Most of the things you wanted to know about servicing a Rotax 912/914 series aircraft engine but were afraid to ask…. By Conrad Beale

The intention of this article is to assist the many Rotax 4 stroke engine owners, operators and engineers to carry out the work necessary to prolong the life of their Rotax 912/914 series aircraft engines. This article will touch on a number of subjects and will hopefully clear up some of the common questions we get asked. Some areas will be covered in detail, others less so. I hope it covers everything sufficiently.

I have been involved with Rotax engines for 25+ years, 18 of which have been working commercially on Rotax aircraft engines. 8 years ago I set up ConAir Sports Ltd with my wife Louise and we are the only UK Skydrive appointed Service Centre for Rotax Aircraft Engines. In the last 25 years I have seen all sorts of unnecessary engine disasters. I hope to stop a few of you from making the same mistakes that I have seen others make. The views expressed are my opinions and do not constitute a recommendation from Rotax or their distributors. Periodic updates or experience may affect the content of this article and all owners should follow the instructions issued by the aircraft manufacturer or kit supplier.

GENERAL INFORMATION:

The information in this article should help the private owner to have a better understanding of their Rotax 912UL/912ULS or 914UL series engine, in turn helping you to carry out the correct maintenance procedures. A must read is the line maintenance manual, which can be downloaded free from the Rotax aircraft engines web site www.Rotax-aircraft-engines.com. Some service tools are required to carry out the work correctly but most of the work can be achieved with standard hand tools. It should go without saying, but any work on aircraft engines should only be undertaken by adequately qualified or experienced personnel. Please take a moment to download a copy of the **latest** line maintenance manuals (correct at time of print),
for the 912UL / 912ULS from: http://www.rotax-aircraft-engines.com/pdf/dokus/d04140.pdf
or for the 914UL from: http://www.rotax-aircraft-engines.com/pdf/dokus/d04157.pdf

Figure 01: Latest Heavy Maintenance Manual

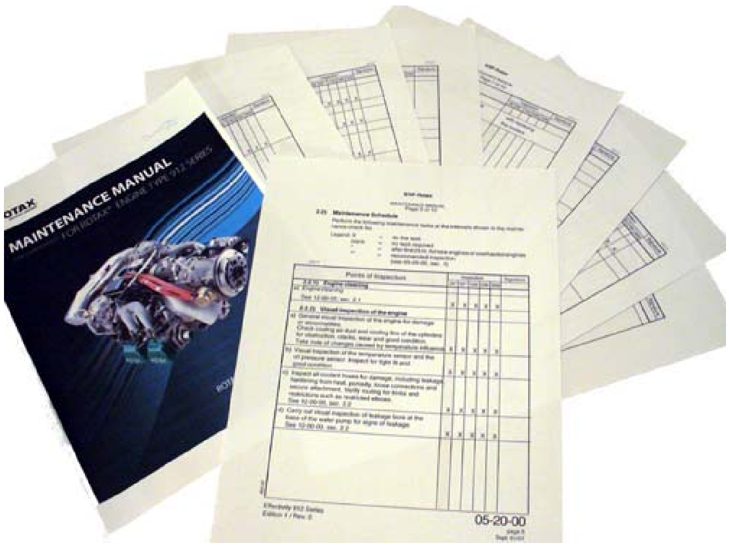

Figure 02: Service Schedule shown in latest Line Manual

The 914 is a little more complicated and for now I will only cover one or two items specific to the 914, but I will not go into too much detail.

A lot of service information and a free bulletin notification subscription scheme are available from the Rotax Owners Assistance Network "ROAN". Alternatively, the UK Rotax Distributor Skydrive offer a service where they will email bulletins directly to you as pdf attachments. The Rotax Aircraft Engines website publishes all bulletins for free download – more about that later. We are continuing to build our web site www.conairsports.co.uk and you should soon see a lot more useful information there, including a download of this article.

Note that Service Bulletins etc should be forwarded to you by your engine supplier. Submitting a warranty registration form will not affect this. If you imported an engine or obtained it second hand you may wish to subscribe to a bulletin service as above to ensure that you don't miss out on any vital information.

With every engine supplied, Rotax provide a number of documents on a CD: Installation Manual, Maintenance Manual, Operators Manual, Parts Catalogue etc. If you did not receive a copy you should contact the supplier of your aircraft or kit to obtain a copy. If they cannot supply it, you can download the latest documents from the Rotax aircraft engines website mentioned above, or if you do not have web access, the CD is available for about £15, paper copies can be purchased but they are more expensive. It is well worth taking the time to read these documents and absorb the information as it will substantially increase your knowledge of your engine. An **important** point to note is that a **warranty registration** form is supplied with every new engine. The registration is necessary (especially on imported engines) to obtain any warranty from Rotax. Failure to submit your registration within the time limits specified may void any warranty from Rotax.

It would be useful for you to take a look at your aircraft instrument panel and check that the limits have been correctly placarded. Some simple instrument marking kits are available that make a good quick reference. Check that the function of the instrument is correctly placarded as occasionally I have come across gauges labelled incorrectly. Most commonly I see Cylinder Head Temperature gauges labelled as Water Temperature.

Figure 3: Instrument marking kit fitted to a Eurostar

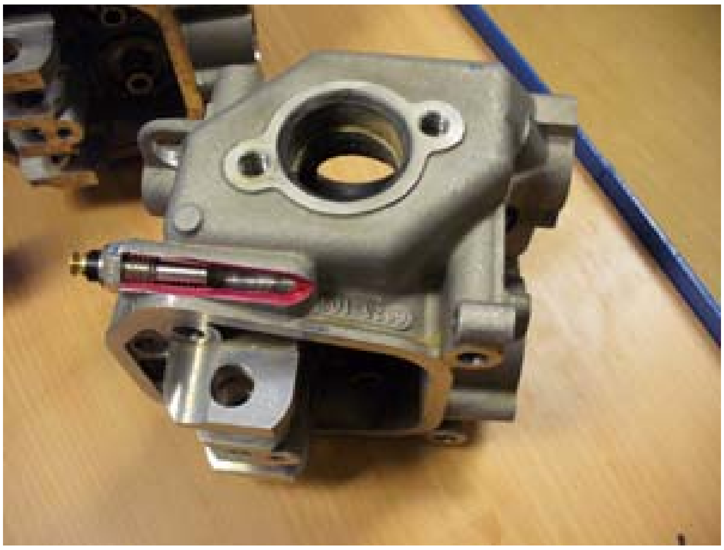

Figure 4: Cylinder head temp probe on cylinders 2/4 (not water temp)

The engine serial number can be found on the engine number plate located on the magneto housing which is hidden behind one of the carbs (see Figure 5 below). You will need this number and engine type if you want to carry out a Service Bulletin Check (there is a section on Service Bulletin Checking later in this article).

Figure 5: Position of engine serial number

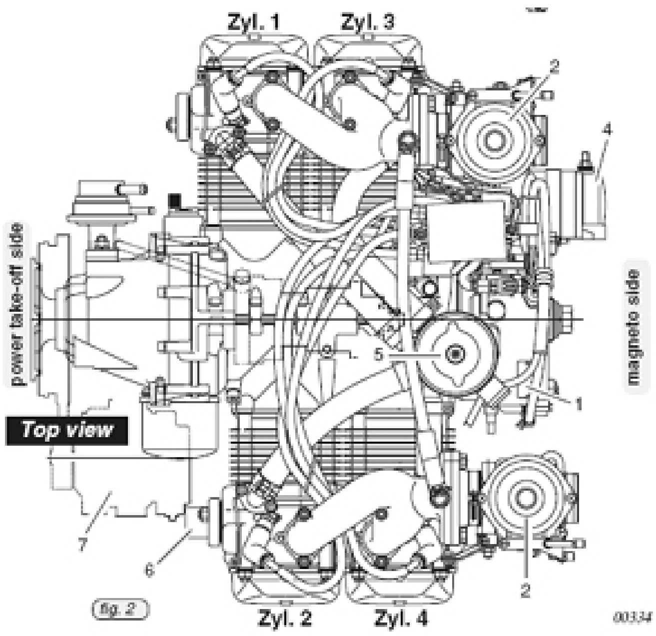

Figure 6: Drawing of cylinder orientation

The cylinder numbers can be identified by counting from the gearbox end of the engine. If you look at Figure 6 on the previous page and count from the prop shaft you will see how the cylinders are numbered (Zyl1, Zyl2, Zyl3, Zyl4). On later engines the crankcase and inlet manifolds are embossed with the cylinder number. BUT take care as some aircraft manufacturers swap the inlet manifolds from side to side.

A separate Engine Log Book must be kept. Most commonly two separate logbooks will be used, but the log book available from the BMAA has a dedicated section at the back (that is not very obvious). In the Rotax 912/914 series Line Maintenance Manual, section 05-20-00 there is a really useful table detailing the service items that need to be completed at each interval (see Figure 2). This form can be easily printed out and is a really handy work sheet on which to record the maintenance you have carried out on your engine. It is not adequate to record for example "100 hour service", reference to any work sheets must be entered in the logbook.

BASIC OUTLINE OF WORK REQUIRED AT EACH SERVICE INTERVAL:

Service Interval	**Work Required**
25Hr (first 25 hour only)	1) General inspection including visual check of electrical system, coolant system, fuel system, leakage bore, exhaust system etc 2) Measurement of friction torque 3) Check of waste gate operation (914 only) 4) Oil change 5) Oil filter replacement & dissection 6) Magnetic plug inspection 7) Air filter inspection 8) Inspection & cleaning of plugs 9) Pneumatic Balance of carbs and adjustment of idle speed 10) Service bulletin check 11) Check fuel filter (Unless otherwise specified by aircraft manufacturer)
100Hr (first and Every 100Hrs)	***25 hour points, plus:** 12) Replacement of spark plugs (912ULS/912S & 914 variants only) 13) Inspection of carb rubbers 14) Replacement of fuel filter. (Unless otherwise specified by aircraft manufacturer)
200Hr (every 200hrs)	***100 hour points, plus:** 15) Replacement of spark plugs 16) Remove strip and inspect carbs 17) Compression test 18) Change coolant (recently removed in favour of changes in accordance with coolant manufacturer's recommendation – see later section)
400Hr (every 400hrs)	***200 hour points, plus:** 19) Gearbox service (Non Slipper clutch version only) 20) Cleaning out of oil tank
600Hr (every 600Hrs)	***200 hour points, plus:** 21) Strip slipper clutch and measure slipping torque if using Avgas (advisable even if not using avgas)
800Hr (every 800Hrs)	***400 hour points, plus:** 21) Gearbox overhaul (Gearbox with slipper clutch installed on 912ULS engines only)
OVERHAUL	The **TBO** (time before overhaul) is the maximum operating hours or life before the engine needs to be fully stripped, inspected and some of the major engine components replaced. It is not a warranty period or an expected life of the engine. Depending on engine model & serial number, this work should be carried out at 600hrs, 1000hrs, 1200hrs **or** 1500Hr. In addition to the hour's periods, there is also a TBO calendar life specification. Again dependant on engine type & serial number, the TBO varies between 6 years and 12 years. The gearbox installed with a slipper clutch on a 912ULS has a TBO of 800Hrs. Please refer to ConAir Sports web site for further information.

USE OF AVGAS:

If you find it necessary to use Avgas in your Rotax 912/914 aircraft engine you will need to replace your spark plugs twice as often, and change the oil and oil filter at least every 50 hours. The gearbox may also need some extra work, but only if your gearbox has a slipper clutch, and it is only necessary every 600 hours. The bi-products of burning Avgas also cause deposits in the cylinders and crankcase that increase the likelihood of corrosion. The use of unleaded fuel is far better for your Rotax 912/914 series engine. Some concerns over carb icing and vapour locks can be overcome by a well designed fuel system that includes a vapour return system and a suitable carb heat system. Unleaded Mogas can contain ethanol that is not permitted for some aircraft types and the use of unleaded fuels should only be considered after consultation with your aircraft manufacturer and the governing body responsible for your aircraft type. Avgas is much more convenient for some operators as it is more readily available at airfields but for the sake of your Rotax engine it should only be used where absolutely necessary. The photographs in figure 7 on the following page show the sprag clutch in an engine using avgas and the same component from engine using unleaded Mogas. Figure 8 shows a valve from an engine that has run for 1000 hours on Avgas, and Figure 9 shows the white lead deposits on the top end of a conrod that are the result of using Avgas.

Figure 7: Sprag clutch in an engine run on Avgas (left) and the same component in an engine run on Unleaded Mogas

Figure 8: Valve after 1000 hours Avgas use

Figure 9: White lead deposits from Avgas on top of conrod

START OF DAY INSPECTION, POINTS TO NOTE:

- Check engine controls, throttle, prop controls and fuel taps for correct operation.
- Check coolant level in both the overflow bottle & expansion tank. Any distortion or swelling of the overflow bottle can indicate a cooling system problem that has caused boiling and it should be addressed immediately. Visually check the coolant radiator for damage or leaks.
- Ensure the magnetos are turned off (consider the magnetos to be live and at all times be prepared for the engine to start unexpectedly). Remove the oil filler cap. Rotate the engine slowly in the normal direction by hand. Whilst rotating listen for unusual noises, and check that the engine feels normal (normal is virtually impossible to define, and will come with experience). Some engines have slipper clutches installed that allow a small amount of free movement between the prop and the crankshaft, you may feel the gearbox slide at a low specified torque. Make sure that the friction in this free movement feels normal (if the friction drops too low then the gearbox will require further maintenance). Check that the oil level is between the minimum and maximum points identified by the flat section on the dipstick. The oil level can only be checked after the engine has been “gurgled” please see more detailed explanation below.
- Look for any signs of oil, coolant or fuel leaks and for any perished rubber parts. Check the security of the carbs and air filters.
- Basically have a really good look at everything visible on and around the engine. It should take about 5 mins, anything less and you are not checking it well enough.

- Before attempting each start of your engine it is highly recommended that you turn the engine over a few times by hand and then crank the engine on the starter motor long enough to achieve normal oil pressure. Installations with combined magneto and starter key systems can have a separate starter button wired in parallel with the existing one to enable you to do this. The starter should not be operated for longer than 10 seconds at a time, after which time it should be allowed a 2 minutes cooling off period. It is normal for the oil pressure to rise within the first 10 seconds of cranking. If yours does not it may be worth while having a closer look at the lubrication system.

CHECKING OIL LEVEL:

WARNING Under certain conditions it is possible for oil to remain in the crankcase of the engine giving a false indication on the oil dipstick. To get an accurate indication it is necessary to return the oil back to the tank. This is achieved by removing the oil tank cap and rotating the engine until you hear a gurgling noise. For reliable results wait a few seconds and turn again until a second gurgle is heard. Only then can you remove the dipstick and check the level. If you are unsure about the level and reinstall the dipstick for a second measurement leave it in place for a few seconds to allow the level to settle. Oil tanks that are mounted with the middle of the tank above the crankshaft center line can allow the oil in the tank to siphon into the crankcase. As a result there is an increased risk of there being a lot of oil in the crankcase. Under certain circumstances particularly if the engine has been left standing for a long time it is possible for the oil to seep past the piston rings and cause a hydraulic lock in any of the cylinders. Omitting to rotate the engine by hand prior to operating the starter motor could be a very expensive mistake.

Figure 10: Dismantled oil tank

CHECKING FUEL FILTER

The fuel filter is specified and fitted by the aircraft manufacturer, therefore respect the service intervals suggested by them. Hopefully the filter is clear and the level of contamination can reasonably easily be seen. Care should be taken with a visual check as it is not always a true indication of the level of debris in the filter. I have seen several cases of filters that are badly restricted but no apparent contamination can be seen. New aircraft with composite or polyethylene tanks seem to contaminate filters very quickly. It probably wouldn't hurt to replace the fuel filter after the first 10 hours, first 25 hours and then every 100 hours. I would recommend the fitting of a fuel pressure gauge, these instruments are very cheap but rarely fitted, and would easily prevent a number of engine stoppages caused by fuel starvation - it could possibly be the best investment you make.

Figure 11: Fuel pressure gauge fitted

<u>GENERAL INSPECTION:</u>

COOLANT SYSTEM; RUBBER PROTECTOR ON THE EXPANSION TANK; OIL SYSTEM; HARDENING OR DEGREDATION OF RUBBER COMPONENTS; LEAKAGE BORE; ELECTRICAL SYSTEM; EXHAUST SYSTEM; PROPELLER; PRESSURE SENSORS; TEMPERATURE SENSORS; FUEL LINES; FUEL FILTERS; ENGINE MOUNTS; FASTENERS:

Well it explains itself well enough doesn't it? But a few points to concentrate on are:

- Perished fuel hoses.
- Hardened oil lines particularly where they run close to any exhaust parts.
- Discoloured coolant should be replaced immediately. The Evans NPG+ looks like dirty water, so make sure you know what the coolant is before making a judgement.
- Corrosion around the neck of expansion tank can prevent the cooling system from pressurising or the overflow system from working correctly. Any signs of corrosion should be dealt with. The rubber seals in the pressure cap must be in perfect condition.
- On the underside of the coolant expansion tank there is a rubber protector which should be examined for signs of perishing and replaced accordingly. Early engines had a protector glued in place but glue can be affected by solvents or extreme heat and the protector can fall off. On later engines the protector is fitted around the hoses and cannot escape. In all cases the tank should be checked for any signs of fretting.
- Generally look around all hoses and wiring for chafing leaks etc.
- The coolant pump leakage bore is located on the underside of the engine near the flywheel. Generally there will be no evidence of a coolant leak at all. If you see evidence of a leak refer to the manuals for additional checks.
- Have a good look over the entire exhaust system for cracks. Be particularly vigilant if a cabin heat system is fitted as poisonous carbon monoxide fumes can enter the cockpit.
- Also refer to checking of waste gate operation below.

Some of these, and some additional issues are shown in Figures 12 to 16 below.

Figure 12: HT leads fretting on head due to poorly positioned sleeve

Figure 13: Oil tube worn through on hose clamp

Figure 14: Using refractometer to check glycol ratio

Figure 15: Crack in 914 exhaust pipe.

Figure 16: Corroded expansion tank

CHECKING OF WASTE GATE OPERATION (914 ONLY): POWER UP FUNCTION CHECK.

The 914 engine is basically a turbo charged 912. The turbo increases the air pressure at the carb inlet that in turn provides an increase in power output. The amount of pressure increase "boost" is controlled electronically. The turbo is fitted with a waste gate that controls the amount of exhaust gases that bypass the turbine. The wider open the bypass the slower the turbine and the less boost. The waste gate is operated by a servo motor pulling a cable that alters the position of the waste gate. The free movement of the waste gate and cable are essential for the correct operation of the turbo. With the electrical master switched on, and by simply operating the throttle lever, the waste gate arm must be seen to move. Great care should be taken to ensure the servo motor switch is in the on position. An incorrectly positioned switch will isolate the waste gate servo motor and this can lead to a turbo over boost, and a probable engine failure.

During initial power up of the turbo control unit "TCU", the servo motor goes through a self test cycle, and both the orange and red TCU warning lights (usually located on the aircraft instrument panel) should illuminate for a couple of seconds and then extinguish. If the lights stay lit or if they continue to flash, there is, or has been, a fault and the reason needs to be investigated before the engine is started. During this self test, check that the waste gate lever on the turbo moves back and forth.

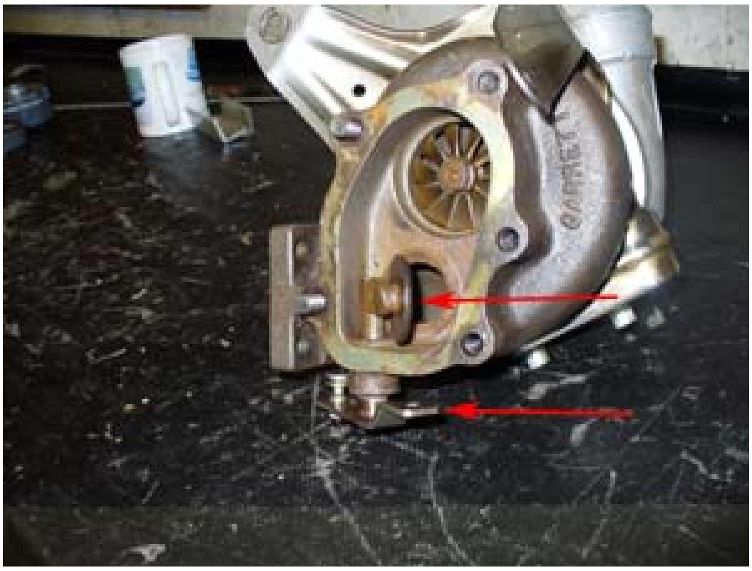

Figure 17: Inside of turbo showing waste gate and control lever

OIL & OIL FILTER CHANGE:

It is a common misconception that all you need to do on the 100 hour service is an oil and oil filter change. There is a significant amount more that needs to be carried out. Please read on…..To ensure that the oil level check and oil change is carried out correctly I will cover it carefully.

The 912/914 engine oil lubricates both the main engine and the gearbox. There is no separate gearbox oil to change!

Before draining the oil, all of the oil in the crankcase needs to be returned to the oil tank and this is done by “gurgling the system” (see oil level check above). A check of the oil level at this point is advised. This can help to establish the oil consumption since the last oil fill. Remove the drain plug from the bottom of the oil tank (please note that Rotax have provided a hex on the bottom of the tank that needs supporting with a spanner during slackening/tightening of the drain bung – see Figure 18 below). Drain the old oil from the tank and dispose of it responsibly. It is advised **not** to drain the oil lines or oil cooler to minimise the air in the system. Remove the old oil filter and replace it with a new Genuine Rotax oil filter. Apply a small amount of oil to the filter gasket, then tighten the filter correctly (see recent Service Bulletin SB912-055 - screw on until the gasket touches then turn through a further 270 degrees). Re-install the drain bung with a new gasket and torque to 25Nm, then wire lock it. Refill the oil tank with oil to the upper level mark on the dipstick.

Figure 18: Undoing oil tank drain bung

Figure 19: Shell VSX4 oil.

Oil selection should be made with reference to the documentation supplied by Rotax (currently SI-912-016). The commonly available oil used in the UK is Shell Advance VSX4 10W-40 (as shown in Figure 19 above). Its formulation is suitable for use with both Unleaded Mogas and Avgas. It is very important that the oil that you use does not have any friction modifiers but does have a gear lubricant as the engine oil is circulated through the gearbox. The use of any friction modifier additives should be avoided as they can affect the friction settings in the gearbox.

Prime the oil system as follows. Firstly check that the Master switch is turned on, but that the magnetos are turned OFF. Remove a spark plug from each of the 4 cylinders. Rotate the engine by hand in the normal direction until the oil pressure comes up to within the normal range. This can take some time, but be patient - it is worth it. Priming is now complete. Refit the spark plugs and torque them up to 20Nm, and rotate the engine until it gurgles. Check the oil level and top up as necessary.

Figure 20: Prop being turned by hand to prime the oil system

Figure 21: Flydat showing 2.7 bar oil pressure

It is virtually impossible to evacuate all the air from an oil cooler that is mounted with the outlet connections on the underside of it. To ensure the oil cooler works efficiently and prevent air being trapped in it, the outlet connected to the oil pump should be on the topside of the cooler. If your oil cooler has been installed with the outlets at the bottom you will need to take extra care to ensure it is full before the engine is run as it could lead to air entering the lubrication system. Incorrect venting of the oil system can lead to problems such as improper operation of the valve hydraulic lifters. Improperly filled hydraulic lifters could cause failures of items such as valve spring retainers due to excessive loads in the valve train.

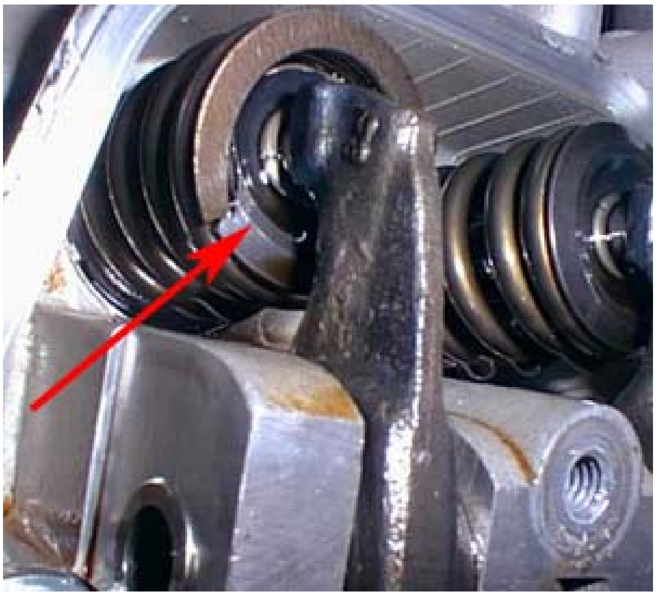

Figure 22: Broken VSR, consequence of air in hydraulic lifters

If an oil thermostat is installed you will need to be particularly careful as it it's possible for air to be trapped in the oil cooler. You should ensure that the oil cooler and hoses are full of oil before high power settings are used.

The oil filter you removed needs to be carefully cut open and inspected for contamination. It is a very useful inspection to give an indication of the condition of the engine internals. A specialised filter cutter is needed to ensure that no chips enter the element when it is being cut open. Once open the cartridge can be removed. Oil flows through the filter mat from the outside inwards, so all the contamination will be evident on the outside of the mat. The filter mat can be removed by carefully slicing it off with sharp knife. Once removed cut the filter mat into manageable lengths, squeeze the pleats together to remove as much oil as possible, then place it "outside up" onto some paper tissue to draw the remaining oil out. After about half an hour you will be able to inspect the filter mat for contamination. It is very difficult to explain how much contamination is normal, but you will always find some small pieces. After opening a few oil filters you will become accustomed to what to expect.

Figure 23: Cutting open the filter

Figure 24: Removing the filter paper.

Figure 25: Contaminated filter papers (This engine needed further investigation)

Figure 26: Genuine filter and pattern one. Pattern filter is on left with much smaller filter area.

Unleaded Mogas is much cleaner than Avgas. Should you choose to use Avgas, the oil circuit and spark plugs will become contaminated much faster than if you use unleaded and therefore the oil, filter & spark plugs have a reduced service life.

It is very important that a genuine Rotax Oil Filter is used. The quality of the filtering media, the filtering area, the bypass valve pressure, the canister burst pressure, and even simple points like having the correct thread are all critical aspects and have been determined by Rotax. If you chose to purchase a £3.00 filter from the local automotive store, remember that you should really be putting in a modification application into the PFA or BMAA for the use of non-standard parts. You should also consider the consequences of an incorrect filter being fitted.

INSPECT THE MAGNETIC PLUG:

The magnetic plug located in the crankcase near the gearbox is primarily designed to catch metal particles from the gearbox, but due to the common oil supply for the gearbox and engine it is possible for the plug to be contaminated if a problem arises elsewhere in the engine. There are 3 different head configurations: 6mm Allen screw, Torx TX40, and 17mm Hex. The magnetic plugs are often difficult to remove. Removal can be eased by tapping the head of it prior to unscrewing it. The removal of this plug is essential to give an indication of the internal condition of the engine gearbox. When removing the plug please be aware that there is a small accumulation of oil behind it. The level of contamination can be difficult to establish due to oil being between the small metal filings. A quick rinse in some carb cleaner will remove the oil but leave the ferrous material on the magnetic plug. After inspection it should be cleaned, refitted, torqued to 25Nm and wire locked.

Figure 27: Clouting the magnetic plug to free it off

Figure 28: Oil behind magnetic plug

Figure 29: furred magnetic plug before cleaning

Figure 30: Cleaning magnetic plug

Figure 31: Plug after cleaning in carb cleaner

SPARK PLUG REPLACEMENT:

The correct plugs should be used:
912UL, Rotax part number 897255 (NGK DCPR7E)
912ULS, Rotax part number 297940 (NGK DCPR8E)
914UL, Rotax part number 897257 (NIPPONDENSO X27EPR-U9)

The spark plug heat grade is critical for correct engine operation and the use of an “equivalent” may not be suitable. To ensure the correct heat transfer from the spark plugs to the cylinder heads, the plug threads need to be coated with a small smear of a specific heat sink paste. The 912UL engine has a 200 hour spark plug change interval whilst the

912ULS (100HP) and the 914UL have a 100 hour spark change plug interval (assuming the engine is operated on unleaded Mogas).

The correct spark plug gap can be found in the line maintenance manual, but are 912UL & 912ULS 0.7-0.8mm and 914UL 0.6-0.7mm. In all cases the torque of the plugs on a cold engine is 20Nm. In cases of starting difficulty the plug gaps can be reduced to 0.50mm.

Spark plugs can be cleaned using a brass wire brush, but for the relatively low cost of a set of plugs for a 912 being just over £20 it is hardly worth it.

Figure 32: Applying heat sink paste


Figure 33: Checking plug gaps before installation

CARBURETTOR INSPECTION:

Some external inspections of the carbs are required, such as free movement of the throttle and choke controls and correct venting of the float chamber. The choke movement needs to be across the full range. If the lever does not move fully then you will not get the full rich setting, and this may cause starting issues. The choke control is progressive: full choke gives a very rich mixture and increased idle speed and as the choke is released the richening is reduced but the increased idle speed is maintained. It is very important that both chokes are moving freely and evenly. If the choke sticks slightly open on one side the increased idle speed can badly affect the carb balancing. Please note the correct orientation of the choke lever as it is easy to fit incorrectly. Care should also be taken with respect to the carb vent tubes. They control the pressure on top of the float chamber and any alterations may cause the engine to run incorrectly, and it is not unusual that the alterations will have an affect on the fuel air ratio whilst airborne, sometimes with catastrophic consequences. Some manufacturers install mixture control systems that connect to the carb vent connection, all hoses should be checked for security and perishing. A more detailed inspection of the carb is required at the 200 hour check, but carrying out an inspection of the carb needle and float chamber would be a useful check at every service. Occasionally water can enter the float bowl as a consequence of icing, or contamination in the fuel system. The removal of the float chamber on the 914 is a bit more of a challenge, but it should not be omitted just to save a few minutes. The fuel inlet valve and brass operating lever should be examined. When re-installing the float chamber check the gasket is in good condition. With the carb removed it does not hurt to carry out an inspection of the carb needle and diaphragm, however removal of the needle can be a bit of a challenge due to the Loctite patch used on the aluminium screw (It is not normally necessary to re-loctite after removal). A small amount of heat will reduce the strength of the Loctite and will ease removal of this screw. Carefully tug on the diaphragm and look for any pin holes, perishing or splits. The rubber diaphragm has a location lug on it that must be positioned in the corresponding recess in the carb housing during re-assembly. If the diaphragm is ever removed from the slide a similar arrangement should be noted.

The routing and securing of any throttle cables should be made with care. A tightening of the radius of a cable bend can affect the inner cable length and mess up carb balancing. After any carb strip you will need to balance the carbs using a set of pneumatic gauges. A ground run will be necessary to ensure correct assembly and the carbs are not flooding (see section on Carburettor Balancing below).

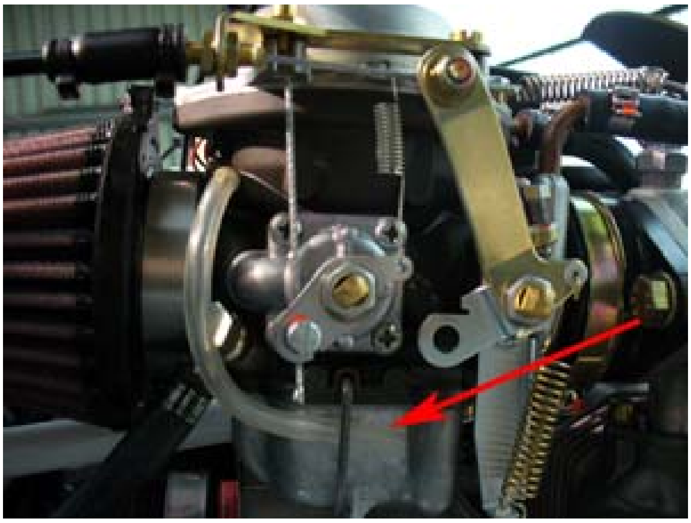

Figure 34: Correct carb overflow pipe vent arrangement and sprung open throttle system with correctly fitted choke levers.

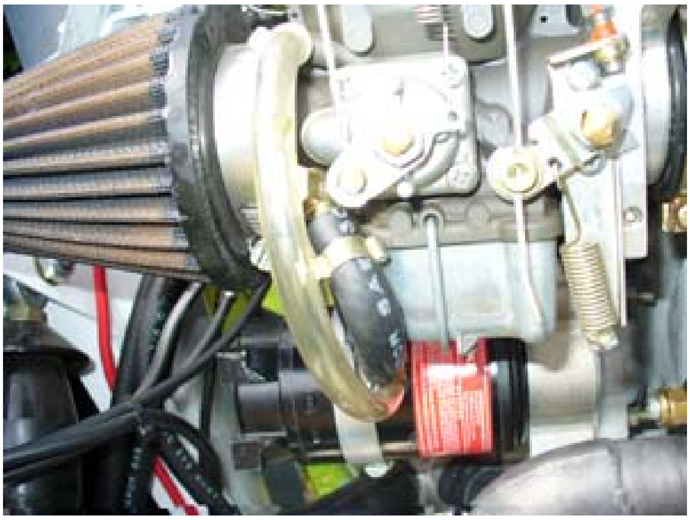

Figure 35: Typically modified vent tube that could affect mixture, (sprung closed throttle system)

Figure 36: Water in the float bowl

Figure 37: softening Loctite by applying heat to remove carb needle

Figure 38: Diaphragm location lug and recess.

INSPECTION OF THE RUBBER CARB FLANGE ADAPTOR:

The inspection of the carb rubber is covered by Service Bulletin SB-912-030, and the inspection intervals depend on the type of rubber manifold installed. To simplify the process I would suggest that at 50 hour intervals the carb is removed, and the rubber is inspected internally for cracks. The carb can usually be easily removed. Any installation with a supported airbox is less susceptible to splits, but not exempt.

There are some less expensive pattern carb rubbers available, but be aware that they vary in quality and may not be suitable for your installation, they also constitute a modification.


Figure 39: Checking carb rubber flange for cracks

CARBURETTOR BALANCING:
On a new installation the synchronising process needs to be carried out in 2 stages: mechanical synchronising and then pneumatic synchronising. If you are carrying out the balancing process as part of routine maintenance, the carbs should be set up well enough that you can skip the mechanical synchronising stage. Pneumatic synchronising is essential as whilst mechanically setting up the cables is a good starting point it is just not adequate to get good results. Correct carburettor synchronising will give you a smoother running engine and the correct mixture distribution. Often a single black spark plug can be explained by improper carb balance especially if accompanied by a lean looking spark plug in the opposite corner of the engine. If your carbs are poorly balanced the torque pulses will be uneven. This will increase vibration and wear on all engine components in particular gearboxes, wiring, and carburettors. It will not do any favours to a whole host of airframe components and will reduce pilot comfort.

Balancing will have the greatest effect at lower throttle settings. If the throttles are 1% different at full throttle (one throttle position at 100%, the other at 99%) the imbalance will be barely noticeable. With the same cable length error at half throttle the imbalance is more noticeable (one throttle at 50% the other at 49%). At idle position the difference becomes extreme (one throttle at 2% the other at 1%). You can see that with this example that at idle 2 cylinders will be working twice as hard as the other 2. Now you should be able to understand why an engine that has had the carbs synchronised properly will sit nice and steadily at low engine speed whilst an engine with even slightly out of balance carbs will rock around all over the place.

The throttle valve levers on a 912 as supplied by Rotax are set up to be sprung open. This is so that in the event of a cable failure the engine will advance to full power and the aircraft can continue to a safe landing area where the pilot can shut the engine down. Some aircraft manufacturers alter the throttle levers to a sprung closed system. It is worth taking a few minutes to familiarise yourself with the different configurations and check which system you are working on.

If you have a sprung open throttle arrangement it is essential that when the throttle is closed the throttle controls in the cockpit hits a hard stop and does not rely on the stop on the carb valve lever. If the stop in the cockpit is incorrectly adjusted or omitted it is possible for the pilot to bend the throttle stops on the carbs. This could cause the engine to stop. In the same respect, with a sprung closed system the throttle controls in the cockpit should reach the full throttle stop without putting a load on the cable (it must have a small clearance between the throttle valve lever and the bracket on the carb). If the stop at the pilot end control is omitted there is a considerable risk of pulling the nipple off the throttle cable or breaking the throttle cable.

MECHANICAL SYNCHRONISING - This step is really only necessary if you are installing a new engine or replacing the throttle cables. All steps in mechanical synchronising are to be carried out without running the engine.

You have 2 main adjustments to make.
1) Rough cable length adjustment, by moving the cable through the swivelling screw on the throttle valve lever. Take care not to over tighten the M5 nut as this can prevent the swivel screw from moving freely.
2) Fine cable length adjustment, using the cable adjuster.

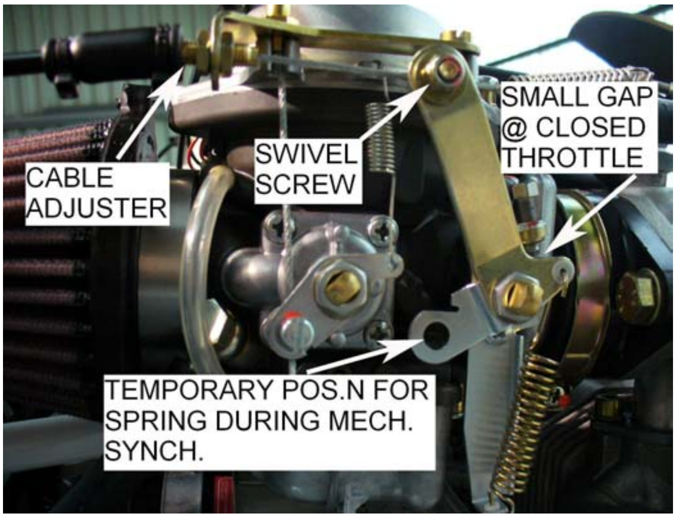

Figure 40a: Sprung open throttle system

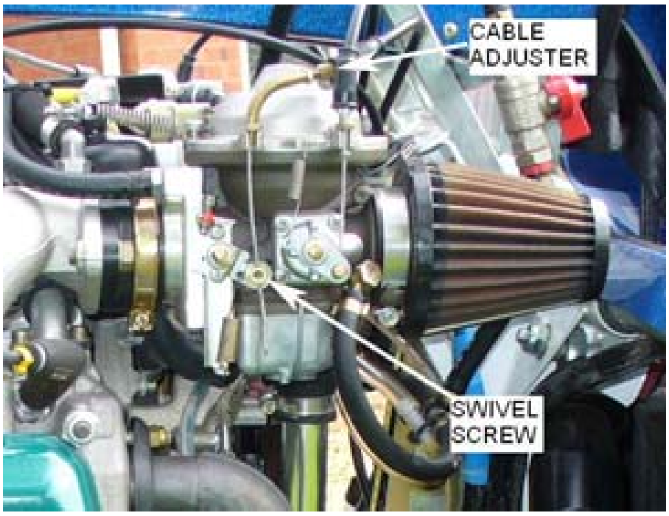

Figure 40b: Sprung closed throttle system

Hint - if you have a sprung open throttle system, temporarily alter the spring position to the position indicated in the photo in Figure 40a. This will make setting up the initial cable length much easier. Insert the throttle cable through the cable adjuster and place the inner cable through the swivel screw on the throttle valve lever. Ensure the outer cable is seated correctly in the adjuster. Close the throttle control in the cockpit, pull the inner cable through the hole in the swivel screw and carefully tighten it in place. Repeat the process on the other carb. Refit the throttle spring to the intended position.

With the help of an assistant slowly open the throttle in the cockpit until there is a small gap between the idle stop and the throttle valve lever stop. Check the gap on the second carb and adjust the cable length on the cable adjuster until the same gap is achieved. Double check the throttle valve levers move off the stops at the same time.

Check the throttle valve lever movement throughout the full range and if everything is working correctly the levers will reach the full throttle position at the same time. Check that any adjustments you have made will not cause a load to be applied to the cable at either end of the range.

<u>PNEUMATIC SYNCHRONISING</u> - Firstly check that the chokes and throttles are moving fully and freely, as if not they can affect the balancing process. The swivelling screw through which the cable passes must rotate freely in the throttle lever arm. Any binding will give an uneven travel and undo all your careful work. Check the position of the mixture screws.

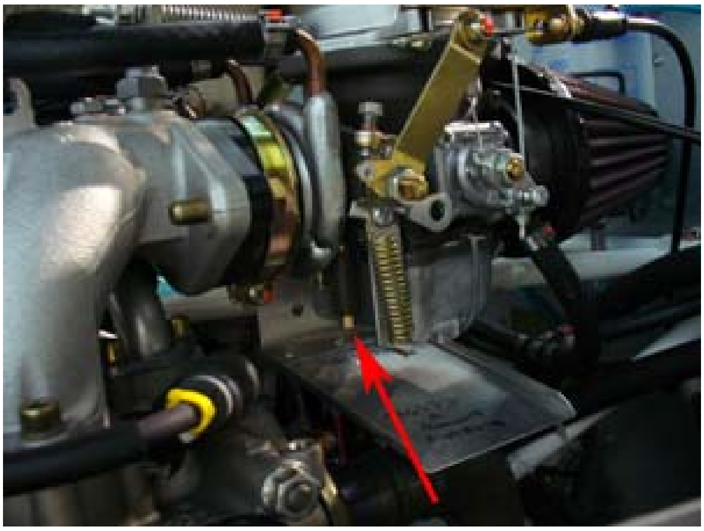

Figure 41: Photo 37 of idle mixture screw (hex).

Figure 42: Pneumatic carb balancers

Factory standard setting is 1½ turns out from fully closed, 2 turns out will often improve the idle smoothness. During the pneumatic synchronising process you may find you will be running the engine on the ground for some time. During the ground runs keep a close eye on all engine operating parameters in particular the temperatures and oil pressure.

<u>Instructions for Pneumatic synchronising on engines with sprung OPEN throttle systems:</u>

- Warm the engine to normal operating temperatures using standard procedures as per the aircraft manual.
- Shut the engine down and disconnect the balance pipe that sits between the two inlet manifolds by loosening the clamp at one end. Unclip the carb support spring first.
- Fit the vacuum gauge hose with the sleeve on it onto the hose outlet on the manifold.

- Push the other vacuum gauge hose into the loose end of the balance pipe. Slacken adjusters on throttle cables.
- Ensure the routing of the throttle cables has not been altered as extra bends or kinks could affect the balance significantly.
- Unscrew the throttle stops so that they cannot come into contact with the plate on the throttle valve lever. These stops are no longer required and will be adjusted again later.
- Make sure the aircraft is secured properly and the throttles function correctly. Close the throttles. Ensure that there are no loose objects around that may enter the rotating parts of the engine/aircraft including securing the hoses for your vacuum gauges.
- Start the engine. Run the engine until warm – you may find that the engine will run rough during the balancing process especially as the automatic compensation provided by the balance pipe has been removed.
- Adjust 'damping' taps (if fitted to your gauges) until the needles oscillate slightly.
- Open throttle to give approximately 2200rpm and if an in-flight adjustable-pitch propeller is fitted, adjust to fine pitch.
- *Warning: For your safety all adjustments must be made with the engine shut down.*
- Look at the gauges making a note of the readings on the gauges. The carb that has the widest open throttle will produce a smaller vacuum level. Adjust the cable adjusters until you manage to get both gauges indicating the same reading.
- Once the carbs are balanced at 2200rpm, close the throttle and ensure the idle speed is as required (normally 1500rpm). If not you will need to adjust the cable length to achieve the correct idle speed and balance. Your aim is to obtain a good balance at both 1500rpm & 2200rpm.
- Once satisfactorily balanced - stop engine, remove gauges and refit balance tube, clamp and carb support spring.
- Start engine and check idle rpm (it may have increased slightly) if any adjustment is required stop the engine and alter the cable adjusters evenly.
- With the engine turned OFF close the throttle fully (the throttle control should come up against the throttle hard stop in the cockpit. Adjust the throttle stop screw on the carb to be just clear of the throttle valve lever stop (0.002" is sufficient). This will ensure that when the throttle is closed by the pilot the throttle cable cannot be overloaded, and ensures the idle speed is maintained (without this gap it is possible to bend the idle stop on the carb which could result in an engine stoppage).

<u>Instructions for Pneumatic synchronising on engines with sprung CLOSED throttle systems:</u>

- Warm the engine to normal operating temperatures using standard procedures as per the aircraft manual.
- Shut the engine down and disconnect the balance pipe that sits between the two inlet manifolds by loosening the clamp at one end. Unclip the carb support spring first.
- Fit the vacuum gauge hose with the sleeve on it onto the hose outlet on the manifold.
- Push the other vacuum gauge hose into the loose end of the balance pipe. Slacken adjusters on throttle cables.
- Ensure the routing of the throttles has not been affected as extra bends or kinks could affect the balance significantly. Ensure there is a small amount of slack in the cables when the throttle is closed.
- Make sure the aircraft is secured properly and the throttles function correctly. Close the throttles. Ensure that there are no loose objects around that may enter the rotating parts of the engine/aircraft including securing the hoses for your vacuum gauges.
- Start the engine. Run the engine until warm – you may find that the engine will run rough during the balancing process especially as the automatic compensation provided by the balance pipe has been removed.
- Adjust 'damping' taps (if fitted to your gauges) until the needles only oscillate slightly.
- Open throttle to give approximately 2200rpm and if an in-flight adjustable-pitch propeller is fitted, adjust to fine pitch.
- *Warning: For your safety all adjustments must be made with the engine shut down.*
- Look at the gauges making a note of the readings on the gauges. The carb that has the widest open throttle will produce a smaller vacuum level. Adjust the cable adjusters until you manage to get both gauges indicating the same reading.
- Once the carbs are balanced at 2200rpm, lock the cable adjusters.
- Run the engine again and check the adjustment at 2200rpm. Return the throttle to idle. This system can use the idle throttle stops. Adjust the idle throttle stops to obtain desired tick-over rpm (normally 1500rpm) and adjust stops side to side to obtain even balance – you may find the damping taps need adjusting to reduce needle flicker.
- Once satisfactorily balanced, stop the engine, remove gauges and refit balance tube, clamp and carb support spring.
- Start engine and check idle rpm (it may increase slightly) and adjust speed by turning both stops by the same amount anti-clockwise.
- With the engine turned OFF use the pilots throttle controls (foot & or hand) to open the throttle fully (the throttle control should come up against a hard stop built into the control mechanism). Ensure that the throttle lever on the carburetor has a small amount of clearance from its full throttle stop, thus ensuring that the throttle cable cannot be overloaded when the pilot applies full throttle. If any adjustment is needed to prevent cable overload then the complete balancing procedure will have to be carried out again. Return the throttle to the closed position.

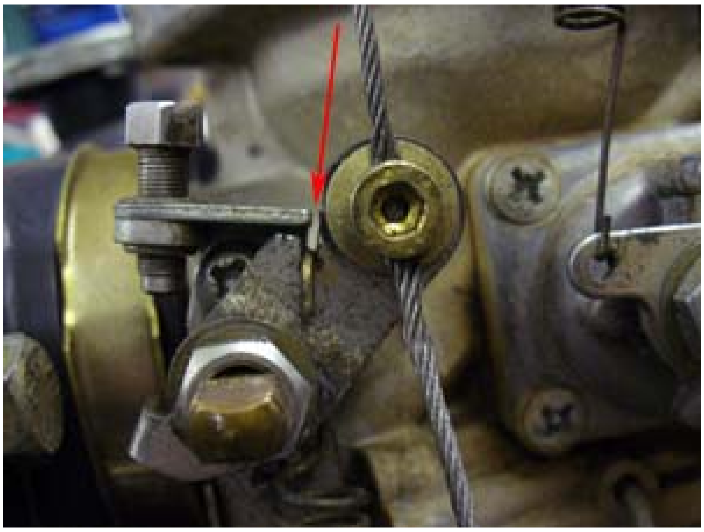

Figure 40: Throttle lever with clearance at full throttle

AFTER BALANCING you should find that your engine runs smoother and gives more even spark plug colours.

After making any adjustment to the throttle cables you may need to secure the cables and adjusters with locking wire. Then have the job checked and signed off in the engine logbook. Please note the throttle is a primary control and a duplicate inspection is required.

Hint - If you tie up the throttle cables after carrying out the balancing process or disturb the routing of the cables when you install the cowlings it will alter the inner cable lengths. This might undo your synchronising work and give you disappointing results – You have been warned!!

AIR FILTER - CHECK, CLEAN AND RE-OIL:

Most aircraft are fitted with K&N type Air filters. When the air filters show signs of discolouration (K&N filters are normally pink) the filters need to be cleaned in accordance with the filter manufacturer's instructions. After cleaning the air filters they will need to be re-oiled (see filter manufacturer instructions). If you have replaced or cleaned your air filters it will be necessary to pneumatically re-balance the carbs.

Figure 43: Clean air filter shown with dirty filter about to be cleaned

GEARBOX INSPECTIONS:

There are various configurations of the 912/914 series gearbox, but for maintenance purposes we only need to concern ourselves with 2 basic variations. Gearboxes fitted with a slipper clutch and gearboxes without a slipper clutch. Gearboxes without a slipper clutch require a strip down and inspection at 400 hour intervals. A 912 ULS engine with a Gearbox with a slipper clutch fitted requires a strip down at 800 hour intervals (except when run on Avgas when a further strip at 600 hours to clean the slipper clutch is necessary). The checking of the slipper clutch needs equipment capable of measuring the huge breaking torque (about 700Nm) and should be left to organisations geared up to carry out these checks.

The gearbox needs specialist equipment to strip it and it is not a job that should be undertaken without training.

Figure 44: Gearbox with slipper clutch

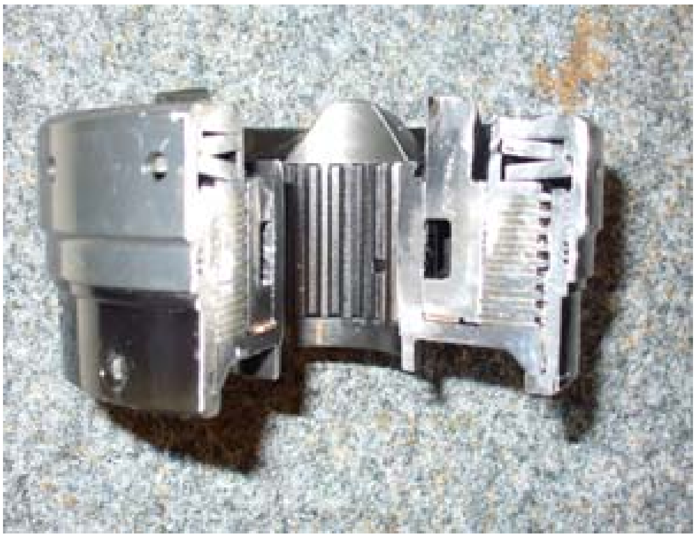

Figure 45: Cut away of slipper clutch

Figure 47: Gearbox without slipper clutch

FRICTION TORQUE:

Engines fitted with a slipper clutch require a check of a free movement called friction torque (do not get this mixed up with slipping torque mentioned in the previous section). If your gearbox does not have the slipper clutch fitted you will not be able to measure any friction torque as there is only about 1° of movement.

The angle of free movement is either 15 or 30° depending on the model of slipper clutch installed. To obtain reliable measurements it is necessary to temporarily lock the crankshaft. Between the gearbox and cylinder 2 you will find an M8 cap head screw. Removing this bolt, and rotating the engine so that cylinder 1 is at Top Dead Centre will enable the crank to be locked. With every engine a locking bolt is supplied in the engine tool kit. The friction torque can easily be measured by using a webbing strap around the prop at 500mm radius. Using a spring balance the force to rotate the prop over the 15/30°can be measured. You will need to turn the prop backwards a few times to get an average reading (this does not rotate the crankshaft). The load used should be the force used to maintain movement, not the breaking force. The torque = force x distance. So with a force of 80N (approx 8Kg) at a distance of 1/2m we have a friction torque of 40Nm. The torque needs to be between 30-60Nm. If found to be outside these limits the gearbox should be sent to a facility for adjustment as specialized equipment is needed to carry out these adjustments. After checking the friction torque, the blanking bolt should be reinstalled with a new copper washer and torqued to 15Nm.

Figure 48: Crankshaft locking pin location

Figure 49: measuring friction torque at ½ m on the prop

COMPRESSION CHECK:

There are two methods of carrying out a compression test. In both cases they should be conducted on an engine at operating temperature. The simplest system is the conventional tester that measures the pressure achieved whilst turning the engine on the starter motor. The conventional car tester is simple and fairly effective, but it does not help the engineer to identify the reason for a low compression. Using this method you should expect to see pressures between 130-174PSI.

The leak down or differential test requires a bit more specialised equipment including a source of compressed air. A pressure of 87 PSI is applied to each combustion chamber (whilst at top dead center on the compression stroke) through a 1mm orifice. The amount of leakage from the combustion chamber can be measured by measuring the pressure in the cylinder. If a low pressure is measured it is easy to identify the source of the leak by listening to the carb, exhaust or oil tank for air escaping. The maximum permissible loss is 25% i.e. 65 PSI.

Figure 50: Conventional automotive style compression tester

Figure 51: Leak down (differential) compression tester

COOLING SYSTEM / DRAINING COOLANT:

Some aircraft have the coolant radiator below the coolant drain screw on the water pump, which may make it necessary to remove the lowest hose or in some cases remove the radiator itself to drain it. Rotax have provided a screw at the bottom of the water pump and this should be used to drain all the coolant from the engine. The screw should be stainless steel and should have a copper sealing washer on it. Once drained the system should be flushed using pure water at a maximum pressure of 2 BAR.

Refill the cooling system with the correct ratio and type of coolant as specified by the aircraft manufacturer. Generally the coolant will be ethylene glycol mixed 50/50 with distilled water, or Evans NPG+ with no water, however some manufacturers specify 100% ethylene glycol. If you should have chosen to use the Evans coolant it will be necessary to flush the cooling circuit with their special preparation fluid before re-filling it. It is critical that the Evans does not get mixed with water. The maximum permissible water content of the Evans is 3.6%. At each maintenance interval it is recommended that you check to see what the specific gravity of the coolant is using a refractometer, you can then confirm the ratio before topping it up or replacing it.

Bleeding the cooling system (in order to remove air locks) - refer to the aircraft manufacturers instructions, but without fail check the coolant level and then if necessary carry out the process again, after having run the engine for about 30 seconds, and ensure that there is no air in the cooling system.

If your engine has 50/50 glycol/water you should have a 1.2 bar radiator cap fitted and there should be a permanent coolant temperature gauge installed in addition to the cylinder head temperature gauge, unless a relationship between coolant & CHT has been established (refer to the latest issue of the installation manual and Service Bulletin SB 912-043).

Figure 52: Water drain screw on water pump

SERVICE BULLETIN CHECK:

STOP. Do not walk away. The Rotax bulletin system is not as bad as you think. I know they are a bit more complicated than they might need to be, but there is nothing we can do about that. There is however a simple process for you to identify which bulletins apply to your engine.

Go to www.rotax-aircraft-engines.com, select the Documentations tab, fill in your engine type, engine serial number and document type “service bulletin”, leave all other boxes blank. Hit Search Database. **“BINGO”**. You now have a list of all service bulletins relevant to your engine, and for each bulletin there is a link so you can download it. Now understanding them is a bit more of a challenge, but at least you know which ones apply to your engine. The same system can be used for other technical documents such as service instructions, service letters, manuals, parts lists Etc.

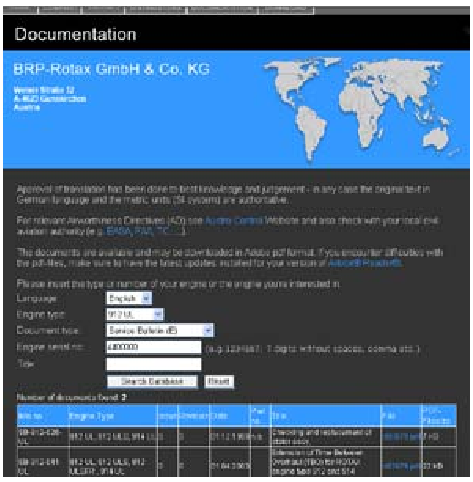

Figure 53: Documentation section of Rotax Aircraft engines web site

LIFED ITEMS:

A 100 hour engine service should be carried out at least every 12months, a 200 hour every 2 years and so on.

2 year replacement items	Rotax have just removed the requirement to change the coolant every 2 years/200 hours to change it as specified by the coolant manufacturer's specification. Most coolants today are 5 year lifed, but please check on the packaging of the coolant you have used
5 year replacement items	All rubber parts, including fuel hoses, carb rubbers, coolant hoses, oil hoses and carburettor diaphragms, should be renewed every 5 years

Please remember: Any work carried out must be entered in the engine logbook and where necessary signed off by an appropriately authorised person.

I would like to thank the UK Rotax Distributor SKYDRIVE for their constant support and their assistance in producing this article. www.skydrive.co.uk