ALL OF A FLUTTER

The latest in the ongoing saga of the Zenair wing flutter problems, and also the underlying problems of two failed undercarriages

IT doesn't seem possible, another year virtually over. Mince pies, the shortest day and presents under the tree are just around the corner. I'm looking forward to the New Year – winter is great but spring is definitely better.

Back to real life and the here and now; as this is being written my dog has only just stopped shaking after firework night and the Christmas celebrations seem a long way off in the distant future. It's far too busy here at LAA HQ to reflect anything except, perhaps, light. The frenzy of activity is due, in part at least, to the extra workload imposed by further chapters being written in the continuing saga of the Zenair CH601XL. The unexpected introduction of factory 'required' modifications – just as the LAA is bringing members' machines back to full airworthiness – has thrown the worldwide Zenair community into turmoil. I will try to explain what's going on and show how the LAA, principally a member's organisation, is well placed to deal with this sort of issue, later in Safety Spot.

I haven't seen it yet, but Ken Craigie, the LAA Chief Inspector, is writing this year's accident summary (of last year's accidents – that's 2008 if you're still reading this in January!). It is featured elsewhere in this magazine though I haven't seen it yet; he keeps the draft very close to his chest. At this very moment in time, Ken's only keyboard trained digit is flying across the keys at an alarming rate. I haven't been able to pick out a word yet, but there is definitely a recognisable Morse signature. I think Ken will need a long lie down, and, possibly a bandage for that finger by the time he's finished... I shall sneak a look then as I haven't seen it yet (did I say already that?)!

Before we take our usual in depth foray into the world of other people's engineering misfortunes, let me first apologise to the unnamed people who I offended in last month's SPOT. Regular readers will recall the very brief story of the incorrectly fitted reduction drive bearing which failed, causing an engine failure on the first flight of a Pietenpol Air Camper.

I intimated that the damage caused to the bearing face was the result of ungentlemanly behaviour, possibly with a hammer and a cold chisel. I have been assured that this was not the case by the builder of the machine, the surface damage to the bearing having been caused during the extraction process after the failure. I popped up to the LAA's Black Museum and took another look at the actual bearing; I can see how this damage would be caused trying to get the thing out. So, apologies to all concerned, I should have been more thorough with my checking process.

'Unexpected factory required modifications has thrown the Zenair community into turmoil'

Speaking of checking; this particular Pietenpol is (from one or two accounts) a brilliant example and beautifully made, so I can understand why the builder took exception to my rather rude inference. What was the reason for the bearing failure? Well, we'll have to assume that lack of lubrication due to the fact that the bearing had been put in back to front. The installation manual is being updated by the technical chaps from the Pietenpol Owner's Club to stop this happening again.

Remember, you can read all the old Safety Spots on our website. Head to www.laa.uk.com or use any search engine and type Light Aircraft Association. When you find the website, go to Engineering, where each archived Safety Spot is listed by month.

It's looking less like a hammer and chisel 'putting in' and more like a screwdriver 'taking out' with this damage to a Subaru Reduction Drive bearing, first described in last month's Safety Spot!

PHOTO Malcolm McBride

With Malcolm McBride
Airworthiness Engineer

Zenair CH601XL – more modifications

REGULAR readers of SPOT will remember the problems that befell the CH601XL about this time last year. I wrote about them in the 2008 December issue of Light Aviation where I explained that the LAA had reluctantly recommended to the CAA that the type be grounded because of the suggestion, from the designer, that the ailerons were prone to flutter if the cable tensions were low.

This suggestion of flutter came as a response from Zenair Europe Ltd after a fatal accident in Holland grounded the type there; until the suggestion of flutter, LAA Engineering had not considered grounding the type. Thus began a long investigation about the airworthiness (or otherwise) of the type, culminating in the issue of an LAA MOD procedure requiring various changes to the aircraft. These changes included the mass balancing of the ailerons (to minimize the possibility of flutter) and the addition of stiffeners on the main spars, along with all sorts of other smaller changes.

PHOTO Nigel Bamber

The test aircraft at Hinton during the extensive flutter evaluation earlier this year

During the evaluation process we became concerned that a feature of this machine is its quite low stick force per G characteristics. This, in essence, means that the aircraft has very light pitch forces and that the machine could be easily overstressed. The fact that the aircraft is fairly stiff in roll and that it has a very powerful elevator trim doesn't help much, although pilots who fly the aircraft in the UK tell me that "you soon get used to it". I have had a report where an experienced pilot inadvertently pulled 4g because his map fell onto the elevator trimmer switch.

It is true that there have been quite a number of fatal accidents worldwide involving CH601XL aircraft and this looks like a statistical cluster. In many of these accidents the aircraft's structure failed in flight, leading to worries that the aircraft was simply not strong enough. Certainly, under current rules, we couldn't clear the aircraft to the various higher weight limits used in other countries around the world.

Could it be that some other sinister forces were at work? Perhaps a combination of factors is to blame; the structure failures may be the result of these other factors. Perhaps wing or, more accurately, aileron flutter leading to wing flutter was responsible for the reported wing failures. Could it be that pilot technique has a part to play? We haven't had an accident involving an XL in the UK and unfortunately have been relying on patchy, often anecdotal, information about the accidents elsewhere.

Various interested groups around did, and in some cases are still doing, all sorts of analysis. Zenair Europe sponsored a vibration audit, clearing the aircraft in this respect even without the LAA aileron mass balance. Recent load tests by the manufacturer demonstrate that the airframe is strong enough to withstand the loads required by the LAA accepted CS-VLA standard when applied to the UK's 560Kg limited machines.

The fifteen or so LAA aircraft grounded initially have now been or are in the process of being modified to a standard acceptable to the LAA. Almost all of them have been returned to flying status. At the time of writing these aircraft still retain this status. In addition to the current LAA permit aircraft we also have a further seventeen aircraft under construction. The LAA mods require a lot of time and expertise to fit, plus there has been a high financial cost involved to both the owners of the aircraft and the LAA.

You can imagine my reaction when, after returning to work after a pleasant weekend, I was confronted with a Safety Alert/Directive requiring substantial modifications to CH601XL aircraft issued by the Zenair manufacturers AMD. Such is the worldwide nature of the sport aeroplane business. We weren't involved in the creation of this Directive which, at first sight, looked as if it would ground the UK fleet again.

Naturally, we're looking closely at the AMD modifications to see whether they actually improve the aircraft, but right now LAA machines must not be fitted with these modifications; they've not been approved. We're a bit worried about AMD's reasons for issuing this modification package so suddenly, and without consultation, but AMD's boss, Mathew Heintz, has assured us the test figures given to the LAA for UK certification purposes in the past (and recently) are 100% correct.

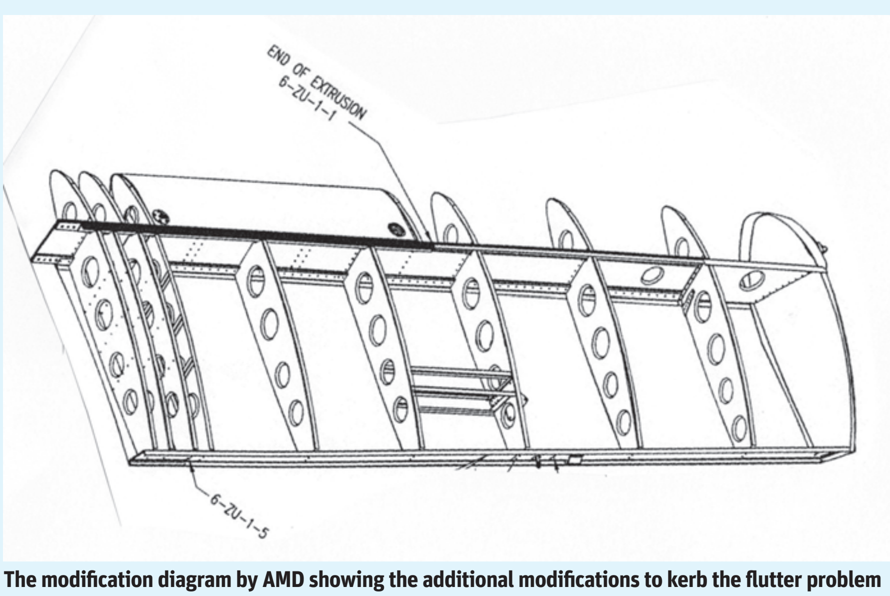

PHOTO AMD

The modification diagram by AMD showing the additional modifications to kerb the flutter problem

SAFETYSPOT

Extra EA230 – undercarriage failure

I REMEMBER White Waltham airfield very well from my youth. I remember the Chipmunks and the T21s, Faireys old Dakota and Douglas Bader's Beagle. I remember a grass runway so smooth that you could play bowls on it. If you bounced on landing, well, it was your fault. I went in there a couple of years ago for some reason or another. Wow! What a difference a few years makes. I nearly got a touch of the 'mal de mer' taxiing back to the club; at some points you could lose sight of the horizon as your eyeballs rattled in their sockets.

Naturally, undercarriages are designed to take some fairly hefty loads during an aircraft's certifying procedure – drop tests at various angles etc. In real life these tests are very demanding on the structure and there is generally a trade off made between energy absorption rate, which can be controlled by stiffness, and the possible maximum deflection, which is naturally determined by structure, role and engine/propeller clearances.

Engineers choose different solutions to accommodate the differing requirements, some very complicated, like the variable resistance hydro-pneumatic oleos, and some simpler – the wrapping of rubber bungees between the undercarriage and the fuselage is a good example.

By far the simplest undercarriage is the solid leaf spring arrangement, where the shape of the spring and the material used can be varied to suit the requirements. One type of arrangement commonly used on sports aircraft is the inverted U. In this type of design the undercarriage's total stiffness, and stiffness verses deflection rate, can be adjusted to requirements by adjusting the relative geometry. Widening the wheel track, for example, will change the effective stress within the leg and adjust strain; tapering the spring will balance the applied stress within the beam. In essence, the wider the track, the further the undercarriage will move. In other words an undercarriage could be likened to an energy capacitor, smoothing out the large instantaneous forces encountered on landing.

All this movement is ok when it comes to smoothing out the bumps, but regular readers will have got to grips with the problem metal has resisting regularly applied loads. They will also know that, after a certain amount of load applications which engineers call 'cycles', most materials will eventually fail. This is absolutely true of all materials if the applied load is close to the ultimate failure load of the material, but some metals, especially the aluminium alloys, will eventually fail almost regardless of the relationship between applied and failure loads. In other words aluminium will fail after a certain number of cycles even with very small applied loads. This, as you will already know, is fatigue.

I have to thank Rex Parkinson from the AAIB and Bill Taylor from Qinetiq for the rest of the information about the particular incident that stimulated the above discussions. It's a straightforward case of undercarriage failure and there are no particular culprits in the frame but there are lessons to be learnt, especially, but not only, by design engineers.

This particular incident – involving the wonderful Extra 230 aerobatic aircraft – began one Friday lunchtime in October last year. The pilot was taxiing out to the holding point for runway 21 at White Waltham when the right undercarriage leg fractured at the top bend inside the composite fairing. The starboard wing tip contacted the ground and the wooden propeller disintegrated. The aircraft was recovered and the undercarriage completely removed. It should be said that this aircraft had completed a fair number of hours (about 1700) but had only flown about 28 hours since its annual. I've mentioned that White Waltham is a bit on the bumpy side and the pilot reports that he was taxiing very slowly because of this.

After a visual examination on site the leg was sent to Farnborough for scientific examination. These days Farnborough means Qinetiq and here the components were placed into the capable hands of forensic engineer, Bill Taylor. I spoke with Bill about this; it was a long conversation – two 'anoraks' together – and there's not enough space in SPOT to relate the whole conversation so I will let the

'An undercarriage could be likened to an energy capacitor, smoothing out the large instantaneous forces encountered on landing'

PHOTO Quinetiq

This picture shows the broken undercarriage leg. I've marked the tiny corrosion pit that was the origin of the crack. As the crack grew the area of material left to resist the stress reduced increasing local stresses. This lead to an eventual overload failure.

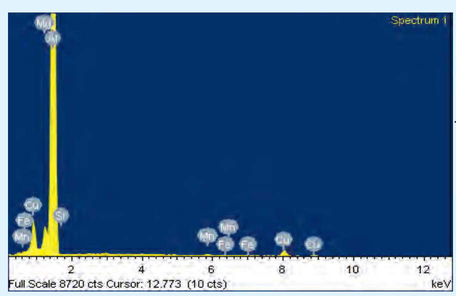

PHOTO Quinetiq

Using the technique of Energy Dispersive X-ray (EDX) analysis it is possible to work backwards and find out what material was used in the undercarriage's construction (it's one of the add-ons often fitted to electron microscopes). EDX works by energising atoms in the material being analysed and recording their energy response. Each element has a different response. By some clever maths the constituent of the material are revealed. In this example, the three biggies are aluminium (Al) which is off the scale, copper (Cu) a transition metal, magnesium (Mg) an alkali earth metal and another transition metal, manganese (Mn). It's the copper in this material that makes it very susceptible to corrosion cracking. This material, by the way, is 2024 aluminium alloy. Credit: Courtesy of Quinetiq.

PHOTO Quinetiq

Closer look at the corrosion pit that wrecked the propeller of the Extra 230. The growth rings can clearly be seen in this optical picture.

PHOTO Quinetiq

An electron microscope picture reveals the growth rings emanating from the corrosion pit. Corrosion pitting is dangerous because it is very difficult to spot. The high copper content of 2024, a common alloy used in aircraft manufacture, means the material is electrically quite active; it is postulated that corrosion pits are often caused by local cathodic sites in an otherwise normal surface.

accompanying pictures do the talking. I shall try to explain what's going on in the subtext.

To cut straight to the chase as they say, this failure was the result of a fatigue crack which originated at a small corrosion pit on the inner surface of the bend radius at the top of the leg. It was virtually impossible to inspect this area during a normal pre-flight inspection. In fact to be inspected fully the undercarriage would need to be removed from the airframe. Close inspection of the other side (port side) showed evidence of a crack forming in, more or less, the same place. This is a really good example of the effects of fatigue on a system – the port and starboard legs were failing at the same time. A bit like my shoes incidentally, last week they both started to leak water on the same day – incredible!

This sort of failure – gradual, inevitable, but difficult to inspect against – could have been prevented if the leg had been removed and inspected from time to time. It demonstrates the need for pilots operating on a Permit to Fly to create and manage a sensible inspection programme tailored to suit the individual aircraft and its operation. This must be done in conjunction with the LAA Inspector and should include the occasional major job. There's no reason why you cannot design a schedule that spreads these big jobs over a number of years, like undercarriage removal, for instance.

Glasair 1RG – undercarriage failure

THERE can be little doubt that there is no shortage of diversity within the LAA fleet. You have just been reading about the problems encountered by the owner of the wonderful (did I say that already?) Extra 230 and now I am going to tell you about an incident that left another aircraft sitting on one wheel with its wingtip resting on the ground. The reasons (note the plural) for the owner ending up in this unfortunate position are very different from the example above.

Let's start by saying that I would consider the Glasair a 'hot ship'; one look at the aircraft should tell you that it's going to be quick. The Lycoming O-320 driving a Hoffman three bladed constant speed propeller will get the aircraft rolling in short order, and it's a short coupled aircraft, which should tell you that it could be a bit of a handful. Not a machine for the beginner.

What do you get in return for all this pain? Well, with a top speed of 260mph and handling like a fighter, I will let you guess.

In LAA terms I would describe this aircraft as a complex type for other reasons. Firstly, there's the fully retractable tricycle undercarriage which I will describe in some detail later. Then we have to take into account the wobbly propeller. Regular readers will know that we've had our engineering problems with these over the last few months. I came into work one Thursday morning to find a message draped over the keyboard: 'Dr. Peter Mansfield called to say that he has crashed his 'plane. Nobody hurt. Everything under control, could you give him a ring?' Between us we worked out what went wrong. The investigators from the AAIB agreed with our findings, and this is the story...

The take off from Humberside Airport was conducted by the qualified (but not yet cleared for solo on type) person from the right hand seat, but very quickly he experienced a stick/

PHOTO Rick Hand

Dr. Peter Mansfield's fantastic Glasair after the repairs and ready to go.

rudder induced Pilot Induced Oscillation (PIO). This is a dangerous event, normally divergent. The left hand seat pilot (the owner of the machine) who is experienced on type, took control of the situation and the aircraft was recovered to normal flight, the wheels were retracted, and cruise power and the heading set for the flight back to the aircraft's home base of Cranwell. Whilst the take off had been a bit hairy everything at this point in time appeared fairly normal.

After a short time en route it was noted that the undercarriage transit lights had come on. The owner knew this meant at least one of the undercarriage legs had descended away from it's 'up' position, opening the microswitch.

At this point in the tale it is probably worth explaining the basic workings of this undercarriage system. The system is electro-hydraulic; what this basically means is that hydraulic power is created and controlled electrically. It's probably easier to explain the operation through a normal cycle.

The system employed on the Glasair does not have mechanical down locks, the mains being held down by spring pressure and the nose held in place by a gas strut, similar to those used to hold the tailgates open on estate cars.

When the legs are fully down independent microswitches close and green lights illuminate in the cockpit (i.e. three greens!). There is a separate pressure switch which, after reaching a pre-set pressure, cuts power to the electrical hydraulic pump.

After take off the gear is raised using an electrical switch, hydraulic pressure is fed to one side of the hydraulic jacks, hydraulic pressure overcomes the spring pressure and the gear legs rise into their respective bays. Because the gear is neither up nor down at this point, an amber transit lamp illuminates in the cockpit – this is the lamp aforementioned.

When the gear is nicely tucked up it contacts an 'up' microswitch, and when all three of these are closed the transit lamp extinguishes. The pump keeps running for a while to pressurise the system and, when the desired 'up' pressure has been reached, the power to the pump is removed.

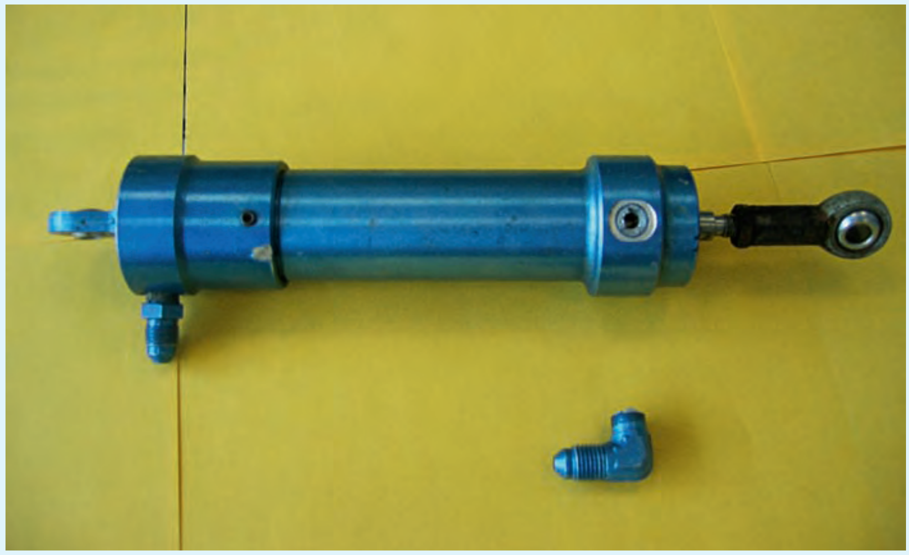

PHOTO Malcolm McBride

This hydraulic failed during the event. It couldn't have failed completely at the point of impact because it's on the up side of the jack and the pilot wouldn't have been able to raise the gear on this side.

This type of system is fairly common amongst small to medium sized GA types; the Piper PA28 'Arrow' uses an almost identical system (before you write, I know it's got mechanical downlocks!) and it works very well. So, what went wrong in this case leaving the pilot and passenger sat on one wheel at Cranwell?

As I have mentioned, the sequence of events started with the worrisome development of an illuminated transit lamp. It should be noted here that, whilst the down-greens are illuminated independently – so you would know which one's not working properly by the absence of a light – the ups are different and it's impossible to tell from the cockpit which leg is causing trouble.

As the destination airfield approached, the aircraft was slowed and the undercarriage selected 'down'. After a normal time the port and nose undercarriage down and locked green lights illuminated (the transit lights remained on throughout) and it started to look like there was trouble with the starboard leg. The pilot requested a visual check from the tower which was gladly given. It was confirmed that the starboard undercarriage was not showing, i.e. it was completely up.

Peter decided to try to recycle the undercarriage but, on the second attempt at lowering the undercarriage only the port undercarriage down and locked light became illuminated – the situation was going from bad to worse. Thinking that no undercarriage is better than one undercarriage (with which I'd agree), an attempt was made to raise the port undercarriage. But this undercarriage was now fixed in the down position. So, with full emergency service cover provided by the Royal Air Force and with only one green light showing, Peter worked hard to pull off a greaser. He did it, landing the aircraft on one wheel, the starboard wing impacting the tarmac, followed by the propeller (expensive), shortly after landing. The aircraft slewed to a halt suffering only minor structural damage.

The aircraft was recovered to the hangar and placed on jacks and, after a bit of thinking, it became clear (more or less) what had happened. It is likely that the starboard wheel struck either the ground or, more likely, a runway light, bending the fesculised (shiny) portion backwards slightly during the hairy take off at Humberside. The wheel is a fairly close fit into this bay and the wheel probably jammed in the up position.

It is very probable that this impact also weakened or partially fractured the AN fitting supplying hydraulic fluid to the 'up' side of the starboard undercarriage jack, initializing a failure sequence in this component, beginning with a small leak and ending in complete separation. It is likely that the bent undercarriage jammed fairly solidly into the wheel bay after retraction and, once the hydraulic fluid had been pumped out of the system as the motor ran, desperately trying to re-establish 'up' pressure, the stage was set. If you are really following this story then you should be wondering why the nose wheel didn't come down after system pressure was lost. Well, it was found that the gas pressure in this strut was too low to oppose the aerodynamic force generated by the leg itself.

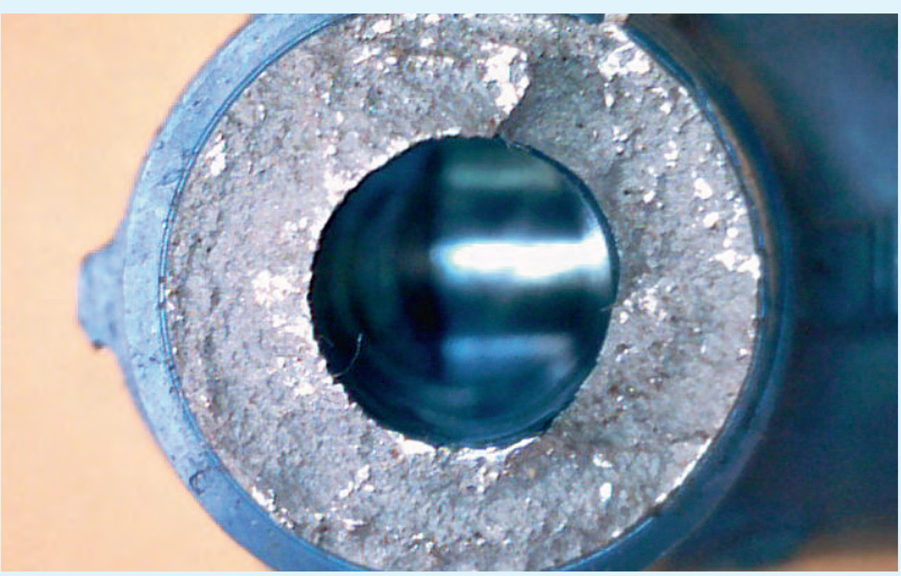

PHOTO Malcolm McBride

There's no evidence of a sequential failure in this close-up of the failed AN hydraulic fitting. A tapered thread is usually found on this type of fitting. It is easy to over stress whilst assembling the pipework.

With Malcolm McBride
Airworthiness Engineer

Van's flap drives

WELL, space has got the better of me again and I shortly have to leave this keyboard for another; I am due to play this afternoon in a band (God help the listeners!). I mustn't finish though without sharing with you a problem spotted by Manuel Queiroz (of RV 6 'around the world' fame in 2006) and Steve Noujaim (an old mate who is currently in preparation for an attempt to re-take (for Britain) the London - Cape Town - London speed record originally set by Alex Henshaw, but recently nabbed by the South African, Captain Chalkie Stobbart). Steve and Manuel are in the process of fitting out Steve's RV7 with a Garmin G900X EFIS – lucky devils! Steve takes up the story...

"Fitting the EFIS has entailed rewiring a large part of the aircraft so I have taken the opportunity to open up and inspect the aircraft as part of a fresh annual before test flying in the final record configuration. As part of this work I have disconnected the electric screw jack system which raises and lowers the flaps; such actions can make access within the aircraft painful as the flap actuating arm sticks up and will readily bite one in the rear. This is annoying, so the flaps are tie-wrapped up. Witnesses were looking at the aircraft when the tie wrap snapped and allowed the flap to fall past the full down position. Less than a minute later the port flap linkage, then the starboard flap linkage, snapped."

'The tie wrap snapped and allowed the flap to fall past the full down position'

It's true that the failure of the tie-wrap probably overloaded this flap linkage and this is probably a fairly one-off event. I've not had other reports of flap linkage failure occurring to UK owners, although this has happened before in the US. Note the witness marks on the pictures. When Steve reassembled the flap drive he noted the hole in the fuselage was not big enough to afford proper clearance between the link and the fuselage – in the US this same lack of clearance may have contributed to a flap drive failure that ended up in a totalled RV6 back in 2001. Manuel checked his aircraft and found a similar situation. Remember, if a component is being placed regularly under a stress that it's not designed to take, it's almost bound to fail eventually. Now, where's that Saxophone? Oh, and where are my manners... Have a great Christmas!

Fair winds.

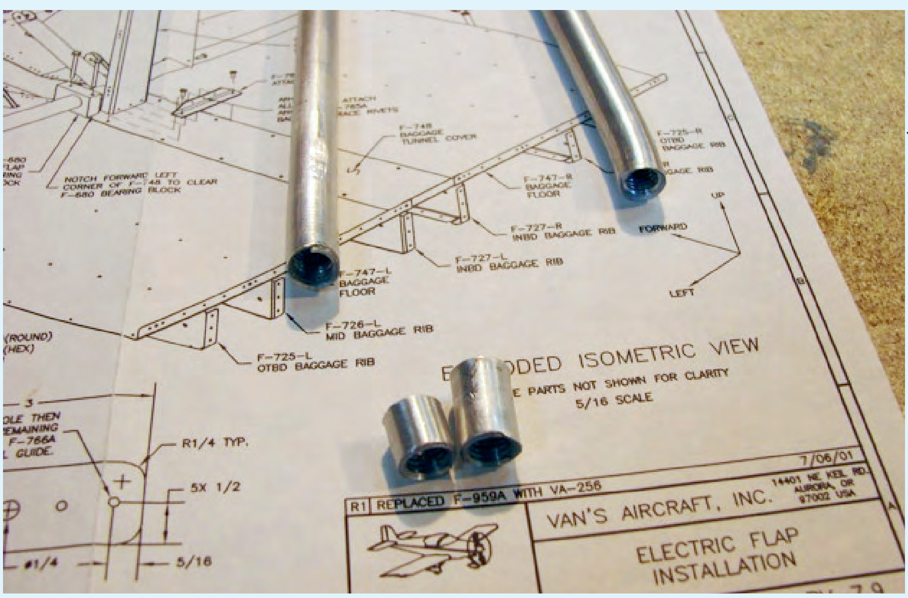

PHOTO Steve Noujaim

The result of this double flap drive rod failure. In the workshop the flaps 'free fell' beyond their normal range and failed at the top of the internal threaded portion. Subsequent investigations revealed the cut-out made to accommodate the flap drive was not big enough, the chafing can clearly be seen.

PHOTO Manuel Queiroz

Manuel Queiroz found the clearance between the flap drive rod and the airframe was far too small and that his flap drive rod had been chafing.

LAA ENGINEERING SCALE OF CHARGES

LAA Project Registration	
Kit Built Aircraft	£300
Plans Built Aircraft	£50
Issue of a Permit to Test Fly	
Non-LAA approved design only	£40
Initial Permit issue	
Up to 390kg	£300
391 - 499kg	£405
500kg and above	£540
Three seats and above	£600
Permit renewal	
Up to 390kg	£100
391 - 499kg	£135
500kg and above	£180
Three seats and above	£200

Modification application	
Prototype modification	£45
Repeat modification	£22.50
Transfer	
(from CofA to Permit or CAA Permit to LAA Permit)	
Up to 499kg	£135
500 kg and above	£250
Three seats and above	£350
Four-seat aircraft	
Manufacturer's/agent's type acceptance fee	£2,000
Project registration royalty	£50
Category change	
Group A to microlight	£110
Microlight to Group A	£110
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