Safety Spot
By Malcolm McBride

KNEE-JERK REACTIONS, TAILPIPES, JABIRU FLYWHEELS AND SEAT HARNESSES

The latest LAA Engineering topics and investigations

Season's Greetings and welcome to this yuletide edition of *Safety Spot*. I hope that you (and yours) remain in good form and that, whilst reflecting on 2018, the emotions generated remain essentially positive. We can't, after all, moan about the weather this year can we? Months of warmth, just about enough rain to keep the farmers happy and not too much wind – though in my case, the wind always seemed to be blowing the wrong way.

True, flying members of the LAA have had their fair share of misadventure but, even if the list might just be a tad longer this year, this more-likely reflects an increasing acceptance that reporting failures has to be a good idea so more of you are putting pen to paper. Even though putting one's hand up to an error can be difficult, well done to those of you who have shared the details of their misadventure for the benefit of aviation community at large.

Another difficult thing to do, from a continuing airworthiness management perspective, is working out just what should happen after a report of a failure is received here at Engineering HQ. It's easy to build automaticity into a response loop, but simple cause-effect programmes might look good from an often target-driven management perspective, but they may have little overall effect on fleet safety. Care is needed in deciding what an appropriate response might be – a knee-jerk happens before a signal is received by the brain.

So, what's on offer in this edition of *Safety Spot*? Well, if you've taken a quick flypast of the attached pictures before reading this, you'll see that we've had another Pioneer 300 exhaust system failure reported – there's a couple of fixes for this now offered by the manufacturer, so it might be worth a full read.

Amongst the more recent reports received we've had a little cluster of pilotage problems during take-off and landing. It's true that this area in the LAA's accident statistic is normally 'well-populated' but I noticed a bit of a trend which might be associated with winter operations so I'll describe two very recent incidents which may serve as a heads-up for us all.

One big subject we've recently tackled is the ongoing saga of Jabiru flywheels falling off. LAA Engineering has recently issued an Airworthiness Information Leaflet (AIL) mandating changes to both the method of fixing the flywheels to the crankshaft and the frequency of inspection on all Jabiru engines. It has to be said that the manufacturers of the engine seem to have identified and solved this problem on their latest Gen.4 engine but as none of these engines have reached UK shores,

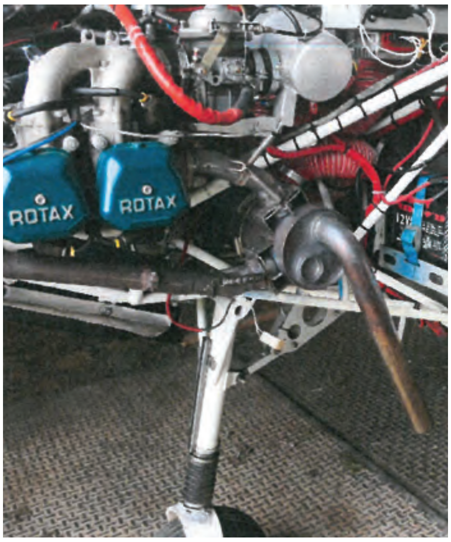
(Above) **A very nasty accident in 2016 involving a Yak-52, where one pilot was killed and another seriously injured, has focussed attention on the ongoing condition of seat belts, particularly seat restraint systems in some of our older aircraft. The CAA has recently instigated an industry-wide consultation seeking suggestions about how operators can ensure that an acceptable in-service strength is retained throughout a belt's life to ensure that it won't fail prematurely when needed. Engineers from the LAA are working with engineers from the UK CAA and AAIB to assess the various suggestions made and formulate inspection advice to owners and inspectors of aircraft operating under an LAA administered Permit to Fly. If you have expertise in this area, please take the time to respond to this consultation exercise.**
(Photo: Malcolm McBride)

we're more concerned about engines operating in the LAA's fleet – some of which are from the earliest times of this engine's evolution.

I have to say that the LAA's engineering team were very pleased to see that the CAA have adopted a very careful approach to the AAIB's Safety Recommendation (2017-021) to review the maintenance rules surrounding the continuing airworthiness requirements of seat-belts, issued as a result of a seat-belt failure during an accident with a Yak-52 in June 2016 (see above).

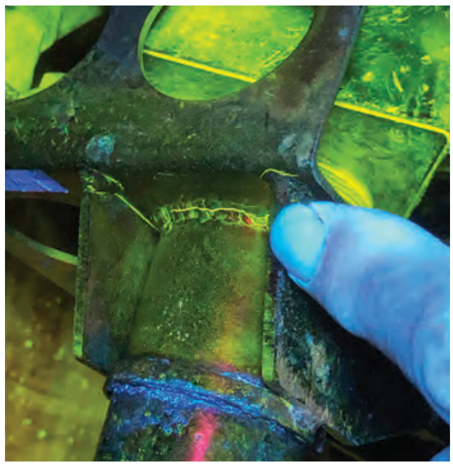
Both the CAA and the AAIB acknowledge that the whole subject of safety restraint systems fitted to aircraft is a tricky one. Indeed, in the CAA's own Safety Notice calling for the comments from the GA community at large, they say that prescribing any achievable fix, should a fix be deemed necessary, is likely to be considerably challenging. That said of course, there's no point in wearing a seat belt that would fail when called upon to do its work, and noting, as we do on a daily basis, that many of the LAA's aircraft are now quite old we do, as an engineering team, feel this review is both timely and sensible. Please feel free to let us know your thoughts about this so that we can feed your knowledge into the system. ›

THE PIONEER PIPE SAGA




(Above) **Earlier in the year two Pioneer 300 flyers suffered problems when the exhaust tailpipe detached from the silencer canister in-flight. You may remember that one of the aircraft ended up having to make an emergency landing after his cockpit filled with smoke. Aircraft exhaust systems operate in one of the harshest environments imaginable, so a close eye needs to be applied to spot minor problems before they grow into troublesome, perhaps dangerous, ones. This story features again because we've had another failure reported. The story started when the owner, Alan Robinson, noticed a crack developing in the tailpipe (see the picture above). He had this crack welded up and there didn't appear to be any other signs of distress in the connection between the tailpipe and the silencer's body. A short time later, whilst on the downwind leg to his strip, the tailpipe departed the aircraft. This picture of the installation with the cowling removed shows the exhaust's general fit. Notice two things from a design perspective: 1 the silencer canister is cantilevered back from the main body of the engine quite some distance, and 2 the very long tailpipe. Alan remarked, "We had a good track record of the last flight on our GPS, so we set off to find the missing tailpipe – we noticed straight away that the track followed a motorway – we never found the missing tailpipe but, thinking about the increased risk to road users, we won't be using the motorway as a ground feature to follow again."** *(Photo: Alan Robinson)*


(Above) **To avoid any further Pioneer 300 tailpipe losses, CKT Engineering has strengthened the connection of the pipe to the silencer canister by adding a bracket (left), and has volunteered to add this bracket free of charge to all Pioneer 300/400 systems. The picture on the right shows the two most commonly used exhaust to cylinder connections – left the CKT 'Olive' type of connection is shown, right is the original Rotax 'cylinder insert' type. Arguments continue about which attachment method is best – certainly the earlier (Rotax) in-cylinder connection proved troublesome on the P.300 systems. Chris Piper of CKT Engineering, thinks that it might be better (from a support point of view) to use the CKT flange system on the front cylinders and the Rotax system on the rear, this though is 'work in progress'.**
For now, please take up the advice given in last month's Safety Spot and regularly check, preferably before the first flight of the day, your exhaust system.
(Photo: Alan Robinson/Chris Piper



(Above) **The November issue of *Safety Spot* included a story where Pioneer pilot Simon Swift had to conduct an emergency landing after his cockpit filled with smoke. Simon also described the very heavy loads imposed on the airframe after a 'difficult' take-off - essentially the aircraft hit a bump fairly early in the take-off roll, "which launched the half-flying aircraft into the air below stalling speed". So, effectively, the take-off became a heavy landing – more than one by all accounts! Naturally Simon, along with his inspector, Gary Masters (of 'Airmasters'), have been carrying out extensive heavy landing checks – the picture above shows a crack in the main undercarriage support frame (attached to the wooden main spar) – without a magnetic particle inspection (MPI) this crack through the main weld may not have been spotted.** *(Photo: Gary Masters)*

WINTER OPERATIONS ONE – WATCH OUT FOR THE SUN

This particular incident features a fairly common (in the LAA fleet) high-wing monoplane, though I'm not sure that knowing this would change the lesson to be learnt very much; except perhaps that the aircraft itself, being quite a small low-inertia machine, does need the pilot to be actively controlling the aircraft right through the landing and take-off phase. This is an incident involving visual perception.

Now, I'm guessing that you might think that you're a little ahead of me here – we all know about the dangers of landing 'into sun', and we're all aware that knowing where the sun will roughly be during a planned approach is a good idea – after all, landing on an easterly runway early in the morning can be tricky but what about landing with the sun behind you? Surely this shouldn't be a problem?

Well, our pilot had flown off on a cross-country early on a nice autumn morning, met a few mates, had a look round the local sights and, happy with what the day had thus far bestowed, flown back to his home strip, all without incident or fuss.

The airfield was his regular base and he knew the topography very well indeed – though he had noted, as he taxied out earlier in the day, that the landowner had chopped down the huge oak tree that for years all pilots had learnt to avoid.

As he approached the airfield on his return he noted that the sun was getting very low on the western horizon though, as there was no wind, a landing on the easterly strip wouldn't, or at least shouldn't, present an issue, especially as the oak tree on the approach to this strip was gone.

Unfortunately, things didn't quite turn out quite that well and, after extracting himself from the cockpit of an aircraft with a buckled nose undercarriage, he tried to work out what had gone wrong.

Luckily, the damage appeared to be limited to the nose undercarriage and, of course, the propeller. He was, feeling around a bit, apparently in one piece. Thinking back, piecing together the events just prior to touchdown, it was clear to him that the tail of the aircraft had, just as he was beginning his flare, hit a pile of wood (Quercus!) placed before the beginning of the runway – this impact had thrown the tail up and, well, you know more of less what happened next.

How could this have happened? During our subsequent discussion, the pilot reckons that two things had set about confusing his senses. Firstly, the low sun changed his perception of the aircraft completely, long shadows coupled with an unusually brightly lit far boundary hedge had made him think that the field was a lot shorter than it actually was – so his landing approach was all wrong and he touched down far too early. Secondly, he hadn't realised just how good that oak tree was in helping to define the approach; with it gone he had rather lost his bearings.

I spoke with the pilot later to ask whether he minded me chatting about the story in Safety Spot. He didn't of course, otherwise you wouldn't be reading the tale, but he also commented that he'd recently suffered a family tragedy which had been playing on his mind rather, so he was also out-of-sorts generally – he thought it worth commenting that it's unwise to go flying if you're not 100% up to it, after all, flying an aircraft is rather a difficult thing to do.

WINTER OPERATIONS TWO – SYSTEM WARM-UP

Placing time pressure on anything we do always seems to change the function somehow. I remember being in a job where I had to travel a lot. Generally I didn't worry too much about 'getting home time' – no real stress, I got there when I got there. That was the situation every day except Tuesday for this was band-practice evening. It seemed like everything I did during the Tuesday, wherever I was, whatever I was doing, took three times as long – even, for some unaccountable reason, first thing in the morning.

Such was the situation for our second winter ops incident victim. He'd promised to do a flypast of the local war memorial at exactly 11 o'clock, you'll understand why. Now, the plan was to fly-past in loose formation with another aircraft, something well-practiced and sensibly arranged but, at least initially, the weather didn't look as if it would play ball – both pilots thought they would have to cancel because of low cloud and a bit of drizzle.

Then, a hoped-for break in the weather crossed the take-off field and the pilots sprang into action, both thinking that they'd just be able to make the event as the bugler smartly lowered their instrument after reveille after all. They did, well done to them, but right from the start of the flight, our pilot noticed that the windscreen was misting up badly - especially as he returned for a rushed landing before the weather closed-in again.

Yes, no point in going on really, you'll have guessed the outcome. In short, he didn't make much of the flare and broke the aircraft on landing. Though the windscreen misting-up didn't help the pilot, who, incidentally was just a few days short of his fortieth 'without incident' year flying sports aircraft, he explained that the reason for the mess-up was a combination of factors effectively stressed him out.

Firstly, the weather. Then, because of the cold/damp conditions, the battery was 'a bit flat' and the engine had trouble starting then, panic setting in, he didn't have much time to thoroughly warm the engine – so the de-mist didn't work.

Both events described above have something in common other than the obvious season-related message headlined – that's multiple factors. It's a rare event that only has one cause. A good tip for all pilots might be, "If you see the negatives piling up, stop. Take stock, wind down the volume, take a deep breath and sort out the negatives before attempting to fly an aircraft."

JABIRU ENGINES – FLYWHEEL ATTACHMENT BOLTS

In early 1988 Rodney Stiff and Phil Ainsworth formed Jabiru to develop a highly efficient, composite light aircraft. This original aircraft was designed around the KFM112M 60hp flat-four, but only one month after the initial Australian approval, the Italian engine manufacturer advised that it was ceasing aircraft engine production.

Thus Rod and Phil were forced either to redesign the aircraft to accept the much heavier (and more expensive) Rotax 912 engine, or take the almost unimaginably brave step of developing a flat-four engine themselves, comparable to the KFM.

Incredibly, the 60hp J1600 was developed over a period of just 18 months. In March 1993, this new engine was approved by Australian CAA for installation in Jabiru aircraft,and the first engines were released to the market in September 1995.

The LAA, then of course the PFA, came into the Jabiru picture more fully in April 1997, when we approved the first kit-built Jabiru SK. This aircraft was fitted with the later 80hp 2200A engine and, again, this example is still operating under the LAA's banner.

The LAA now has a little over 600 Jabiru engines in service (compared with about 1,600 Rotax 912 (series) engines) and their failure rate, doesn't look to be any worse than any of the other comparable engines operating in LAA aircraft. Engineers amongst you will know that by far the biggest reason for engine failures is something going wrong with an ancillary component not, generally, the base-engine itself. Probably top of the list is fuel delivery issues of one kind or another.

One issue that has bedogged the Jabiru 2200 engine over the years has been the failure of the bolts attaching the flywheel to the back end of the crankshaft, and it's a recent flywheel failure on a Jabiru 3300A powered SportCruiser that's brought this engine failure mode back into sharp focus.

We've spoken about this issue before in *Safety Spot*, most recently in March 2015 when we chatted about the introduction of the Nord-Lock washers by the manufacturers. Since that time, we've not had any significant failures reported and this recent failure is also our first report involving the six-cylinder variant.

Jabiru introduced the Nord-Lock washer as a standard method of locking the flywheel bolts after LAA Engineering approached them for a letter of no objection to their use on a Jabiru engine in the LAA fleet. This came about after we received a modification application from the Jabiru Owners Club, notably, Dino Licheri and Bob Panther, asking to approve their use.

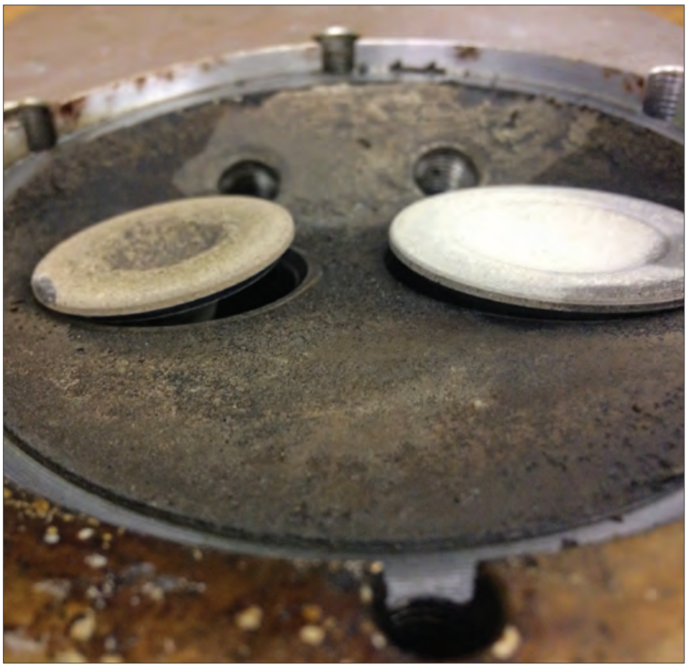
Bob argued that the original method of locking the bolts, a high-strength Loctite (620), wasn't doing its job properly for various reasons and, worse, making it impossible to check the bolt torque correctly without removing them completely at each torque check.

Naturally, if all the flywheel attachment bolts fail then the flywheel will fall off and the engine will stop. But actually, because the rear-mounted generator system (part of which supplies power to the ignition system) could be damaged by one single failed bolt head jamming between the generator's rotating parts, even the loss of one of the six attachments could end up with an engine stoppage and considerable mechanical damage. In the most recent failure case, probably because the camshaft gear jumped a couple of teeth during the flywheel's departure, the engine was completely wrecked.

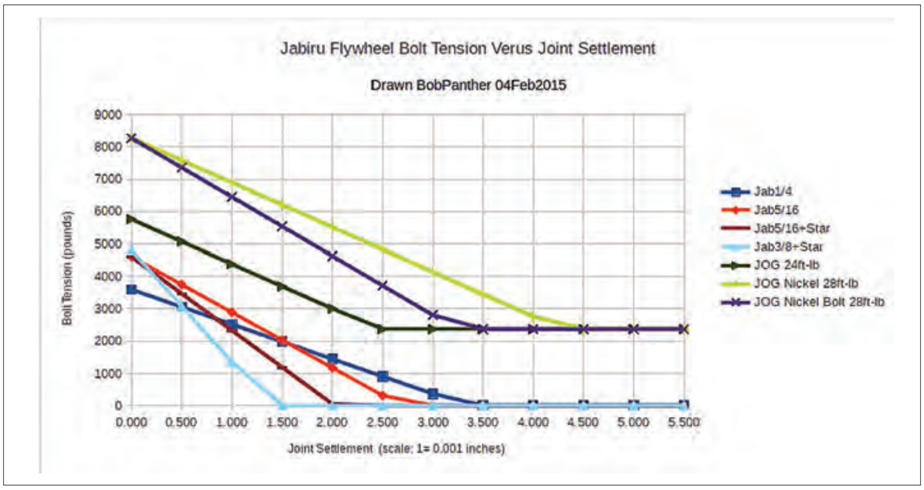
It cannot be said that the engine manufacturers have been blind to this issue, over the years there's been a stepwise increase in the size of bolts from 1/4in to 3/8in and there have been a number of different flywheels tried. The latest is the 'starfish' type which removes the steel to aluminium attachment completely in the hope of removing joint settlage and subsequent reduction of clamping force – more about this later.

In addition to this, dowels were fitted to share the shear load with the bolts, in theory reducing the issue of fatigue which, by looking at the fracture faces of the recovered failed bolts, was the primary cause of the bolt's head breaking off.

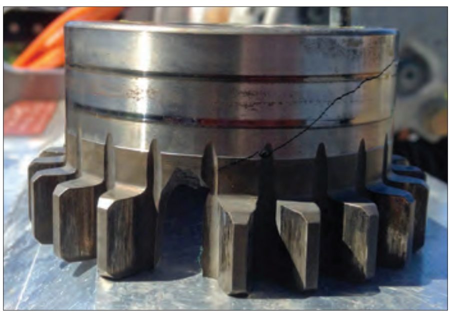
For many years Jabiru themselves have ›



(Above) **From the very earliest days of the engine, it seems that Jabiru 2200 owners have been plagued with occasional failures of the bolts that secure the flywheel, so this is an issue that has a fairly interesting (from an engineering perspective) history. The two big reasons why we see material failure in a component are overload and fatigue; identifying which of these two predominate in a failure case is sometimes quite difficult. Initially, though the evidence from fracture faces in failed flywheel connection bolts showed that the failure resulted from fatigue, the engine designers decided that the core reason for this was understrength bolts so, in a rather stepwise manner, bolt sizes have steadily increased. The pictures above show damage to a Jabiru 3300 engine caused as the flywheel became detached after all the flywheel bolts failed sequentially. The picture on the left shows damage to the end of the crankshaft, the picture on the right shows valve stem damage caused when the mechanical timing of the engine was disturbed when the camshaft gear slipped as the flywheel departed. Every valve and pushrod was damaged due to the valves being struck by the pistons.** *(Photo: Kevin Hyam)*



(Above) **After a close study of the flywheel to crankshaft connection both in terms of initial design and by reviewing post-failure evidence, it became clear that the primary reason for the failure of the bolts was that tension was being lost over time due to settlage in the joint. The bolts, having effectively lost their clamping force, were now subject to local cyclic loading – the primary cause of fatigue. The graph on the left shows the loss of tension in various bolts against various levels of settlage. Interestingly, by upping the size of the bolts, less settlage is required to lose bolt tension, so instead of improving the attachments longevity, it actually makes matters worse. The picture on the right shows the fracture face of a failed bolt from the recent 3300 failure – as you will recognise, a fairly typical cyclic fatigue failure.***(Photo: Bob Panther/Malcolm McBride)*



(Left) **After chatting to engine overhaulers who specialise in keeping our fleet of Jabiru engines serviceable, another important point to note regarding re-assembly after overhaul came to the surface. The picture above shows a failed camshaft drive cog which, in-service, fits over the end of the crankshaft (between the crank and the flywheel). Note there's a tooth missing and, more importantly, the body of the gear is cracked. When the engineer checked the fit of this cog over the end of the crankshaft, he found that it was very tight indeed, even with the dimension-changing crack. This cog is held in place by the flywheel attachment bolts, so it's easy to imagine that if the cog wasn't seated absolutely correctly during engine assembly then, as time progressed, it would eventually settle into the fully seated position. This settlage would completely release any tension in the flywheel bolts.**
(Photo: Gary Cotterell)

maintained that the reason for the failure of these flywheel bolts was the introduction (worldwide) of heavier propellers. Jabiru only recommend the use of their lightweight hoop pine propellers.

Certainly, when considering the cyclic forces in the crankshaft, the increased moment of inertia, a function of mass, felt by the crank by the use of heavier propellers will have an effect, though it's difficult to connect this issue with the flywheel end of the engine.

The very latest engine, the Gen 4, has a very lightweight flywheel – known as the X-Y flywheel – though at the time of writing this new engine hasn't been evaluated by the design chaps here at LAA HQ.

If the tensile load in a bolt repeatedly fluctuates above a certain percentage of its ultimate tensile load carrying ability, the bolt will be subject to fatigue and will eventually fail.

However, it was learnt back in the 1920s that if a bolt is torqued up so that it is permanently stressed in tension to a level above that created by the alternating force, the bolt doesn't 'feel' an alternating stress, so fatigue doesn't happen. But if the bolt loses its torque-induced tension due to settlage in the joint, it will experience the alternating stress and quickly start to accumulate fatigue damage.

We think that in the case of the Jabiru flywheel bolts, it is the loss of clamping effect and pre-tension in the bolts due to joint settlage which causes fatigue to become a factor in the life of this bolt.

Added to this, whilst all six bolts together are up to the job of retaining the flywheel, if one or more becomes compromised (or fail altogether) then then the sum of the alternating load is transferred to the adjacent bolts – leading to them failing in turn.

So, the issue really is that it is essential that the clamping forces in all the bolts are preserved, maintaining an equal pressure around the attachment ring. If you can keep this state the individual bolts will all be loaded in a way such that fatigue won't be an issue.

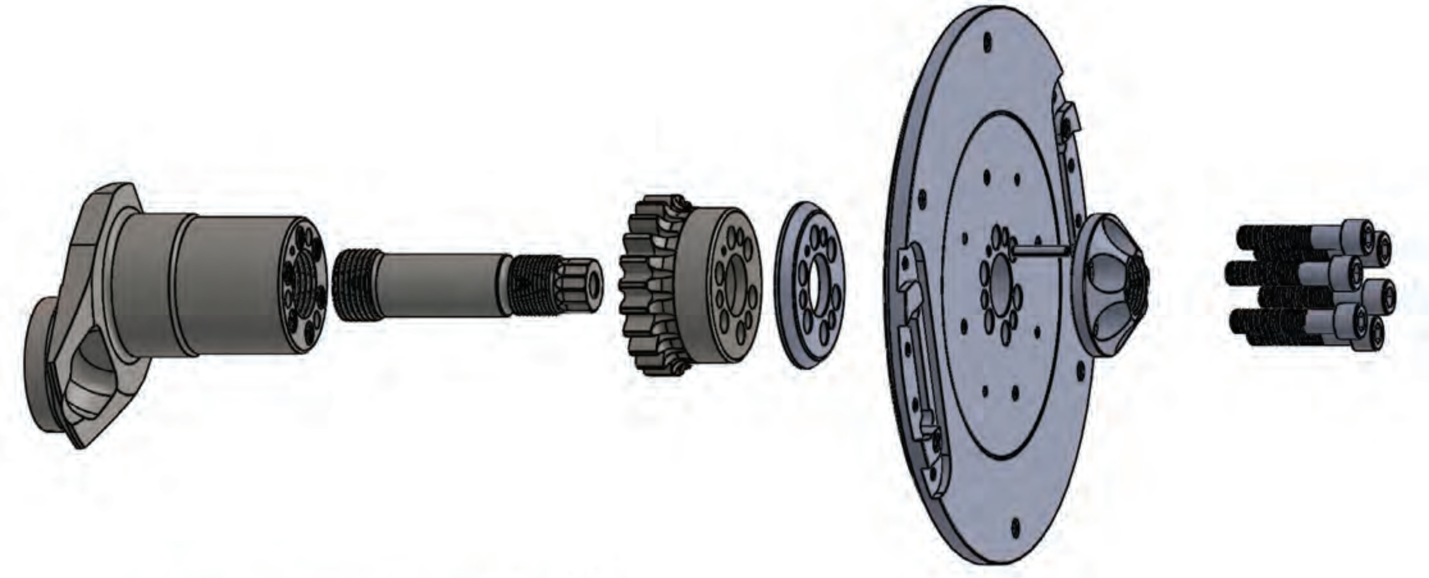
Maintaining clamping force in high tensile steel bolts though is quite difficult though, mainly because the bolts themselves don't stretch much – it's the stretch that provides the tension in a bolt in service. The smallest amount of settlage in a bolted joint will reduce the tension, and therefore, in this set-up, the clamping force.

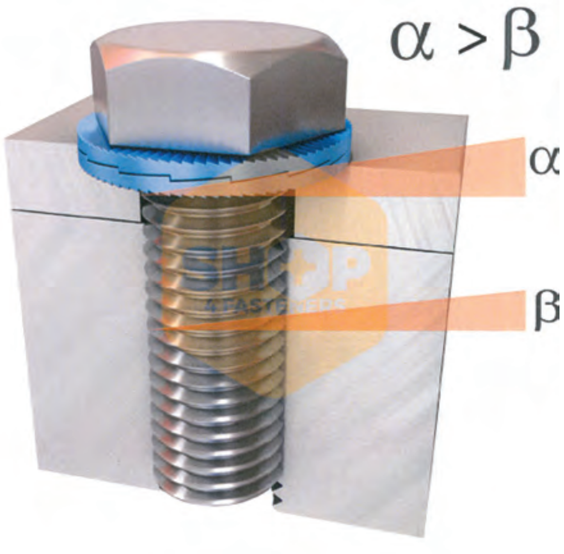
Counter-intuitively, by increasing the diameter of the bolt, the problem of maintaining 'stretch' becomes worse. As a function of applied load, a bigger bolt will (in terms of measured change in length) stretch less, so the tiniest amount of settlage removes the clamping force. There are many examples like this in engineering, where the 'if it breaks – make it stronger' ideology can lead to worse failures.

Better, by far, to identify the root cause of a problem and fix the issue. Bob did some sums and created a graph where the pressure applied by a bolt is shown against a theoretical joint settlement amount. Essentially, there are two sets of values shown in this graph, the lower set (where the clamping force drops to zero) is with the conventional 'Loctite' fixing method – the upper set relates to the residual force left even after some considerable settlage when Nord-Lock washers are used to lock the bolts.

Because of this most recent failure, the LAA has issued an Airworthiness Information Leaflet (AIL) reducing the inspection interval and the life in service of these bolts. In addition to this, we're ceasing to endorse Jabiru's Loctite approach to locking these bolts. In effect, we're mandating Jabiru's alternative method of using Nord-Lock washers which we consider much more effective in maintaining the clamping force in this joint and preventing the bolts fatiguing. Loctite is a great way of locking a bolted joint but, the only way to subsequently checking the torque on the bolt is to remove and replace the bolt – so it's not an appropriate way of locking this particular connection.

So, another year just about over and another bunch of *Safety Spots* written. May I, on behalf of all the engineering bods stationed at our Turweston HQ, wish you and all those you love, a very happy Christmas and naturally, for 2019, Fair Winds. ■





(Left and above) **In the light of the most recent Jabiru 3300 engine failure, LAA Engineering, after a thorough review, has decided to issue an Airworthiness Information Leaflet (AIL) changing both the required inspection intervals and the approved methods of fixing.**
The sketch on the left shows one flywheel attachment method that has been recently approved – the developer of this attachment method, Kevin Hyam of CAMit Aero Engines UK Ltd., believes that its incorporation will completely solve the problem of flywheel detachment because the primary attachment is now through the differentially threaded centre flywheel clamp. As you can see, the flywheel bolts are still there but they only act to prevent the centre clamp nut from rotating and becoming loose.
Another solution, we believe equally effective, is the incorporation of NordLock X-series washers which both lock the bolt (thus removing the need for, and problems associated with, high-strength Loctite) and, because of their domed Belville effect, retain clamping force after settlage.
(Photo: Kevin Hyam/NordLock)

(Above) **On the Jabiru engine, electrical energy, both for engine ignition and system power requirements, is created by a flywheel-mounted rotor rotating around a stator containing a series of coils (you can just see a couple of them through the lightening holes). This stator is held in place by an aluminium structure known as the spider. It's a system that's simple and effective, but it can make it difficult to check-tighten (or replace) the flywheel attachment bolts but this picture shows a simple solution that we would encourage all owners to adopt – an arch is cut into the spider between the stator attachment bolts which allows easy access for a socket and extension.** *(Photo: Kevin Hyam)*

LAA ENGINEERING CHARGES – PLEASE NOTE, NEW FEES HAVE APPLIED SINCE 1 APRIL 2015

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 450kg	£450
451-999kg	£550
1,000kg and above	£650
***Permit Renewal* (can now be paid online via LAA Shop)**	
Up to 450kg	**£155**
451-999kg	**£200**
1,000kg and above	**£230**
Factory-built gyroplanes (all weights) *Note: if the last Renewal wasn't administered by the LAA an extra fee of £125 applies*	**£250**
Modification application	
Prototype modification	minimum £60
Repeat modification	minimum £30

Transfer	
(from *C of A* to *Permit* or *CAA Permit* to *LAA Permit*)	
Up to 450kg	£150
451-999kg	£250
1,000kg 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	£135
Microlight to Group A	£135
Change of G-Registration fee	
Issue of *Permit* documents following G-Reg change	£45
Replacement Documents	
Lost, stolen etc (fee is per document)	£20
Latest SPARS – No 17 April 2018	

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