Dry Sump Oil Systems

By: Mark Pivac, B Eng (Hons), Senior Engineer, BDG Motorsport.

Why?

More power
Less oil drag
Vacuum so less windage and internal engine power loss
Better lubrication, better pressure control, higher flow
Less air in the oil
Settling time
Always sucks “good” oil for the pressure stage
Scavenges air/oil/foam and sends it to the tank, not the bearings.
Multiple pick ups, scavenge at “source”
More oil in the system
Better handling (lower centre of gravity since engine can be placed lower).
Allows use of an Oil Cooler.
Original system often not adequate for big power engines

What is It

A typical dry sump system will include the following elements sump, pickups, pump, relief valve, tank, lines, cooler, instruments and drive. There are many variations that can be mixed and matched to suit a particular application.

The sump will be designed to suit the installation. A dry sump does not need to hold the oil so the dry sump can be much shallower than a wet sump. Consequently the engine can sit low and this has a beneficial effect on the cars centre of gravity. So indirectly a dry sump system can have a dramatic effect on a cars handling, acceleration and cornering ability. In some cases a dry sump engine can sit as much as 100mm (4inches) lower than an equivalent wet sump engine.

Dry sump design can in many ways be much easier than a wet sump design. At first sight it may appear to be more complex, often including multiple pickups, crank scrapers, screens and baffling. However it is these features that make the design easier than for a wet sump. The multiple pickups allow the engine designer/builder to scavenge oil from the best places, generally the corners of the sump rather than just one place. The dry sump will retain a minimum amount of oil and thus there is less oil to slosh around during cornering, acceleration and braking. This in turn makes baffles less critical and most dry sumps have no baffles at all. Similarly the windage tray or crank scraper can be much simpler. A simple metal screen has proven effective on most designs. Many successful installations are based on modified wet sumps, although often these installations do not make full use of the dry sump advantage.

The location of pickups can be tailored to suit the application. Simple installations may use a single pickup point whilst the most sophisticated installations will have front and rear valley pickups and three sump pickups. A good way to work out the best pickup points is to prioritise where the oil will tend to accumulate during use. Obviously gravity has a big effect and attracts the oil to the bottom of the engine. The crank bearings are also a major oil user so a lot of oil will be leaking from down low in the engine. The first priority is to get rid of this oil. Oil has mass and inertia and tends to want to stay moving how it was, regardless of how the race car is cornering, accelerating or braking around it. If you need to get an idea for how much the oil sloshes around, put some oil (cooking oil is good) in a clear plastic container (with a good lid) and rest it on your lap while a friend takes you far a lap around the block. The engine will be making the most power and leaking the most oil under acceleration so pickups toward the back of the sump can be useful. The biggest accelerations happen under braking and although the engine is under low load, any oil in the sump will quickly move to the front wall. Many dry sumps do not have a forward pickup and rely on the oil in the tank to make up supply. However in big power critical applications a front pickup is usually used such as on NASCAR. A front pickup is also useful to save the bearings on drag cars that use parachute braking. Most track cars will have side pickups and oval track cars will bias the pickups toward the outside. The typical sump will be rectangular in shape and oil will tend to naturally accumulate in the corners because the acceleration is rarely just sideways or forwards but usually a bit of both. So pickups are often placed in toward the back corners.

The valve train is the next big user of oil and the amount of oil it can receive is limited by how quickly it can flow away. The valve guides can also be a source of exhaust leakage and scavenging the gas near its source will help oil life. The valley is a convenient place to pick up valve train oil on a vee engine. Inline engines generally let the oil return to the sump.

So in summary the priority for pickups is centre bottom of the sump, back outside corner of the sump, front inside corner of the sump (outside for an oval track car), then the valley.

The dry sump pump is usually a multi stage positive displacement pump. Each stage scavenges in isolation to the others. It is very important that the inlet to each segment is kept independent so that each stage sucks properly. If it is set up wrong with the inlets joined together (in parallel) then the flow will take the least path of resistance so that if say one pickup is in air, the pump will just suck air because the oil will be harder to suck than the air. If the segment inlets are correctly kept separate then if one pickup is in air, then only that segment will suck air, the other segments will continue to suck oil. The scavenge stages discharge in parallel. The pump segments are positive displacement so whatever goes in must go out and thus it does not matter if one segment is flowing more oil than another, it will all go down a common outlet line. The pressure stage usually has an internal bypass relief that prevents excessive pressure. The relief is screw adjustable and if the correct adjustment can not be made the spring can be changed to obtain a different adjustment range. The pressure relief is usually a simple poppet valve that allows excess outlet oil to return to the inlet side of the pump.

From the outlet of the suction segments the oil may flow to a cooler. Oil coolers are subject in themselves. The key point to remember is that oil should be kept at the right temperature. Hot oil loses viscosity and its load bearing capacity in bearings and degrades due to oxidation. Cold oil has high viscosity, high drag and will lead to high pumping power losses. To keep oil at the right temperature the cooler should have a thermostat bypass so that the oil will warm up quickly and the cooler should be sized so that the oil never gets too hot. Ideal oil temperature should be advised by the oil supplier. Many applications run successfully at 80 degrees C. If the correct oil cooler size is not known then it is best to slightly over size it so it cools the oil which will then open the thermostat occasionally so that the thermostat is used to maintain oil temperature. From this point smaller coolers can be tested (or the effective cooler area reduced by blocking the airflow) to determine the optimum size for future use.

The tank is more than just a storage device. The oil coming from the pump will be aerated. The tank allows the oil to settle and the air to separate out. It also allows for surges in oil use. The race car engine is very dynamic so that the amount of oil it consumes via the pump is constantly changing. The oil does not immediately return to the tank so the amount of oil in the engine will be constantly varying. Typically what happens is that at high rpm the pump moves lots of oil into the engine (lowering the tank level), this oil then gets into the engine and takes time to move through the engine back to the pickups. By this time the engine may be running a lot slower so it could take even more time to get pumped back to the tank. However the multiple suction stages ensure that even at low speed the suction rate is greater than the supply rate at high speed. So the oil level in the tank rises and falls quite a bit and it must be vented correctly. The tank should be designed to help separate the air bubbles from the oil. The inlet to the tank will usually be at the top and tangential to the tank walls if the tank is cylindrical. This directs the oil to swirl around the tank and the cyclonic action helps to separate the air from the heavier oil. The outlet should be at the bottom. The tank is often mounted in the boot to help weight distribution.

Big lines are good lines. The bigger the diameter the lower the pressure losses. This is particularly important for long suction hoses. Oil hose of suitable pressure rating must be used together with the correct fittings for the type of hose. Definitely be careful to avoid routing oil hose near hot spots such as exhausts and turbos. If this can't be avoided then the hot area lines must be solid steel pipe and be insulated and have a metal heat shield. Remember that oil is a serious fire hazard. A good source of hose and the correct fittings are the mobile hydraulic hose repair vans who can come to your site.

Instrumentation in a dry sump system is usually fairly minimal. A pressure gauge connected to the pressure pump outlet or in the engine block and a temperature gauge connected anywhere in the oil circuit is useful. However the reality of race car driving is that if you are looking at the gauges you are probably looking in the wrong spot so many track wise crew chiefs have a "big red stop light". Two switches are hooked up in parallel to the "big red stop light". These switches are set to 130ºC for engine coolant and 20 psi for engine oil pressure. The driver can be confidant that these will only come on if things are real bad and then the driver can decide to risk trashing the engine or stop to save a lot of money. It also takes away the need to look at the gauges and lets the driver drive. There is no need for an oil temperature switch, if it gets that hot, the engine will probably be losing oil pressure. Of course if the class permits telemetry then oil pressure and oil temperature are key diagnostics. In fact they are such good indicators of engine health that multiple transducers such as turbo oil temp, sump vacuum pressure and oil inlet and outlet temperatures are justified.

The pump is only as reliable as the drive. Like all parts of the system there are many options. The two most common drive options are belt or gear drive and relate to the mounting position in fundamental ways. The most common installation is to bracket mount the pump and belt drive it from the front of the engine. Typically a toothed belt is used and the pump is driven at half engine speed. The best belts to use have a HTD (High Torque Drive) tooth profile because this profile gives smooth running, long life and low noise. As a guide a small block Chev' engine with at four stage pump will use a 3/8" or 8mm pitch belt that is 25mm (1") wide. The best pumps have a hex either milled or broached into the drive shaft so that the pump can be turned over manually to prime the engine before starting. This can dramatically reduce bearing and cam wear. The other method of pump mounting is to flange mount the pump to the timing cover and gear drive it from the timing gears or accessory drive. This is the most common mounting method used on sprint cars and in marine installations where there is room at the back of the engine. This is a very reliable and light-weight solution but will not fit in many front engine cars.

Who Can Use Them

In virtually all the classes where dry sumps are legal, the top racers are using them. Their advantages far outweigh the slight cost and in most cases the improved engine life alone will more than pay for the installation over a short period of time. To this end we firmly believe that dry sump oil systems should be allowed in all classes. Engines need oil and as soon as cars are raced their oil sloshes around and the best way to keep oil supplied to the engine is to use a dry sump oil system. However not all classes allow dry sump oil systems.

Engine builder
Racer
Maintainer

Where are they used

Pumps can be mounted on brackets or be flange mounted.
Tanks can be mounted almost anywhere. Often the boot is used to help with weight distribution. In some cases a wet sump style sump can be used as the tank.
Coolers can be mounted as required, either in the same location as the radiator or in their own ducting.
Pickups are located where the oil will accumulate, usually at the bottom of the sump, at the corners of the sump and in the valley.
Rules may have an impact on the oil system.

Classes where they are widely used include:
Supercars, Nascars, Sprint cars, Late Models, open wheelers, road cars

When should you do some things

Run in and change the oil after run in. It is good practice to cut the oil filter open when it is changed to inspect for wear debris. Small bronze particles are common during run in but should not be present during normal operation.

Oil change interval depends on the application. Top fuel drag cars change oil every pass. Club racers may go a whole season on one oil change. Be economical and get it right, too long on old oil could damage an expensive engine. Cut open the oil filters and inspect them. They will give a good indication of engine wear debris and its source such ad grey iron from blocks, liners and rings. Bronze from bearings, shiny metal from hard bearings. An early overhaul could save a race withdrawal or expensive failure. The oil is the engines blood and its colour can help tell you its health.

How does it work

The ideal dry sump system is constantly evolving. It not only supplies, gathers and conditions the oil but keeps the engine internals clean and under vacuum. A significant amount of energy is lost pumping air around inside the engine crankcase and between the cylinders. By pulling a vacuum on this airspace the air density is lowered and thus the pumping resistance is lowered. The air drag of the moving parts is also reduced and useful power at the flywheel is gained. In some cases this vacuum can be worth up to 10hp. Maximum efficiency is gained by correct sizing, low losses, low clearance, high vacuum, gear squash relief, big lines and ball bearings to reduce drag. Correct sizing requires the pressure stage outlet to provide the correct amount of oil to the engine. The engine leaks oil internally from its bearings and the leakage varies depending on temperature, speed and load. So the pressure stage has to match the worst case. A relief valve is used to avoid excessive oil pressure. Over sizing or over-speeding the pump will lead to excessive bypassing, high pumping losses and high oil temperatures. Under sizing will give low oil pressure. Internally the pump should be built to close tolerances so that it is an efficient pump and an effective vacuum pump. The slight gap between the gears and the pump housing is sealed by oil. The higher the vacuum it can achieve the lower the air drag inside the engine and the more useful power the engine will produce. To achieve a high internal vacuum, the engine itself must be well sealed. In some cases engine builders turn the main bearing seals around so that they stop air coming in (rather than oil flowing out).