FUNCTION OF THE LUBRICATION SYSTEM

The components that make up a piston engine are subjected to high loads, high temperatures, and high speeds. The component parts are generally made of metals, and as the moving parts of the engine slide against each other, there is a resistance to their movement. This is called **'Friction'.**

The friction will increase as the load, temperature and speed increases, the movement of the components also produces **'Wear'** which is the loss or destruction of the metal components. Both friction and wear can be reduced by preventing the moving surfaces coming into contact by separating them with a material/substance which has lower frictional properties than the component parts. This is referred to as a **'Lubricant'.**

A lubricant can come in many forms. Greases, Powders and some solid materials. However it is in the form of **'Oils'** with which this chapter will concentrate on. The oil can be forced between the moving parts, called **'Pressure Lubrication'** or the components can be **'Splash Lubricated'**.

The '**Primary'** task of the lubrication system of the engine is to **'Reduce Friction'** and component **'Wear',** it also has a number of secondary functions. Of these perhaps the most important is the task of **'Cooling'.** The flow of oil through the engine helps to dissipate the heat away from the internal components of the engine.

As the oil flows through the engine it also carries away the by-products of the combustion process and **'Cleans'** the engine. The internal metal components are protecte against **'Corrosion'** by the oil, which also acts a **'Hydraulic Medium'** reducing the shock loads between crankshaft and bearing and so reducing vibration. The oil can provide the power source for the operation of a hydraulic variable pitch propeller.

The oil system can be used to give an indication of the power being developed by the engine, and its condition. The oil system's use as an **'Indicating Medium'** is of great importance to the pilot as it can give an early warning of mechanical failure or loss of power.

It should be remembered that an increase in friction will cause an increase in Friction Horse Power, and therefore a reduction in the Brake Horse Power developed by the engine.

The **'Reduction in Friction and Wear'** by the lubricant is of prime importance, but the secondary functions of **'Cooling, Cleaning, Protection, Hydraulic** and **Indicating Mediums'** should not be ignored.

THE WET AND DRY SUMP LUBRICATING SYSTEMS

There are two lubrication systems in common use, these are the **'Wet Sump'** and '**Dry Sump**' systems. The system used is normally dependant on the power output of the engine, and role of the aircraft. The principle of lubrication of the engine is the same whichever system is used, the principle difference between the two systems being the method used to store the supply of oil.

Most light, non-aerobatic aircraft engines use the **'Wet Sump'** system. In this system the oil is stored in the bottom or sump of the engine. This simplifies construction but has number of disadvantages:

a) Lubrication difficulties arise during manoeuvres. The oil enters the crankcase, is flung around by the revolving shafts with possible over-oiling of the engine, inverted flight being particularly hazardous.

b) The temperature of the oil is more difficult to control as it is stored within the hot engine casing.

c) The oil becomes contaminated and oxidizes more easily because of the continual contact of the oil with hot engine.

d) The oil supply is limited by the sump capacity.

The **'Dry Sump'** system overcomes the above problems by storing the oil in a remotely mounted **'Tank'.**

As previously stated the principle of oil supply is the same for both systems. A **'Pressure Pump'** circulates the oil through the engine, and so lubricates the moving parts. In a dry sump system, **'Scavenge Pumps'** then return the oil to the tank to prevent the engine sumps flooding.

The arrangement of the oil systems in different aircraft engines varies widely, however the functions of all such systems are the same. A study of one system will clarify the general operation and maintenance requirements of other systems.

The principal units in a typical reciprocating engine oil system includes an '**Oil Tank**' (dry sump), '**Oil Filters**', **'Pressure'** and '**Scavenge Pumps**', **'Oil Cooler**' (radiator), an **'Oil Pressure'** and **'Temperature Gauge'**, plus the necessary interconnecting oil lines, which are all shown in the *Figure 3.1.* This shows a dry sump system, for a wet sump system the oil tank is not used.

The following paragraphs state the function of the main components of the system.

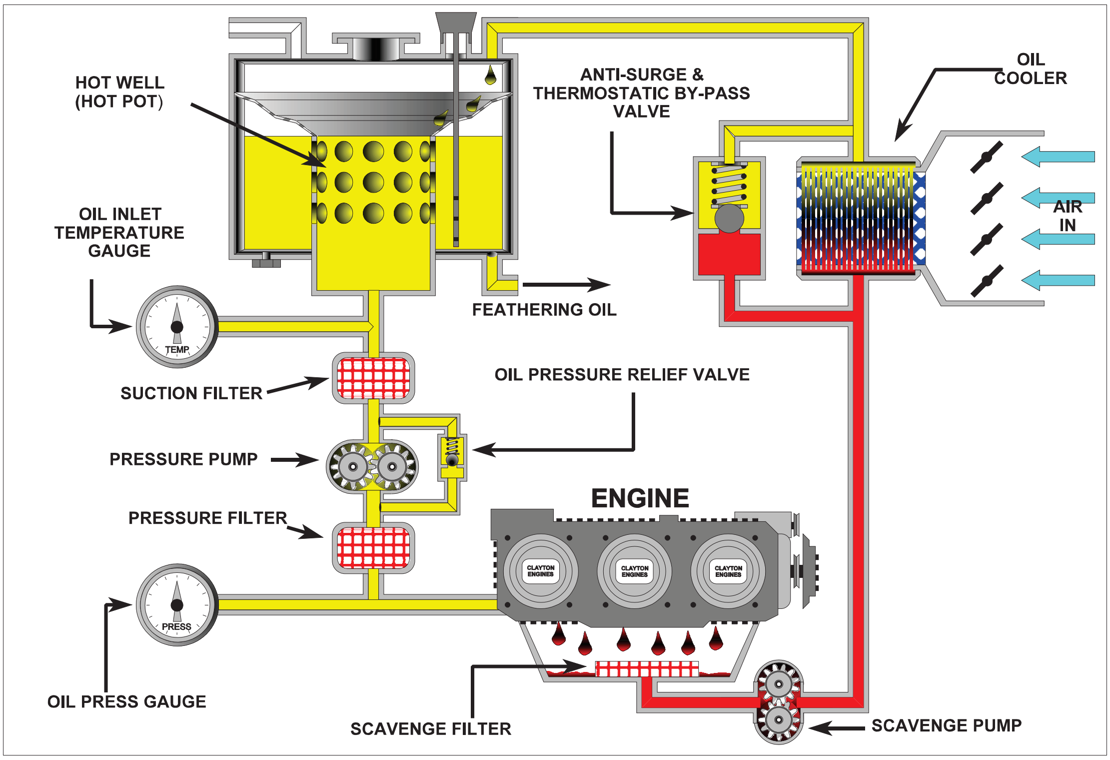

Figure 3.1: Dry sump lubrication.

THE OIL TANK

Oil tanks are made of sheet metal, suitably baffled and strengthened internally to prevent damage due to the oil surging during manoeuvres.

The tank is placed wherever possible at a higher level than the engine to give a gravity feed to the pressure pump, and forms a reservoir of oil large enough for the engine's requirements, plus an air space. The air space allows for:

a) The increased oil return when starting the engine. When the engine is stopped after a previous run, the walls of the crankcase are saturated with oil which will drain into the sump. The oil will remain there until the engine is started, when the scavenge pump will return it to the tank.

b) The expansion of the oil, and therefore it's greater volume as the oil absorbs heat from the bearings

c) 'Frothing' due to aeration of the oil.

d) The displacement of oil from the variable pitch propeller and other automatic controlling devices.

The '**hot pot**' forms a separate compartment within the tank. Its purpose is to reduce the time taken to raise the temperature of the oil when starting the engine from cold by restricting the quantity of oil in circulation when the oil is cold and viscous.

The hot pot consists of a cylinder of metal fitted above the oil outlet to the engine, thus the oil must be inside the hot pot to be able to reach the pressure pump. When starting, the level of oil in the hot pot drops, uncovering a ring of small diameter ports. These ports offer a great resistance to the flow of cold thick oil so that very little passes to the inside of the hot pot. The oil is returned from the engine to the inside of the hot pot and is recirculated.

As the hot oil is returned to the tank some of its heat raises the temperature of the walls of the hot pot. The oil in the immediate vicinity is heated and thins so that the ports offer less resistance to the flow of the thinner oil, and progressively more and more oil is brought into circulation. The oil is filtered by the suction filter before passing to the pressure pump.

When feathering propellers are fitted, the lower ring of feed ports to the hot pot are placed above the bottom of the tank, this provides a feathering reserve of oil even if the main tank has been emptied through the normal outlet, as would occur if the main feed pipeline was to develop a leak or completely fail.

The scavenge oil returning to the tank is passed by an internal pipeline over a de-aerator plate to the inside of the hot pot. The plate separates the air from the oil to reduce frothing. The tank is vented through the crankcase breather to prevent oil losses during excessive frothing conditions.

THE SUCTION FILTER

A coarse wire mesh filter is fitted between the tank and pressure pump. It is designed to remove large solid particles from the oil before it enters the pressure pump and so prevent damage.

THE PRESSURE PUMP

The pump consists of two deep toothed spur gears rotating in a close fitting pump casing and driven via the accessory housing. Oil is carried either side of the casing in the space between the gear teeth, and is made to flow. The outlet side of the pump is enclosed and restriction to flow is given from the engine components to be lubricated. This gives a rise in system pressure.

The actual oil pressure obtained will depend on the **'Speed of the Pump'**, the **'Temperature of the Oil'** and the **'Resistance offered by the Components'**.

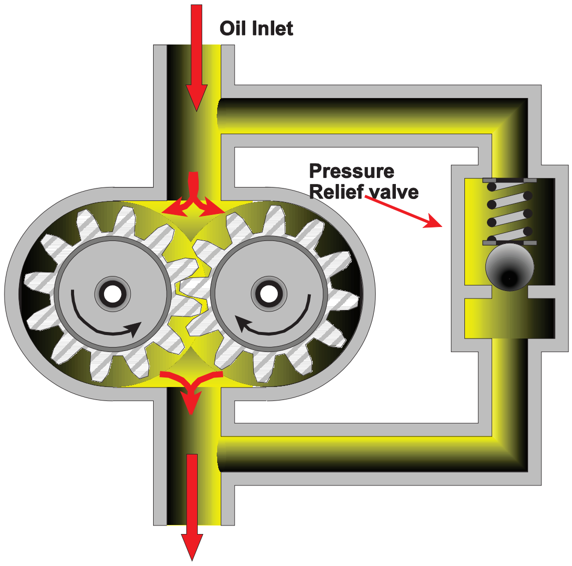

Figure 3.2: Spur gear pump.

The capacity of the pump must be such that it will supply a minimum oil pressure under its most adverse running conditions of low turning speed and high inlet oil temperature. As a consequence of this, under normal running conditions the increased flow would tend to cause a dangerously high oil pressure.

Very high pressures are prevented by a **'Pressure Relief Valve'** (P.R.V.) across the inlet and outlet connections which limits maximum pressure in the system. When the pressure reaches a predetermined Figure, the valve opens and sufficient oil is returned to the inlet side of the pump to limit the maximum oil pressure.

In operation the engine will have range of operating pressure related to engine speed from idle to maximum RPM.

THE CHECK VALVE
(Non Return Valves, or One-Way Valves)

The oil tank may be at a higher level than the pressure pump to provide a gravity feed. When the engine is stopped and the oil is hot and thin, there is sufficient pressure from the gravity feed to force the oil through the clearances in the pressure pump so that the oil tank would drain into the crankcase and the engine would be flooded with oil. This feature of Dry-Sump operation is sometimes referred to as 'Over-Oiling'. To prevent this a check valve is fitted. This consists of either an lightly sprung loaded valve, or electrically-operated S.O.V. which will hold back the oil until the engine is started.

THE PRESSURE FILTER

The pressure filter is fitted down stream of the pressure pump before the oil enters the engine and is designed to remove very small solid particles before the oil passes to the bearing surfaces. A spring loaded relief valve is fitted to by-pass the filter element when the oil is cold, or if the element becomes blocked. It will also protect the engine if the pressure pump breaks up.

VARIABLE INLET GUIDE VANES

Variable inlet guide vanes (V.I.G.V.s) are fitted to engines which have a particular problem with inherent compressor stall at low rpm or during engine acceleration or deceleration. The vanes are fitted just in front of the first rotor stage, they can be automatically pivoted around their own axis to vary the path of the airflow going into the compressor, so maintaining the proper relationship between compressor rotational speed and airflow in the front compressor stages.

At low compressor speeds the V.I.G.V.s are angled to impart the greatest amount of swirl to the air, thereby correcting the relative airflow to obtain the optimum angle of attack over the rotor blades. This optimum angle of attack allows a smooth and rapid engine acceleration.

VARIABLE STATOR VANES

After the first rotor stage has been successfully negotiated, the airflow may still have problems further down the compressor when the engine is operating at other than optimum conditions. To minimise these problems, some engine are fitted with variable stator vanes, see *Figure 15.4.*

These vanes can be pivoted automatically, so that as the compressor speed is reduced from the optimum design value, they are progressively closed to maintain an acceptable angle of attack onto the following rotor blades.

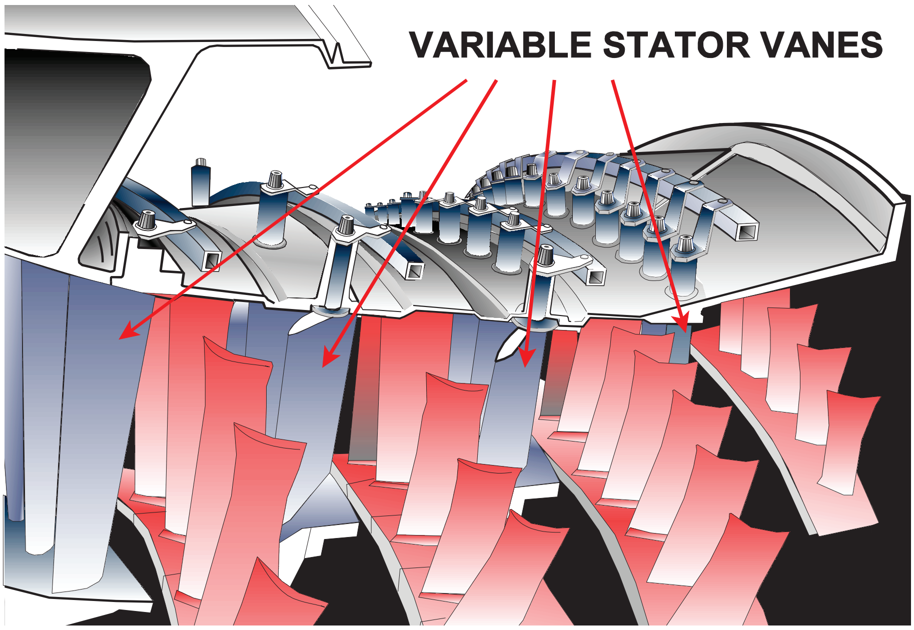

Figure 15.4: Typical variable stator vanes.

COMPRESSOR BLEEDS

As explained earlier, when the engine slows down, its compression ratio will decrease and the volume of air in the rear of the compressor will be greater.

This excess volume causes choking in the rear of the compressor and a decrease in the mass flow. This in turn causes a decrease in the velocity of the air in the front of the compressor and increases the tendency to stall.

If a compressor bleed valve, as shown in *Figure 15.5,* is introduced into the intermediate stages of the compressor, it can be opened at low RPM or during engine acceleration to allow some of the excess volume of air to escape.

This will have the effect of increasing the velocity of the air in the earlier stages of the compressor and reducing the choking effects in the rear of the compressor.

This combination will ensure that compressor stall is less likely to occur during the conditions while the bleeds are open, but there are disadvantages to the use of the system.

Opening compressor bleeds, whether they are stall preventive measures or bleeds used to supply air for aircraft services, decreases the mass flow through the engine.

This will cause a drop in thrust for a given throttle position which raises the engine's specific fuel consumption (s.f.c.) and also raises the E.G.T. because of the drop in the amount of cooling air available.

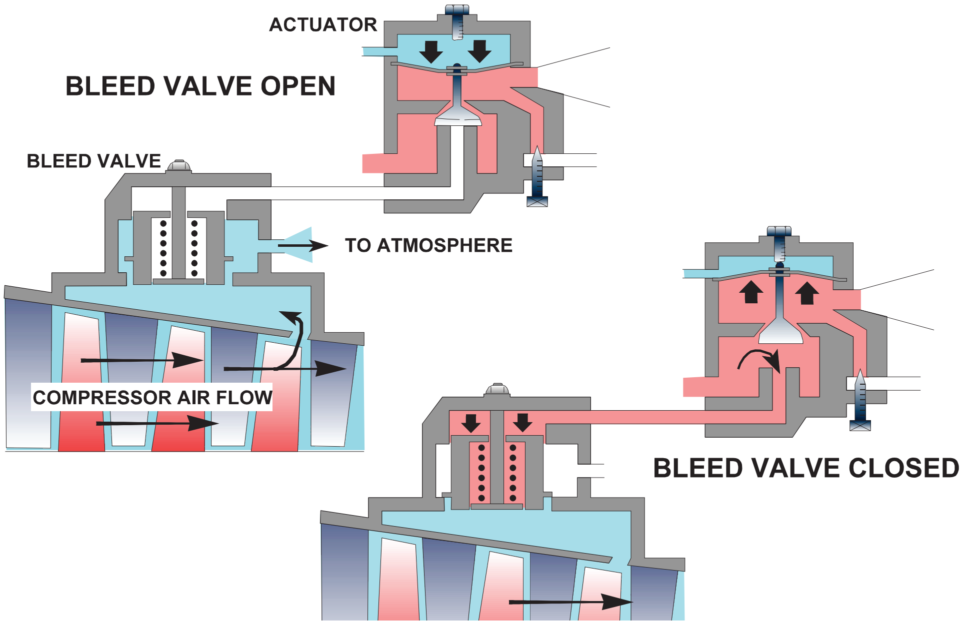

Figure 15.5: The operation of a compressor bleed valve.

MULTI-SPOOL COMPRESSORS

Early axial flow engines were developed by adding more compressor stages on one shaft to obtain higher and higher compression ratios.

This made it increasingly difficult to retain operational flexibility in terms of engine speed. Compressor blade angles are arranged to give peak performance around maximum rpm, when the axial velocity of the airflow and the rotational speed of the blade produce the optimum angle of attack of the airflow over the blade.

Any reduction of engine rpm changes the symmetry of the vector diagram relating it to the axial velocity, and the angle of attack no longer retains its optimum value, stall became an ever present problem at lower engine speeds.

To overcome this, the compressor was split, initially into two, and subsequently into three, sections, each section being driven through a shaft by its own turbine. The speed of rotation of each successive compressor increases, the HP compressor rotating faster than the LP.

The whole unit, compressor, shaft and turbine, forms a spool.

By designing the engine so that, upon closing the throttle, the speed of the low pressure spool falls off more rapidly than the high pressure spools, it can be arranged that the symmetry of the vector diagram relating to angle of attack can be maintained over a much greater range, thus reducing greatly the chance of compressor stall.

ACTIVE CLEARANCE CONTROL

A later development designed to control the airflow through the engine is that of active clearance control. The basic problem with all cases of stall is that the angle of attack of the airflow over the blade is no longer at its optimum value.

This can be the result of changes in either the axial velocity of the airflow over the blades or their rotational speed.

If the axial velocity can be controlled over the whole of the engine speed range, then the chances of stall or surge happening are diminished.

One method of accomplishing this is to vary the size of the air annulus at the high pressure end of the compressor, something which was considered technically impossible not too long ago.

By cooling the compressor casing we can cause it to shrink and so achieve the desired clearance between it and the blade tips. The cooling medium most often used at present is air, which is introduced into tubing running through the exterior of the compressor casing.

COMPRESSOR SURGE ENVELOPE

Compressor stall/surge has been shown to be caused by an imbalance between the flow of air through the compressor and the pressure ratio. *Figure 15.6* shows how an engine is designed with a safety margin built in to reduce the risk of stall/surge.

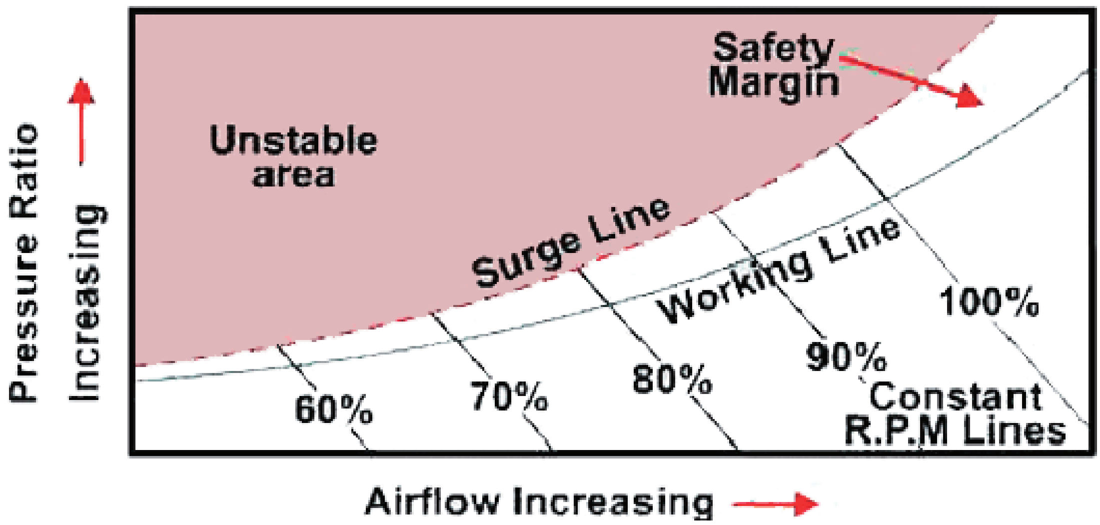

Figure 15.6

CONSTRUCTION

Figure 15.3 shows the basic methods of construction commonly used in compressor assembly. The rotor shaft is supported in bearings and is coupled to the turbine shaft so that minor variations in alignment are allowed for.

The centrifugal load imposed on the compressor dictates that the rotor blades are fixed to a disc which itself is fitted around the rotor shaft.

The types of fixing methods vary, the most common being that where the root of the blade is shaped into a dovetail joint and secured to the disc by a pin or locking tab.

On smaller engines it becomes more and more difficult to design a practical fixing method and at the same time maintain minimum disc weight.

One way of getting over the problem is to produce blades integral with the disc, this type of blade and disc combination has been called the 'blisk'.

The compressor casing is constructed of aluminium alloy at the front stages with the intermediate stage casing being manufactured from steel alloys.

In the high pressure section of the compressor the temperatures are so high that nickel based alloys are the only materials capable of withstanding them.

ROTOR BLADES

The rotor blades are of airfoil section and are normally made from drop forged stainless steel, machined to a close tolerance before being attached to the rotor disc.

The blades reduce in size from the front to the rear of the compressor, to accommodate the convergent shape of the air annulus, see *Figure 15.3.*

Some of the low pressure stages may have blades manufactured from titanium where the temperatures of compression are not too high.

The method of fixing, usually the dovetail system, see *Figure 15.6a,* does not ensure that the blade is held immovable in the disc, in fact the blades are quite loose until firmly seated by centrifugal force during engine operation, so that when windmilling on the ground the blades rattle loosely and sound somewhat like a bag of nails being shaken.

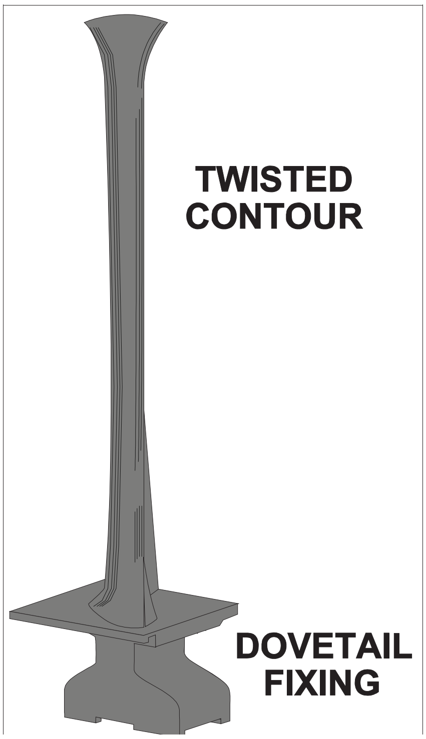

Figure 15.6a: A typical compressor rotor blade.