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READERS' CONTRIBUTIONS

"Ignition Advance"

An article by Tony Cripps

It's unfortunate that while most workshop manuals provide information about how to check, adjust and repair various parts of a car, they seldom have any discussion on what the various parts actually do and their significance to the overall performance of the car. For example, we all know that we have advance mechanisms on the distributor, the most obvious being the vacuum advance unit, but it is a challenge to find any explanation of why it is there in the first place in the average shop manual. In my view, having an understanding of why things are done the way they are is very helpful to diagnosing and repairing problems.

The ignition system is responsible for igniting the fuel/air mixture in the combustion chamber. It may seem strange to know that the ignition timing on the majority of cars is set so that the spark will occur before the piston reaches top dead centre (TDC). That is, the spark at the spark plug appears before the piston reaches the top of the compression stroke, and you may think that the resulting explosion inside the combustion chamber would serve to push the piston back down the way it came and either stop the crankshaft from turning, or forcing it to turn backwards. Of course this does not happen (except in some cases when you see an engine in a poor state of tune "run on" after being switched off where the engine does often turn backwards). Now, in order to explain why the spark is timed to occur before TDC, one must realise that the process of burning the fuel in the combustion chamber is not an instantaneous event. The flame front starts at the spark plug, and then over some milliseconds, widens out and eventually reaches the furthest part of the combustion chamber. The ignition timing is set before TDC so that by the time the flame front has progressed through the combustion chamber, the maximum in the mean effective pressure (m.e.p.) occurs after TDC. By a happy coincidence, the achieving of maximum m.e.p. after TDC also roughly coincides with the deliverance of maximum leverage to the crankshaft. The force from the pressure of combustion, multiplied by the length of the crank offset gives us torque to rotate the engine. Without this leverage, we can push as hard as we like on the piston (say at TDC or bottom dead centre) but we won't get any torque. When the connecting rod is at right angles to the crank, we get maximum torque. We can regard the velocity of the flame front to be a constant (although it also varies with the amount of turbulence and mass, or charge, of air and fuel in the combustion chamber).

When the engine speed increases, then we must advance the ignition timing to compensate – because we still need the maximum pressure to occur at the same place after TDC when the crank leverage is optimum. So, the faster the engine goes, the more advanced the timing has to be so the flame front has enough time to do its job and create the maximum pressure where we need it (at the correct crank angle). It is the job of the mechanical advance to do this – increasing the ignition advance in proportion to engine speed. Note, the mechanical advance is in two stages – one of the weights comes into play at a certain rpm so that the advance curve is not linear throughout the rev range.

There is another advance mechanism often introduced and that is the vacuum advance. This advance mechanism provides additional advance, over and above that given by the mechanical advance, and is dependent on the load on the engine. The vacuum advance take-off port is not at inlet manifold vacuum, but usually from a place in the throttle body just above (on the atmospheric side) of the throttle plate. The maximum vacuum advance signal is obtained at part throttle at light load. Under heavy load, or acceleration, the vacuum advance signal drops off. So why do we have vacuum advance? At light throttle, with engine under light load, the charge (i.e. the mass of fuel and air) in the combustion chamber is much less than that at full throttle or under acceleration. Under these conditions, on the compression stroke, the compression pressure in the combustion chamber is less (which is why you should always do your compression tests with wide open throttle). The velocity of the flame front depends on pressure in the gas in the combustion chamber. At high compression pressures, the flame travels faster, while at low compression, the flame travels slower. Therefore, when we have a light throttle, we need to advance the timing to account for the lower flame front velocity which occurs at lower compression pressures. At acceleration and heavy throttle, we have a greater charge entering the chamber, and lots of compression and so we do not need the extra advance – indeed, too much advance will cause many other problems as we shall see.

Now, you might be tempted to remove the vacuum advance since you have seen racing engines with no such mechanism. For example, some Cooper S distributors have no vacuum advance at all. I would not recommend it. Racing engines have no vacuum advance because for the most part, they are operated at wide open throttle and don’t need to have any vacuum advance since it unlikely that they will be operated at light load conditions. It’s best to take it off these engines so that the distributor advance curve has one less complication (i.e. something to break during a race) so, unless you are thinking of a constant wide open throttle style of driving, it’s far better to have your vacuum advance in good working order.

So, you say, why don’t we therefore have full vacuum advance at idle? A very good question. The take-off port for the vacuum advance is usually on the atmospheric side (upper) of the throttle butterfly position. When motoring along at light throttle, the pressure at this port is very similar to manifold vacuum which is what we want in order to identify light load, part throttle conditions for maximum advance and full throttle low vacuum condition when advance is not required. At idle, when the port is closed off, the vacuum advance drops to zero. The reason for this is not so easily found – it is my view that this is done to produce a steady and smooth idle condition since at idle, the manifold vacuum is indeed very high, but it is also more likely to be pulsating at the low rpm of idle. Better to have no vacuum advance than one which is being pulled on and off by a fluctuating vacuum signal. Also, the idle condition requires a significantly richer mixture (on old cars, about 4% carbon monoxide CO in the tailpipe emissions) compared to light run conditions (where the mixture is about 1 % CO) and this may also influence the choice of advance characteristics, especially for emission control vehicles.

Now, there is an interesting correlation between ignition timing and engine temperature. If the timing is too retarded, not only do we get loss of mean effective pressure (because the piston is too far down on the power stroke before maximum m.e.p. is obtained) but we have a greater surface area of metal exposed to hot gases (i.e. the cylinder walls). So, more heat is transferred into the water jacket. It's a viscous circle. We open the throttle more, to get where we are going, (because we lose torque with the retarded timing) thus increasing the amount of fuel burnt, but expose more of the combustion gases to the cylinder walls, and so the engine runs hotter - sometimes to the point of overheating. Advancing the timing has the opposite effect, but then if we have too much advance, we get maximum m.e.p. before that 90 degree leverage on the crank, and possibly also introduce damaging detonation.

There is another interesting detail about the ignition system that is worth knowing. As most readers will know, the static ignition timing is set when the points are just opening on the distributor cam lobe. The points control current to the low voltage side of the ignition coil. By Faraday's induction law, the voltage induced in the secondary side of the coil depends on the ratio of the number of turns between the primary and the secondary, and as well, on the rate of change of current in the primary of the coil. You may well ask why we do not also get a spark when the ignition points close? When the points close, 12 V (or 8-10V if you have a ballast resistor) is applied to the primary side of the coil and the rate of build up of current in the coil depends on the resistance and inductance of the primary turns. There is indeed a high voltage generated in the secondary at this time, but not high enough to create a spark at the plug. When the points open, the rate of change of current is not limited by the inductance of the coil because the points are opened instantly and the current stops almost immediately. That is, the rate of change of current (from maximum to zero) is very high and so a very high voltage is induced in the secondary - enough to cause a spark a the plug and hopefully ignite the fuel. Also, this sharp interruption of current causes a self-induced voltage to occur in the *primary* side much like the effect of water hammer when you turn off a tap suddenly (up to about 200V) and this also adds to the induction effect in the coil secondary. It is the job of the condenser to absorb this voltage spike in the primary so as to reduce the amount of arcing at the points. Without the condenser, your points would burn out in a few kilometres.

The other component of the ignition which is of course very important is the spark plug – a device which runs at about 2000 C at one end and at near ambient temperature on the other, over a length of a few centimetres. The transfer of heat from the plug tip to the cylinder head is important so that the tip does not melt, or become red-hot. If the plug tip becomes too hot, it may ignite the charge before the spark appears and detonation will result. If the plug tip is too cold, then the products of combustion may not burn off and the plug will become fouled. The correct heat range of plug is therefore essential to good performance. The main difference between plugs of different heat ranges being the surface area of ceramic insulator material that joins the inner electrode to the outer metal thread – the more surface area the colder the plug.

Knowing the reason why we have these controls on our engine often helps to improve one’s efforts in diagnosing problems when things go wrong.