Rambling on about Ignition - High Voltage for Model Engine Ignition

Article 3, 3/27/2007,

Rambling on about Ignition - High Voltage

High voltage or high tension ignition was the first electric ignition used in engines. Ruhmkorff coils which are “buzz” coils originally made for electrical experiments were used. The Ruhmkorff coils were too fragile for practical engine operation and low voltage ignition was the preferred ignition on early engines. As time went on, higher reliability ignition was needed and high voltage ignition moved back in. The primary focus here is how these systems work electrically.

In the last rambling, we examined how low voltage or low tension ignition works and how the coil stores energy and makes the spark or arc when the ignition contacts are opened. High voltage ignition is a continuation of those concepts. As you recall, the current flowing through the coil stores energy in the magnetic field around the coil and releases it when the switch interrupter or points are opened suddenly, causing an arc or spark as the energy stored in the coil is released.

Michael Faraday made the first transformer in 1831 but thought it had no practical use. In 1836, Nicholas Callan invented the first induction coil to produce high voltage that was later improved by Heinrich Ruhmkorff in about 1851. In 1860 Lenoir was building spark ignition engines using Ruhmkorff coils.

We need to start with a simple automotive type ignition coil which is a transformer. A transformer is two or more coils of wires that share a common magnetic field. Transformers are best thought of as being a device that changes the voltage of an input which is changing over time to a different voltage. For example, a small transformer is driven by a 60 hertz alternating current source. This AC voltage is constantly oscillating and changing instantaneous amplitude 60 times a second. For standard 120 VAC power, the voltage cycles between positive170 and negative 170 volts. The 120 VAC is a RMS average of the voltage which is related to the DC equivalent voltage for doing work. If there are 600 turns on the primary winding, the winding power is applied to, each turn of wire in the primary winding of a transformer will have 0.2 VAC across it. It is a simple ratio of dividing the total coil voltage by the number of turns. The output part of a transformer is called the secondary winding. If the 2 coils share the magnetic field perfectly, then each turn of wire in the secondary also ends up with 0.2 VAC across it. If our transformer has 60 secondary winding turns it has an output voltage of 12 VAC, 60 X 0.2 VAC. It can also be looked at as the ratio of turns in the transformer 60/600 = 1/10 of the input voltage. If we put more turns of wire on the secondary winding than were on the primary winding, say 1200, we would get 1200/600 = 2 times the input voltage an output voltage of 240 VAC which is higher than the input voltage.

The automotive type ignition coil is a transformer with aproximatly 100 times more turns in the secondary than in the primary. If we put in a 1 volt transition, we get 100 volt transition out or if we put in 6 volts, we get 600 out.

As you recall from the low tension ignition discussion, when the ignition contacts close the battery voltage appears across the coil and when the ignition contacts open to break the circuit the coil makes a pulse of high voltage attempting to keep the current flowing in the circuit. If that pulse could be 600 volts at its peak, and if the coil being used was an automotive type ignition coil with 1:100 winding ratio, that pulse will appear at the high voltage terminal as 60,000 volts. 60,000 volts can make an arc 0.5 inches long in air.

So it would appear you take one of these automotive type ignition coil replace the old internal ignition contacts with external contacts, points, add a spark gap and should work. If you have ever tried it, you know it does not work. It may make feeble sparks but nothing like what we expect from 60,000 volts.

Remember that the ignition contacts in the low tension system arc as they open, the arc is powered by the energy stored in the coil. That arc starts as soon as they separate. That same arc happens at the new points and starts before the high voltage reaches a high enough level to arc at the spark plug the arc at the points has consumes most of the stored energy in the coil.

Just like the inductor or coil of wire has inertia like affects for current flowing through it, a capacitor has inertia like affects for the voltage across it.

The capacitor added across the points of an ignition transformer circuit allows the current to keep flowing into the capacitor from the energy stored in the magnetic field of the coil. This current path prevents the voltage from increasing enough to arc at the points. If the capacitor is too small, the voltage increases rapidly, and the arc happens across the points. If the capacitor is too large it absorbs too much of the coils energy and prevents the fast voltage spike needed for the transformer. There are ways of calculating the optimum capacitor value for a circuit. They need to take into consideration a number of real world parameters, primarily capacitance from other places. In general, the coil manufacturer will recommend a capacitor value most commonly in the .22µF to 1µF range with a voltage rating of 250-600 VDC.

With the capacitor in the circuit, the peak coil voltage when the contacts open is reduced to about half of the peak voltage that can be obtained with no capacitor. With our 1:100 winding ratio, that pulse will appear at the high voltage terminal as about 30,000 volts. The 30,000 volts can arc over 0.25 inch so it will produce a strong hot arc across our spark plug with a gap from 0.015 to 0.070. Once the arc starts the voltage across the spark plug drops due to the ionized gas conducting the electricity. The lower voltage actually makes the spark last longer by dissipating less energy per unit time.

Remember that energy that went into the capacitor as the points opened, as the magnetic field in the coil collapses and the voltages all change, the capacitor dumps its energy back into the coil and actually extends the time the arc is maintained, a bonus.

The final detail has to do with when the 6 volts is applied to the coil when the points close, That 6 volts produces 600 volts at the high voltage terminal of the ignition transformer. This is enough to ionize air and make a 0.005 inch gap arc but we now have a spark plug with a gap over 0.015 which does not arc when power is applied to the coil. This is why the spark only occurs when the points open.

Ruhmkorff coils which were “buzz” coils are no more than an ignition transformer as we have just discussed and a set of points that are opened by the magnetic field of the primary winding like a buzzer. The magnetic field pulls the points apart, there is an adjustable spring that sets the strength of the magnetic field required to pull the points apart. Hidden in every buzz coil or model “T” ignition coil is the capacitor, the secret part that makes it make high voltage. Ruhmkorff coils had even higher ratios of primary and secondary turns than modern ignition coils. They were used in early spark ignition experiments and some early engines. They were really made for the laboratory and conversation pieces and not as industrial devices.

Later when the reliability issues of low tension ignition were appearing the buzz coil resurfaced. When the coil buzzed, it made a series of sparks and if one spark is good, lots of sparks are better. It was said buzz coil could make engines with marginal fuel mixtures or fouled plugs work because of several sparks per cycle. Today most people understand they may have worked better just because it was a better ignition concept than low tension.

For me one good perfectly timed hot spark is all that's needed. Next time I will continue with Modern Transistor Ignitions.

Reference: Sparks & Flames by J.C.B. MacKaend, Published by Tyndar Press © 1997.