SPARK PLUGS

INTRODUCTION

This discussion is focused on engines of the type likely to be found in vintage and pre-war Alvis with compression ratios in the range of 5:1 to 6.5:1. Please note, some of the parameters quoted do not apply to modern engines with electronically controlled engine management systems.

Whilst most owners of vintage and pre-war Alvis cars are quite knowledgeable about the various heat range values available in spark plugs, not all are aware how this impacts the ignition and combustion process. This, compounded by the fact that spark plug types specified when these cars were new, are not likely to be available nowadays, makes them rather a fit and forget component, and when running issues develop, as long as spark plugs appear serviceable, they are dismissed as not being contributory to the problem, which is not always the case as we shall see.

Before examining spark plugs in detail however, it may be helpful to have a very brief look at the ignition and combustion process, before examining why the correct choice of plug is so vitally important.

NORMAL COMBUSTION

In a petrol powered internal combustion engine, as the piston approaches the end of the compression stroke, the pressure of the air-fuel mixture in the combustion chamber will have risen to about 80 to 120 psi, and the temperature, as a result of compression, will have risen to around 400°C, according to compression ratio and degree of throttle opening. After the occurrence of the spark, there is an *ignition delay period* before the flame front progresses steadily outwards from the point of ignition, with the pressure in the combustion chamber rising to between 500 and 1000 psi, accompanied by peak temperatures in the region of 2000° – 2500°C. It must be stressed this combustion process is not instantaneous but is a steady spread of the flame front, causing a progressive increase of pressure and temperature ahead of it.

IGNITION TIMING

The indicator diagram, Figure 1, shows the delay that occurs after ignition is initiated before any rise in pressure due to combustion occurs. It is because of this delay that timing of the ignition must be advanced to occur before the piston reaches top dead centre. Most engines are designed so that the ignition timing results in peak pressure occurring between 10° and 20° crank angle after top dead centre. This is purely a mechanical consideration so that the geometric angle which the connecting rod makes with the crank is the most favourable at the time there is the greatest pressure exerted on the piston.

It can also be seen from the diagram that excessive ignition advance is undesirable as it will cause unduly high pressures to be exerted on the piston while it is still rising on the compression stroke.

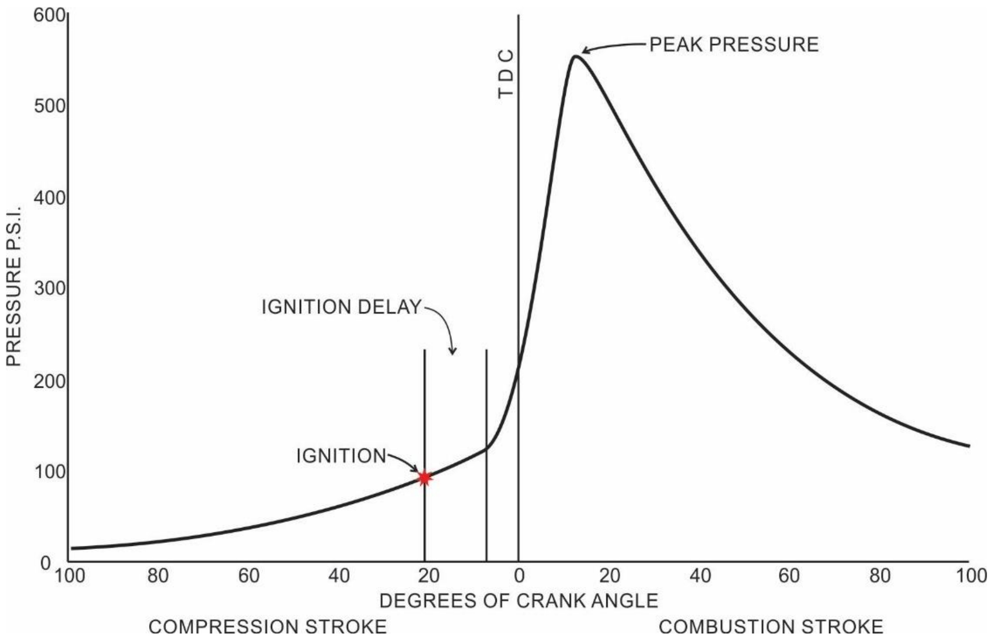

Figure 1

As a number of factors influence the rate of combustion, it is necessary to be able to vary the degree of ignition advance so that peak pressure always occurs at the optimum time. These factors include (amongst others) engine speed, compression ratio, cylinder pressure and mixture strength. An increase in any of these will result in faster burning.

It can be seen that when starting, because of the very low engine speed it is essential that the timing is retarded as far as possible to prevent the rise of pressure forcing the piston back down before it has reached the top of its stroke, causing possible damage to the starter Bendix (or your wrist if you are hand starting).

It is also necessary to retard the ignition under high load conditions for example when climbing hills with the engine running slowly at wide-open throttle, as high cylinder pressure and resulting faster combustion will cause peak pressure to occur too early in the cycle, resulting in rough running, a reduction of torque and possibly leading to the onset of detonation.

DETONATION

Detonation, or ‘knocking’ is uncontrolled combustion and occurs when the temperature and pressure in the combustion chamber rise to a level where the steady, progressive combustion process no longer continues, and the whole of the remaining unburned mixture (the so called ‘end-gas’) ignites spontaneously. The resulting high-pressure wave hitting the cylinder walls and piston crown can produce a metallic knocking sound (the absence of audible knocking does not mean detonation is not taking place however).

Detonation causes loss of power, local overheating, and mechanical shock loading, and sustained detonation will inevitably result in serious engine damage.

The incidence of detonation depends on:

- Operating conditions such as mixture strength, ignition timing and cylinder head temperature.
- Characteristics of the fuel being used.
- Engine design factors including compression ratio and combustion chamber shape, although these are outside the control of the operator.

It is totally erroneous to assume that detonation cannot occur in low compression engines using modern high-octane fuels. If the ignition timing is too advanced then the pressure and temperature rise caused by compression added to the pressure and temperature rise caused by combustion can cause spontaneous combustion of the end gas.

Detonation can lead to pre-ignition because of overheated surfaces in the combustion chamber.

PRE-IGNITION

Pre-ignition is an entirely different phenomenon and should not be confused with detonation. Pre-ignition is an uncontrolled ignition process where the air/fuel mixture is ignited at any time prior to the spark occurring. Ignition in this instance is initiated by localised hot spots in the combustion chamber where the temperature has risen to over 850°C. These hot spots can occur at spark plug electrodes, exhaust valves, overhanging gaskets or ash and carbon deposits. Pre-ignition can occur at any time in the inlet cycle and if it occurs while the inlet valve is still open then back firing through the carburettor will result.

The danger with pre-ignition lies not with the destructive high-pressure shock waves that occur in the case of detonation, but rather the intense heat build-up that results. In nine cases out of ten, pre-ignition is initiated by overheated spark plug electrodes. Every 10° of ignition advance will raise spark plug firing end temperature by 70°C to 100°C.This situation is dangerous and can cause serious damage to the engine, especially when it occurs in only one cylinder, when the effects may not readily be noticed.

In the normal combustion process, the piston crown and combustion chamber surfaces are protected from very high temperatures by a thin boundary layer of relatively stagnant air-fuel mixture. However, if detonation or pre-ignition occur, the extremely rapid combustion removes this boundary layer exposing the surfaces to the full heat of combustion. This almost always manifests itself in softening and consequent pitting of piston crown.

THE SPARK PLUG

Although the spark plug appears to be a fairly simple component, the conditions under which it has to function are very exacting. It has to withstand pressures up to 1000psi and temperatures reaching 2500°C. At moderate engine speeds it has to carry a 5 - 10 000-volt spark 25 times every second. In these conditions, the plug insulator and electrodes must remain within an optimum temperature range of between 450° - 850°C, known as the ‘self-cleaning temperature’. This is hot enough to burn off any combustion deposits that might form, but not so hot as to initiate pre-ignition.

HEAT DISSIPATION

To satisfy this requirement it is necessary for the spark plug to pass to the engine cooling system just enough heat to stay within this temperature range. As engines vary enormously it is obviously necessary to have different spark plugs with varying heat dissipation characteristics to suit different engines. The rate at which a spark plug dissipates heat is known as its 'heat-range'. Spark plugs capable of passing a large amount of heat to the cooling system are known as 'cold' (or 'hard') plugs, generally used in higher performance engines which generate more heat per cycle. Conversely, spark plugs which retain large amounts of heat are known as 'hot' (or 'soft') plugs and find use in cool running engines operating at low speed such as industrial or tractor engines.

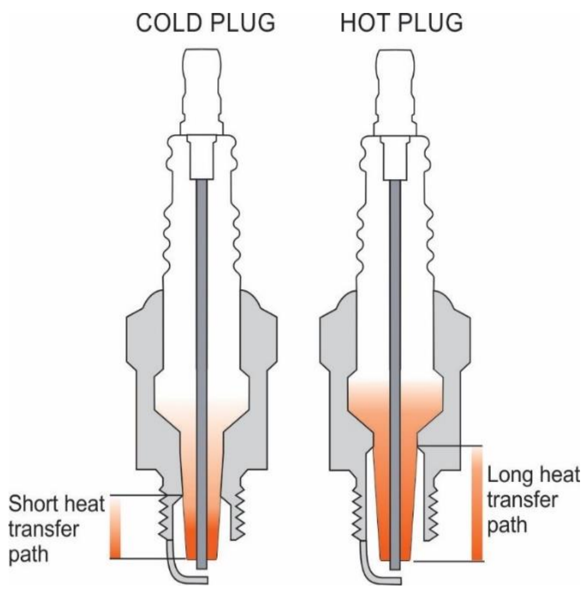

Figure 2

The design of the spark plug determines the rate at which it passes heat to the cooling system. The primary method used to do this is by altering the length of the insulator core nose as shown in Figure 2. A cold plug with low insulator seat will conduct more heat to the cooling system and will remain cooler. Conversely a hot plug with high insulator seat will retain heat from the combustion chamber so the firing end will stay much hotter.

In addition, the gas volume of the plug, which is the area between the insulator nose and the shell, can be varied - a greater gas volume exposes the insulator to more of the combustion flame and as a result it stays hotter. Further, the alloy composition of the electrodes can be formulated to conduct heat faster. This means it is not possible to visually determine the heat range of a particular spark plug.

HEAT RANGE

The method of classifying spark plugs is by using a numbered scale. This was initially based upon the time in seconds it took for a plug to heat from cold to auto-ignition temperature in a test engine. Unfortunately, nowadays there is no universal numbering standard and every spark plug manufacturer uses their own system.

To make things even more confusing some manufacturers, for example Bosch and Champion, use low numbers to indicate a cold plug with the higher the number the hotter the plug, while others, such as NGK, do the opposite, the higher the number the colder the plug.

The Champion range goes from 1 (cold) to 23 (hot) but then there are additional ranges for industrial and racing applications. Furthermore, Champion heat ranges have undergone a number of changes, so it is not a straightforward process to find a current equivalent for a pre-war heat range.

The Bosch range is possibly simpler, ranging from 13 (hottest) to 2 (cold) but then continuing from 09 to 06 for very cold racing plugs.

The NGK general application range is similar to the Bosch range, but reversed, ranging from 2 (hot) to 10 (cold) and then extending to 12 for racing applications.

The KLG range (though KLG plugs are no longer available) equates very closely with the NGK range, one simply has to delete the final zero from the KLG number. This is useful as KLG plugs were often specified in Alvis cars. For example, a KLG TMB50 (mid heat range plug specified for the Alvis 12/50) has a direct equivalent in the NGK A5, or better still the NGK AB5, essentially the same plug but with a reduced 13/16” hex, allowing a standard plug spanner to be used, which is a better fit in the plug recesses of the 12/50 cylinder head.

READING SPARK PLUGS

The best way to tell whether a spark plug is of the correct heat range for a particular application is by ‘reading’ the spark plug firing end as shown in Figure 3. It is essential to do this after a period of normal driving as prolonged idling or slow speed running will give false indications on an otherwise correct plug.

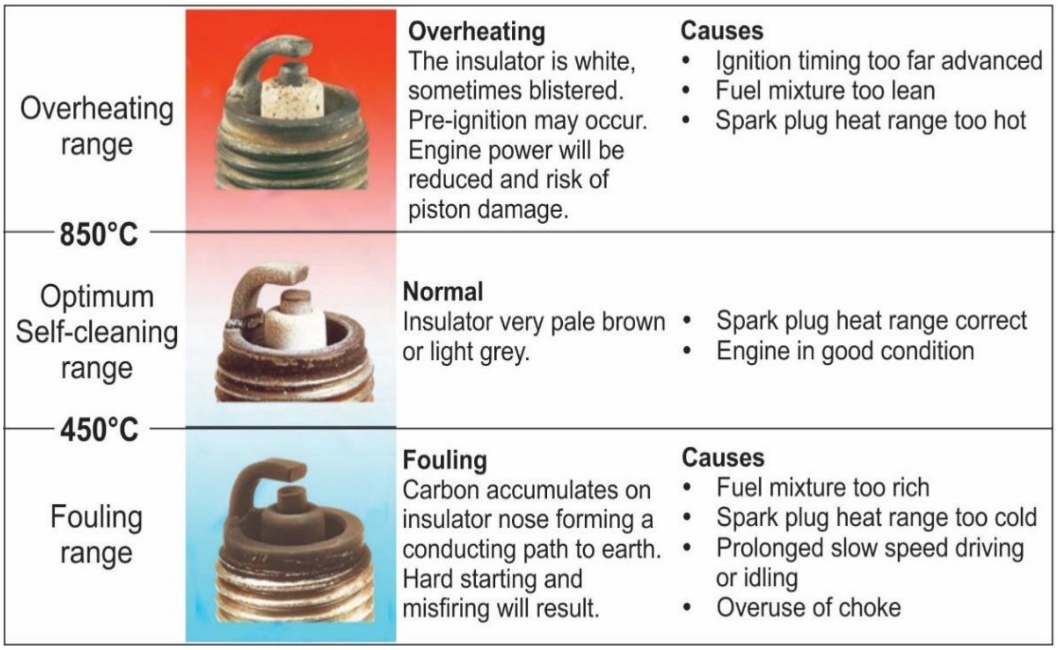

Figure 3

A useful fact to remember is that on the NGK range, a change of one heat range number will result in a change in the firing end temperature of a plug by 70° to 100°C. This means if a plug is operating just inside the overheating range, a reduction of at least two heat range numbers will be required to bring it back to the optimum temperature.

It is not recommended to make spark plug changes at the same time as another engine alterations, such as carburetion or timing. Performing multiple changes at one time will lead to misleading and inaccurate conclusions if any issues occur.

A 12/50 CASE STUDY

This concerns a 12/50 (in fact a 1924 SA 12/40 that has been converted to OHV 12/50 specifications). The history of this vehicle is not known, though it has an early block with recessed side cover, a cylinder head bearing a 1926 casting date, is fitted with a M.L. Magneto and 30mm Solex MOV carburettor.

For some time it has suffered a number of issues, starting off with a case of overheating. Once this had been attended to it appeared to run well, but soon developed issues with loss of power, rough running with associated misfiring and back-firing through the carburettor. The ignition timing was checked and re-set, and new plugs installed. Initially this appeared to offer some improvement but after a while the same symptoms started to re-develop. Finally, a second set of new plugs were installed together with a substitute magneto to eliminate the possibility of a defective capacitor in the magneto.

However, the vehicle still spent more time on the side of the road than actually driving. Again, timing was checked and re-checked, the magneto points were cleaned and re-set, carburettor jets were checked, the fuel filter cleaned, valve clearances checked, all to no avail. After every enforced stop it would run better for a while, but after a period of either high-speed or high-load running it would lose power dramatically with associated violent backfiring through the carburettor. In every instance of these problems occurring, not once were the spark plugs considered as they were “new plugs of the correct type”.

On its final outing it’s performance deteriorated to such an extent that it had to complete the last 100 kilometres or so on the back of a recovery vehicle.

SO, WHAT WAS WRONG?

Firstly, even though the cause of the problems were almost certainly ignition related, the carburettor was comprehensively checked, and found to be fitted with appropriate choke, jets and float of the correct weight, the filter was clean, and there were no leaks in the induction manifold, so the fuel system was ruled out. However, the interior of the carburettor was coated with black soot, this provided the first clue.

Secondly, the ignition timing was set at 42° BTDC. The Alvis handbook for the SA 12/40 and SA 12/50 specifies an ignition timing figure of 28° BTDC, fully advanced. Bear in mind that was the factory specification for a standard engine at the time. The engine in this car is not standard, and in view of its slightly raised compression ratio with consequent faster combustion time, this degree of advance (42° BTDC) is probably somewhat excessive. Nevertheless, it would almost certainly benefit from some advance over the factory setting.

Thirdly, the spark plugs were of an inappropriate heat range. When the symptoms first started to appear Champion D16 spark plugs were in use. These are an 18mm ½” reach plug toward the upper end of the heat range. In no way do they resemble the Champion 16 specified for early Alvis engines, which was in fact a cold plug in the Champion 18mm pre-war range.

Finally, when new plugs were installed, they were Champion D23’s. These are the hottest 18mm plug available from Champion. The advice given was that these were cooler plugs, this may have been caused by confusion with the NGK numbering system which goes the other way!

Figure 4

The photograph in figure 4 is of the plug removed from #3 cylinder, and quite plainly shows all the signs of severe overheating. The insulator is blistered, the centre electrode is very eroded bearing in mind the very short time the plug had been in service, and the earth electrode shows signs of severe overheating.

The other three plugs had also been overheating, but not quite to the same extent, so it would appear that the problem was mainly confined to one cylinder. Interestingly #3-cylinder inlet valve spring was broken.

CONCLUSION

It is likely that all the problems this 12/50 experienced were due to pre-ignition caused by a combination of the use of spark plugs with too high a heat range together with excessively advanced ignition timing. Either of these factors in isolation would probably not have caused these symptoms to appear, but once over advanced timing heated an already hot spark plug electrode to over 850°C, pre-ignition would start. Initially, as the other three cylinders were still running normally, this would manifest itself only as a loss of power with associated rough-running (which indeed was the case). Continued pre-ignition would then further raise the temperature of that spark plug enough to ignite the incoming charge on the inlet stroke while the valve was still open. This would cause the backfiring through the carburettor and would explain the soot on its inner surfaces. It could also explain the broken inlet valve spring on that cylinder, as combustion taking place with the valve open would cause it to be violently opened even further until the spring became coil bound and ultimately fractured.

As already mentioned, after the enforced roadside stops during which time everything bar the spark plugs were examined or adjusted, it would appear to run better for a while, though the symptoms soon re-appeared. In reality what was happening was the engine was simply given time to cool down.

The cure for the problem was quite simple. After installing a replacement valve spring, spark plugs of an appropriate heat range were installed, and the ignition advance was re-set to a more realistic figure. The car is now fitted with NGK AB6 plugs with an ignition advance of 35° and is running just as a 12/50 should! It is extremely fortunate that it does not seem to have suffered from any engine damage.