AeroShell TECH TALK

MANAGING ENGINE TEMPERATURES

Before Start Up

Engine start up is something that we are all familiar with, but what about engine starting in cold weather? Cold winter flying can produce some of the most beautiful and memorable flights, but when temperatures reach 10 to 20 oF (-7 oC to –12 oC) engine pre-heating needs to be considered, even if using multigrade oils. The primary reason for this is that your engine is constructed of different metals, for example the crankcase is aluminium, the crank is made of steel, and these metals expand at different rates. Engines are designed so that the gaps between moving parts are optimal during normal operation, when the internal temperature may be 100oC (212 oF); cool everything down and differential expansion starts to be a major consideration. Aluminium expands and contracts by a much larger degree than steel, so the aluminium crank case shrinks onto the crank shaft and nips up the bearing clearances. If we then consider that the oil is relatively thick when it is cold, then we can start to appreciate that there is a real risk of bearing damage when starting in very cold temperatures.

There are various types of engine heaters available. The first type, the heated dip stick, I would not recommend. These do little to heat the engine casings and, with no oil circulation, promote overheating of the oil around the dip stick, whilst not heating up the rest of the engine adequately.

The second type uses heater pads under the engine sump and cylinders. These work well, and have the advantage of being permanently fixed to the aircraft, but pilots should resist the temptation to leave them turned on permanently. If this type of engine heater is left on for long periods the bottom of the engine heats up, evaporating water out of the oil which then re-condenses on the relatively cool upper engine, causing corrosion. If the engine has a high level camshaft, as do most Lycoming engines, then this can lead to the future, premature failure of the cam.

The final type of engine heater uses a hot air blower to circulate hot air around the engine prior to start. These also work well, but it is worth keeping in mind that the engine needs to be heated for long enough to allow the warmth to penetrate the engine, as it is the temperature of the bearings that is at least as important as that of the oil.

Engine Warm Up

Once the engine is running, even in summer temperatures, it is sensible to warm the engine on the ground before proceeding to take-off power. Again, differential expansion is a significant factor here. Aluminium pistons slide in steel barrels and are a loose fit until the engine is warm. This is particularly significant in those engines that are capable of high power and are of large cylinder bore. Piston rock can result if the piston clearances are too large and high power is applied. The aluminium end caps that hold the gudgeon (or wrist) pin in place are also common victims of this type of operation – they are forced into the cylinder wall and are the common cause of high aluminium levels in oil analysis results.

The minimum operating temperature for take off power differs with different engine types and can be oil temperature related (common with many engines, including the Russian radial engines), but may also be cylinder head temperature related (Lycoming recommend a minimum CHT of 150oF (65oC) for flight in many of their engines). The Pilot's Operating Handbook should give the minimum temperatures for your particular aircraft, but many of the lower powered aircraft do not specify any limits. However, even in these aircraft, I personally like to see the oil temperature off the minimum before I take the engine to high power as I feel that it is kinder in the long term.

Avoiding Shock Cooling

Once flying, the next temperature consideration is that of Cylinder Head Temperature (CHT) management. Air cooled engines run relatively high CHTs when compared to liquid cooled engines, such as those commonly found in automobiles. This leads to another expansion-related problem, that of cylinder cracking. In much the same way that a wine glass may shatter when plunged into boiling water, rapid expansion and contraction rates can set up large internal stresses in the metal as one part of the cylinder head cools more rapidly than another. This can lead to cracking in those areas that are most difficult, and therefore slowest, to cool – typically between the exhaust port and the spark plug hole. This phenomenon is particularly associated with higher-powered engines as they produce more heat, and can also fly at higher altitudes where the air is cooler, which allows more rapid cooling when power is reduced. However good practice can also prevent trouble for lower-powered aircraft and, even if there is not a CHT gauge fitted to the aircraft, flying a sensible profile can help engine longevity.

If you do have reference to a CHT gauge, it is recommended that cylinder head temperature change not exceed 50oF per minute to allow all areas of the cylinder head to cool at a relatively even rate. This means planning ahead. Reduce power gradually and maintain some power throughout the descent. Another good tip is to keep the fuel/air mixture at the leaned cruise setting during the descent; lean combustion mixtures burn hotter than when running over rich, so this helps to keep heat in the engine even when power is reduced. Of course at low power settings there is no risk of detonation so, as long as the mixture is increased before going to high power, the engine can not be damaged. If an exhaust gas temperature gage is installed with a normally aspirated engine, use the mixture setting to keep the EGT close to its peak value. This will insure the greatest possible engine heat for the power setting selected; for a turbocharged installation, lean to peak during descent unless otherwise specified in the Pilot's Operating Handbook, or under conditions where the limiting Turbine Inlet Temperature would be exceeded.

Engine Shut Down

Now we are back close to the end of the flight, we need to consider how we are going to shut the engine down and this can, to a certain extent depend upon the type of engine that you have.

Some aircraft engines (such as some aerobatic, inverted or radial engines) operate on the dry sump principle. With dry sump engines, there is minimal oil actually within the engine during running; the bulk of it being stored in a separate tank typically mounted on the firewall. The more common arrangement, not surprisingly known as a wet sump engine, stores all of the oil within the engine casing where it pools at the bottom, or sump, of the engine. In dry sump engines, once the oil has circulated around the engine, the oil drains down to a low point scavenge sump (a small chamber typically at the lower front of the engine) from where it is collected and pumped back to the external oil tank by a scavenge pump. The problem is that the scavenge pump is typically much less efficient than the oil delivery pump, especially when the engine is operating at low engine speeds. This tends to lead to a lot of oil being pumped into the crankcase that is not returned to the tank when the engine is idling. With radial and inverted engines this can cause a serious problem of not dealt with: a potentially large quantity of oil (which can be several litres) will sit in the engine and slowly leak past the lower pistons when the engine is not in use to cause hydraulic lock. Once there, if this oil is not carefully drained from the combustion space of the lower cylinders before the next time the engine is run, then serious damage and large maintenance bills can result.

The solution is to run the engine at around 1800 rpm (or 60% - 65% if you have a Russian engine gauges) for 30 seconds or so prior to shutdown. This technique should allow the scavenge pump to return the excess oil to the oil tank. Some engines have a maximum CHT limit prior to shutdown, for example with the Russian Vedeneyev M-14 radial this limit is 150 oC, so, where there is a limit, be sure that you know it and keep an eye on the CHT prior to shutdown. Certainly with Yaks, Nanchangs and the like, flying the circuit and approach with cooling gills fully open can be a big help in making sure that the engine temperatures are below limits when you come to engine shut down.

This technique of engine run-up immediately prior to shut down is also a useful one for preventing lead fouling, regardless of engine type, especially if forced into a protracted period of operation at low power settings such as a long taxi or hold.

Of course the first line of defence with lead fouling is to try to prevent it in the first place. If faced with a long taxi or hold, you would do well to remember that there is no risk of damaging the engine by aggressive leaning at low power settings, so you can lean the engine back even up to the point of misfire during taxi without risking damage. Of course, what we are achieving by doing this is both keeping the combustion temperature up as far as possible and limiting the amount of fuel present in the combustion chamber, both of which will reduce the risk of lead fouling.

Combustion temperature is critical in controlling the formation of lead deposits. Avgas can burn to produce lead oxide deposits during periods of low temperature combustion, and these deposits tend to form around the spark plugs (as the whole mixture is quite cool before the flame starts to propagate) and on the exhaust valve stem (as the mixture cools after combustion). The problem is that the deposits are electrically conductive, which shorts out the spark plug; and corrosive, which can start to attack the metal of the valve stems.

To help tackle this problem Avgas contains a lead scavenger, Ethylene Dibromide, which is designed to react with the lead oxides to form lead bromide; a gas at the temperatures found within the gas path of the engine. However, the Ethylene Dibromide is not a very effective scavenger at low combustion temperatures, which is why lead fouling is commonly associated with operation at low power settings, such as ground idle and taxi. As with oil scavenging in the dry sump engine, the solution is to increase the power prior to engine shut down as this allows the scavenger to work and removes the build up of lead deposits.

The technique is as follows. Once the aircraft is on the stand, the engine speed should be kept at the normal ground idle speed (typically 1000 and 1200 rpm) until the cylinder head temperatures have stabilized. Once the temperatures are stable (and this will already have happened whilst taxiing at larger airports), increase the engine speed to 1800 rpm for a period of 15 to 20 seconds. This should generate enough temperature to allow the scavenger to react with any lead deposits and remove them. Reduce the engine speed to 1000 - 1200 rpm once again, quickly check both magnetos for confirm that the spark plugs are clear and then immediately shut down using the mixture control.

So there we are: temperatures from pre-start to shut down. There may be a lot more to temperature management than a novice pilot might first appreciate, but by following some simple guidelines you should be doing the best by your engine and hopefully it will repay you by taking you safely to its scheduled overhaul life.

Happy flying.

Shell Aviation