbs back
100	0
110	1.0 Lbs forward
120	1.7 Lbs forward



Despite the flat gradient of the stick force versus speed relationship, the control harmony of the aircraft was such that the changing forces were clearly perceptible and together with the other cues provided by attitude, cockpit noise etc provided adequate warning of the impending stall and proximity to Vne and was not atypical of other small amateur-built aircraft in this class.

With the flap fully down, power for a 3 degree approach, an approach speed of 60 KIAS and full up trim there was a residual rearward stick force of 6 Lbs required. Holding the aircraft at the slower speed of 50 KIAS resulted in a barely perceptible increase in the residual stick force, which implies that the aircraft was positively statically stable with full flap at this cg and power setting despite the stick forces being dominated by the out-of-trim created by the nose-down pitch associated with flap deployment.

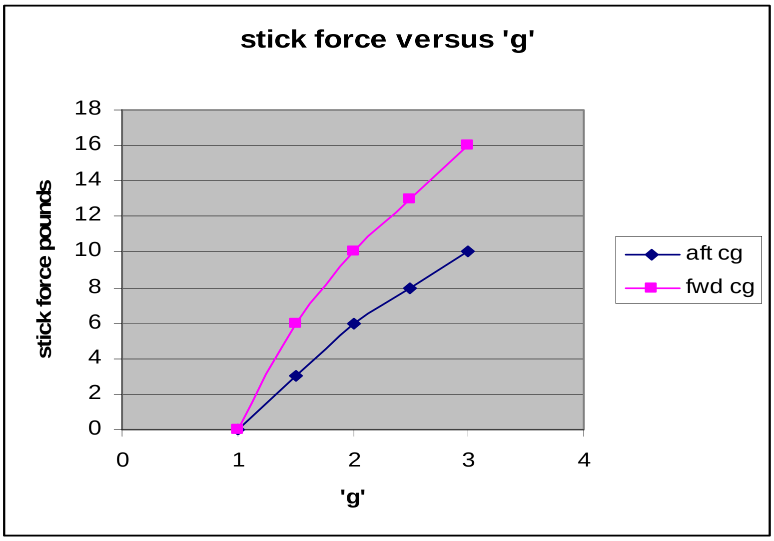
A brief assessment of the flap-up free-return characteristics was made by trimming the aircraft in level flight at 100 KIAS, settling the speed 20 knots above the trim speed and releasing the stick. With a cg of 450 mm AOD the aircraft returned lazily to settle at any speed within 15 kts of the trim speed after around 65 seconds, with two overshoots. With the cg at 369 mm AOD the free return results were more positive and the aircraft settled within 12 kts of the trim speed after around 55 seconds, with three overshoots.

Despite the low levels of longitudinal static stability, with the cg at or forward of 455 mm the aircraft did not require excessive concentration to maintain a desired airspeed, attitude or flight path whether in the climb, cruise or approach configuration.

11. Stick force per g

Stick force per g was assessed in wind-up turns with a cg of 450mm and 369mm AOD (flight 16 and 17). Stick force per g measurements were hampered by the limitation imposed during the test of not exceeding 3g pending the results of the structural load testing, so that it was necessary to use great care not to exceed this level. The ‘g’ level was increased progressively to 3.0 g, requiring a 75-80 degree banked continuous turn at 100 KIAS and full power. It was difficult to read the stick force gauge while flying the aircraft with the degree of accuracy required in this manoeuvre while attention was focussed inside the cockpit. A stick force gauge in the range 0-15 lbs with an expanded scale, tell-tale or electronic monitoring would be very helpful in this type of solo testing. The stick force measurements were as shown below:

	Stick force Lbs	Stick force Lbs
Normal acceleration ‘g’	Forward cg 369mm AOD	Aft cg 450mm AOD
1.0	0	0
1.5	6	3
2.0	10	6
2.5	13	8
3.0	16	10
Stick force per g (Lbs)	8	5
Extrapolated estimated stick force at 4g (Lbs)	20 - 22	12-14



It is noticeable from the results that the stick force per g has a reducing trend with increasing ‘g’.

While these results indicate that there may be a slight shortfall in meeting the CS-VLA requirement of a minimum of 7 daN (15 Lbs) stick force to reach limit load, the error band due to the method of measurement plus the uncertainty of the extrapolation makes this undetermined at this point. There was no tendency to overshoot a desired ‘g’level and the aircraft could be manoeuvred with ease without fear of overstressing. The manoeuvre stability at an aft cg of 455 mm seemed no weaker than many other popular aircraft of this category (eg Vans RV6) and seemed acceptable on that basis.

12. Elevator Trim

The elevator trim was operated by a pair of buttons in the top face of the P1 stick grip. A multi-LED bar indicator on the instrument panel provided trim position indication.

In normal use the elevator trim seemed sensitive, with only very short jabs being required on the trimmer buttons to make small trim adjustments. It was difficult to capture a desired trim setting because the low level of longitudinal static stability resulted in the speed tending to wander away from the trim speed, and the time needed to observe whether this was due to the trim setting being incorrect or merely the long-period response to tiny gusts exaggerated by the width of the free-return band.

The correct trim position for take-off was neutral, irrespective of cg position, which corresponds with the trim tab being approximately in line with the elevator.

Due to the ‘y’ configuration of the central stick, the stick grips were orientated at approximately 30 degrees from the vertical with ailerons in the neutral position. This meant that unlike in the twin-stick Sportcruiser flown recently which shares the same type of stick grip and trim buttons, there was no tendency for inadvertent trim inputs due to the weight of a chart or flight guide resting on the stick grip, because with the ‘y’ stick arrangement the top ‘corner’ of the stick grip acted as a shield for the buttons.

It was noted that there was very little change in pitch trim with speed or power, but a substantial nose-down change in pitch trim when the flaps are lowered.

With trim bias spring connected, at aft cg (flight 3) it was just possible to trim the aircraft in the approach configuration ie power for a three degree approach, with full flap and full up trim. With forward cg (flight 1) there was a slight residual back stick force required (approximately one pound) to trim in this condition.

With the bias spring disconnected, (flight 17) a substantially greater residual back stick force of 6 Lbs was required in the approach configuration with full flap. Releasing the stick in this condition would result in an immediate and severe nose-down pitch.

It was noted that even when flying at the extreme aft cg limit of 500mm AOD, when trimmed in the high speed cruise the trim position was approximately at the neutral position, in other words there is no situation when the ‘down trim’ part of the available range is required.

Looking at the trim runaway case, at aft cg when trimmed for the cruise at 110 knots IAS, pushing and holding the ‘up’ trim button while leaving the stick free resulted in a strong nose-up pitch rate developing after approximately three seconds, but without pilot intervention this could be allowed to take its course for six seconds at which point the nose-up attitude had reached an estimated 45 degrees and the trim servo had reached the full up position. The maximum ‘g’ experienced in the six second period was 1.4g, which was bleeding off by the end of the six second period due to the airspeed sagging away in the climb. The forward stick force required to hold the aircraft in level flight against full up trim was 8 Lbs. This response to the simulated nose-up trim runaway did not seem hazardous.

In the nose-down runaway case, from the same initial conditions, the nose-down pitch rate, hands-off was immediately very strong and pilot intervention was required after only three seconds to avoid a hazardous combination of speed/attitude being reached. At this point the aircraft was diving at an angle of about 30 degrees with a significantly increasing nose-down pitch rate, and ‘g’ rapidly reducing through zero. At this point the trim servo had only reached approximately half of its available travel. From the three-second intervention point it was necessary to close the throttle fully and apply a very positive but not excessive rearward stick force to recover the aircraft to level flight without exceeding Vne or manoeuvre limits. The minimum ‘g’recorded in the manoeuvre was -0.2.

The aft stick force to hold the aircraft in level flight against full nose down trim was 20 Lbs.

It was considered that the bunting sensation obtained in the nose-down runaway case could be very disorientating to a pilot not accustomed to aerobatics and that failing to intervene after four seconds or more would inevitably lead to the aircraft departing from the permitted flight envelope. The response to the nose down pitch runaway was considered potentially hazardous.

13. Pitot-static Position Error

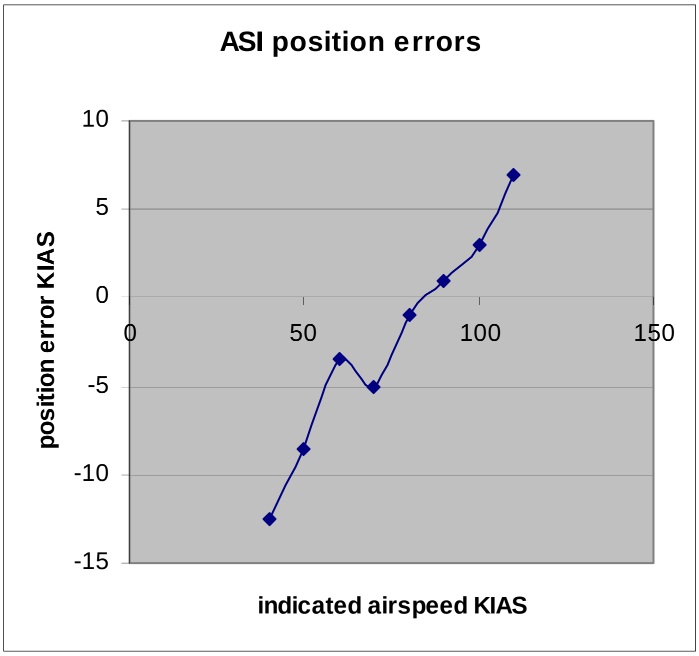
The position error was calibrated by flying level into wind and downwind at the same height over a range of indicated airspeeds, and comparing with the average of the GPS true ground speeds recorded at each indicated speed, corrected for density altitude and ASI instrument error. The results are shown below.

The discontinuity in the results at 70 KIAS is not necessarily significant, being most likely the results of the readings all being subject to error bands of at least 2 knots by virtue of the difficulty of maintaining the test point airspeeds with greater accuracy, especially on the rather windy day used for the test.

Altitude: 6000 ft on 1013 mB
Air temp: 17 degrees C at ground level

IAS KTS	GPS MPH Into wind (250 M)	GPS mph Down wind (070 M)	GPS mph average	GPS Kts average	GPS EAS Kts	ASI instrument error kts	Position error Kts
40	37	86	61.5	53.5	50.5	+2	-12.5
50	43	95	69	60	56.5	+2	-8.5
60	55	100	77.5	67.5	63.5	+0	-3.5
70	66	111	88.5	77	73	+2	-5
80	75	121	98	85	80	+1	-1
90	84	131	107.5	93.5	88	+1	+1
100	96	140	118	102.5	97	+0	+3
110	104	147	125.5	109	103	+0	+7
120	112	156	134	116.5	110	TBD	TBD
130	126	168	147	128	121	TBD	TBD

NB Results for 120 and 130 KIAS not yet available because the ASI instrument calibration test set that was available only read to 110 knots.



14. Discussion

The aileron mass balances appear to be completely effective in eliminating flutter at airspeeds up to a Vdf of 147 KIAS, with a range of aileron cable tensions between 10 and 30 Lbs and static balance from 90 to 100%. The wing/aileron system appears to show heavily damped responses to control inputs, throughout the speed range.

In pitch, the aeroplane has generally light stick forces in normal flight but an unusually strong nose-down trim change with flap. The trim bias spring system, which was a late addition to the design by CZAW, intended to counter the trim change with flap, has further eroded the already weak static stability at aft cg, due to the bias spring acting as an ‘up’ spring which is de-stabilising. The effect of the bias spring is to bring the stick-free neutral point forward of the CZAW rear cg limit of 520mm.

Satisfactory longitudinal static stability and stick force per g is obtained by removing the bias spring and restricting the aft cg limit to 455 mm as originally promulgated by Zenair, rather than 520 mm as later promulgated by CZAW.

The manoeuvre stability is low but weakly positive even with a cg of 500 mm AOD. With the cg at 450mm the stick force per g appears to be probably lower than that required by CS-VLA 151, insofar as the stick force to reach limit load (4g) extrapolates to less than 7 daN (15 Lbs), being estimated at 12-13 Lbs. The stick force per g meets or exceeds the VLA minimum with the aircraft loaded with a solo pilot which results in a forward cg.

The elevator trim system has been made more powerful during the development of the XL, by doubling the span of the trim tab in an attempt to allow trimming out the nose down trim change with flap. This still has inadequate effect to trim with full flap, the residual back stick force (without the bias spring) being 6 Lbs in the approach configuration, even at aft cg. Given the otherwise light stick forces, this dominant trim change with flap is undesirable however this is considered preferable in safety terms to the reduction in longitudinal stability conferred by the spring bias system.

It is noted that the trim tab angle range of ‘up trim’ movement on G-EXLL was less than that specified in the drawings, however the range of movement is not adjustable since the length of the horn and the travel on the servo are both fixed.

Four possibilities come to mind as a means of addressing the trim change with flap. Firstly, the affect of increased trim tab deflection in the ‘up trim’ sense, (ie ‘down’ tab) should be tested. The additional 18 degrees travel suggested by Zenair will increase the trimmer authority to some extent albeit at the expense of greater out-of trim forces in the ‘nose up’ trim runaway situation.

Secondly, the flap travel could be restricted. However this is undesirable because only a very small amount of flap (approximately 1/3 of the available travel, ie 10 degrees) can be lowered while still being able to trim with the existing trim tab authority. Reducing the flap travel to only 10 degrees would significantly worsen the aircraft’s short-field landing performance.

Thirdly, the tailplane setting angle could be changed to a more negative setting sufficient to trim the aircraft in the flap-down configuration, and a bias spring acting as an elevator down spring used in flapless flight, being connected to the flap system so that spring tension was progressively eliminated when flaps are lowered. The spring would increase the longitudinal stability and stick force per g when flaps were up, which would be an added bonus. However this would have the disadvantage of increased trim drag in cruise flight because the elevator angle to trim in the cruise would not be in line with the tailplane.

Also it would need to be checked whether the amount of down elevator authority remained sufficient with the tail setting angle reduced to this extent.

Finally, a second elevator tab could be fitted, controlled by the flap, as on the Beagle Terrier and the LAA's recent mod to the Sonex which addresses exactly the same issue as on the 601 XL. Judging by the effectiveness of the existing starboard elevator tab, the new tab would have to be of similar size ie full-span on one elevator. No drawbacks can be seen with this proposal. As an additional benefit, it might be possible for the bias tab to be rigged to operate also as an anti-balance tab, and so increase stick force gradients and stick force per g.

The effect of doubling the size of the existing elevator tab has been to make this unduly sensitive and powerful in normal flight, and potentially hazardous in a trim runaway situation in a nose-down runaway where pilot intervention is required in just three seconds to prevent an excessive nose-down pitch rate developing. However as the nose-down part of the tab range is currently not needed to trim in any condition, even at aft cg, the range could be halved and the sensitivity / rate halved by doubling the length of the tab actuating horn and altering the range to eliminate any 'down trim' travel beyond the present neutral trim tab position. This would have a significant safety benefit in eliminating the risk from a nose-down trim runaway, make the aircraft easier to trim in flight (less sensitive) and have no perceived drawbacks.

From the position error chart produced, the position error is +7kts at 103 kts therefore the Vc of 104 kts EAS that applies to this aircraft when flown with a max gross weight of 560 Kg relates to an indicated speed of 111 kts. It was noted that the Yellow arc on the ASI of G-EXLL started at 90 KIAS. This is less than 111 KIAS therefore conservative.

The position error at Vne has not yet been established however the results are consistent with the present marking of 140 kts IAS relating to 131 Kts EAS ie a position error of +9 kts which would be a reasonable extrapolation of the existing data.

15. Compliance Findings

It is considered that the tests described in this report demonstrate that with the modifications to wing attachments, aileron mass balances and modified trim tab range in place and a rear cg limit of 455 mm the compliance status for the modified CH601-XL aircraft with the following applicable CS-VLA requirements is as follows:

1. The aircraft was non-compliant with CS-VLA 151, elevator control force in manoeuvres, insofar as at the proposed aft limit of 455 mm the stick force required to reach limit load may be as little as 5.9 daN compared to the normal minimum requirement of 7 daN. The aircraft is compliant at mid and forward cg however. Many other LAA aircraft have similarly light stick force per g eg RV6.

2. The aircraft complies with CS-VLA 161(b)(1) Longitudinal Trim (in cruise)and 161 (b)(2)(i)(in climb). The aircraft is non-compliant with 161 (b)(2)(ii) Longitudinal Trim (in descent) insofar as there is a residual rear stick force of 6 to 8 Lbs in the descent configuration with full flap. It is noted that the equivalent paragraph of BCAR Section S does not require the ability to trim with flaps deflected.

3. The aircraft complies with CS-VLA 173 (a) and (c) Static Longitudinal Stability but non-compliant with 173 (b) insofar as at aft cg the width of the free-return band slightly exceeds the 10% requirement but this is not considered hazardous for day-VFR use.

4. The aircraft complies with CS-VLA 175 Static Longitudinal Stability.

5. The aircraft complies with CS-VLA 629 Flutter paras (a)(1), (c)

6. The aircraft complies with CS-VLA 1309 Equipment Failures as regards the pitch trim tab, providing the range of travel is limited to zero ‘down’ and 22 degrees ‘up’ trim.
The proposed changes to the elevator trimmer sensitivity and trim range will render the system adequately safe in the trim runaway situation.
NB CS-23 ACJ 677 suggests a 3 second pilot recognition time in the cruise configuration for electric trims.

16. Recommendations

- Aileron 100% static mass balances to be fitted to LAA-modified Zenair design
- Wing root and centre section spar reinforcements to be fitted to LAA / Zenair design
- Elevator trim tab horn to be modified to reduce the sensitivity and change the range to avoid unnecessary 'down' travel. Placard cockpit stating associated new trim setting for take-off.
- Flap balance spring and related bias cable to be removed.
- Aileron cable tension to be set to 20 Lbs +/- 5 Lbs (measured at port side drive cable)
- Check that flap up-stops are fitted to standard Zenair design
- Aileron bellcrank mounts to be checked for signs of failure in vicinity of the stiffener angles and their riveted attachment to the wing ribs.
- Aft cg limit to be reinstated to 455mm AOD per original Zenair recommendation.
- Check that yellow arc on ASI commences at Vc of 90 KIAS.
- POH to be amended or a supplement created to show new limitations regarding rear cg limit, check Vc yellow arc marking on ASI, nose down pitch with flap and take off trim position, also max zero fuel weight and aileron cable tension range.
- Amendments to weight and balance schedules required and cockpit placards to be amended on individual aircraft to show new aft cg limit.
- Further evaluation required of risk of inadvertent trim switch operation on any CH601XL aircraft with twin stick configuration rather than single 'y' stick.

Subject to the above actions being carried out it is recommended that the Zenair CH601 XL fleet be released from the grounding imposed by MPD 2008-006.

As a longer-term product improvement, it is recommended that Zenair explore the suggested methods for reducing the nose-down trim change when flap is lowered, as discussed in section 14.

APPENDIX A

SUMMARY OF FLIGHTS CARRIED OUT

Flight #	date	t/o weight Kg	Cg mm	Aileron cable tension	Aileron mass balance	Dur'n	B'last Kg	Task
1	30.6.09	468	369	20 Lbs	100%	0-45	0	General handling fwd cg
2	30.6.09	494	500	20 Lbs	100%	0-30	40	Extreme aft cg handling
3	30.6.09	503	450	20 Lbs	100%	0-30	24	Aft cg handling
4	15.7.09	495	454	20 Lbs	100%	0-25	24	Flutter to 80 KIAS
5	15.7.09	488	458	20 Lbs	100%	0-15	24	Flutter to 100 KIAS
6	15.7.09	481	462	20 Lbs	100%	0-20	24	Flutter to 120 KIAS
7	15.7.09	503	450	20 Lbs	100%	0-40	24	Ferry to Turweston
8	16.7.09	495	454	20 Lbs	100%	0-30	24	Flutter to 140 KIAS
9	16.7.09	488	458	20 Lbs	100%	0-25	24	Flutter to 147 KIAS
10	16.7.09	481	462	5 Lbs	100%	0-30	24	Flutter to 120 KIAS
11	16.7 09	474	466	5 Lbs	100%	0-20	24	Flutter to 147 KIAS
12	23.7.09	503	450	30 Lbs	98%	0-50	24	Flutter to 147 KIAS
13	23.7.09	488	458	10 Lbs	98%	0-50	24	Flutter to 147 KIAS
14	23.7.09	546	488	20 Lbs	100%	0-50	20	ASI calibration
15	23.7.09	543	503	20 Lbs	100%	0-20	24	Extreme aft cg handling
16	23.7.09	512	440	20 Lbs	100%	0-20	0	SF/g at aft cg
17	23.7.09	468	369	20 Lbs	100%	0-20	0	SF/g at fwd cg