Tests of Model Engine CDI Ignition Modules

Introduction

CDI ignition modules are small, have low power drain, and priced competitively. They work very well in most cases but are fussy about wiring layout and intolerant of power supply overvoltage. And you will regret it if you fire one without a spark plug attached! There are a lot of unanswered questions on HMEM and other forums about just how good these things are compared to other types of ignition.

I launched this series of tests to try to answer a couple questions about that. First, there are many versions of CDI modules. S-S and CH modules have been the most common, but those suppliers are phasing down. Current supply is mostly from the Chinese model airplane and toy engine markets. There's almost no information available about them so buying one for your engine becomes an act of faith. For these tests I begged, borrowed, and even bought several modules and tested them for the strength of their output spark so they could be compared.

These results can be considered a baseline for the "strength" of CDI ignition in general. Recently I have read that CDI ignition sparks are so short that they are not very effective at firing lean mixtures. My plan is to follow up the CDI tests with another series of tests of more conventional ignition coil systems. Eventually I hope to find which type consistently gives the hottest spark, and by how much.

What is the "strength" of an ignition pulse? Most people will think the voltage of the pulse as a measure strength. Sorry. Wrong answer! High voltage is what it takes to START a spark, but the important thing is how much "zap" gets delivered into spark once it starts. How many watts for how many seconds. The term for that is "joules." One joule is one watt for one second. One "millijoule" is one watt for one millisecond, or one kilowatt for one microsecond. Knowing the millijoules of energy delivered to the spark gives a reliable measure of just how hot the spark will be.

Another way to evaluate a CDI module is to fire it into a resistor load rather than into a spark plug and measure the millijoules it dumps into the resistor. The reason to do this is to measure approximately how much energy the module itself has stored when it fires. With that information you can tell how efficiently the stored energy in the module ends up in the spark itself.

Conclusions

All CDI modules—except those with failures—were able to drive spark plugs with a range of 0.46 to 1.47 millijoules total energy per spark. The low end of this range is believed to be marginal for reliable operation of model engines[1]. Follow-on tests will be required to determine if coil-based systems deliver their stored energy into the spark more efficiently.

Test Results

I tested sixteen different CDI modules, but four of them were defective, so the sample size is twelve. First, all of them were fired into a resistor of approximately 10kΩ (no spark) to get an approximate measure of the energy stored in the module[2]. Then I measured amount of energy delivered to two different spark plug by nine of the sample CDI modules. Those two spark plugs were a CM6 plug with a 0.025" gap and a Viper Z3 (10-40 thread short plug) with a 0.012 gap. The following table summarizes the results.

[1] This is a tentative opinion, pending further investigation.

[2] 10kΩ is not necessarily the optimum load to get the most output, but all module tests used the same value.

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				Measured Energy - millijoules				
Module ID	Type	Owner	Pulse +/-	10 kΩ res load	CM6 0.025	Viper Z3 0.012	Input Volts	Notes
AVE	S/S 2	Grimm	-	4.5	1.3	0.65	4.5	
ATKD	S/S 2	Grimm	-	5	1	0.85	4.6	
Otto Langen	S/S 1	Grimm	+	14.2	1.03	1.1	5	1K series R in HV pulse output line
Loaned Unit	CH	Knapp	-	3.07	-	-	4.5	returned without spark plug tests
Dual RCEXL	CC	Vietti	-	1.68/1.98	-	-	4.5	returned without spark plug tests
Single, large	CC	Vietti	-	4.53	-	-	4.5	returned without spark plug tests
NFSTRIKE #1	G-01	Grimm	-	10.6	1.25	0.875	9.75	
NFSTRIKE #2	G-01	Grimm	-	11.7	1.16	1.1	9.75	
Cison #1	none	Grimm	-	3.4	1.47	0.47	9.6	
Cison #2	none	Grimm	-	3.2	1.14	0.46	9.6	
RCEXL	A-02 vers 2	Berry	-	6	1.05	1.03	9.5	Unique circuit—unipolar pulse out
S/S	RCEXL kit	Grimm	-	4.8	0.7	0.74	5.1	1K series R in HV pulse output line

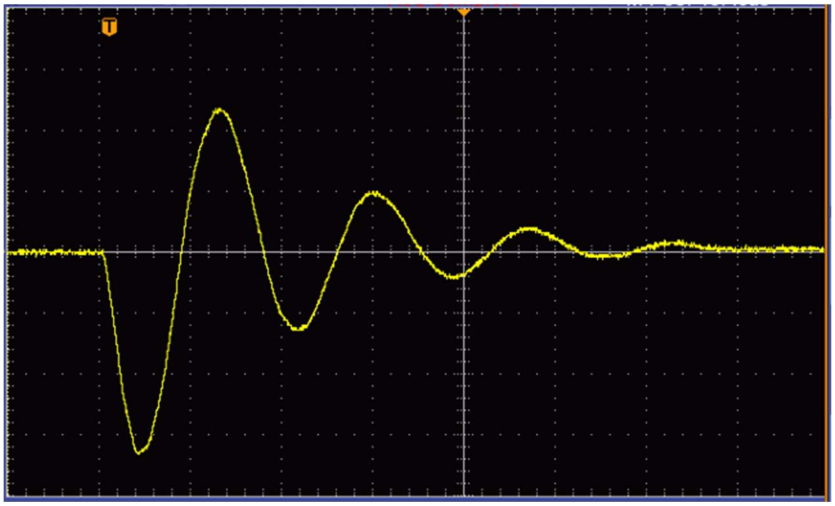
Discussion of Results

These tests consistently showed that the spark energy delivered to the spark is only a fraction of the total energy available from the CDI module. That result was not unexpected. CDI ignitions deliver a very short spark, typically around 40 µsec. Once flashover occurs (initiated by very high voltage) the spark voltage itself drops to a relatively low value. In fact, the higher the current, the lower the voltage[3]. You can clearly see this happening in the sample spark plug waveform below. Low spark voltage limits the rate at which energy can be transferred to the spark (volts x amps.). Energy is volts x amps x time; if both volts and time are limited, you just can't get a lot of energy transferred.

[3] Electric arc - Wikipedia

Resistive Load Waveform

CDI Pulse Voltage into a 10kΩ Resistive Load



5kv/cm; 5µsec/cm; 4.500 mjoule to resistor (calculated)

The waveforms in this paper were captured as single events on a sampling oscilloscope with a 50 MHz bandwidth[4]. The first waveform shows the output of a typical module firing into a 10kΩ resistor. No arcing occurred. The discharge is a damped sine wave. The ringing frequency is about 115 KHz, which corresponds to the natural ringing frequency of a typical module output transformer.

A numerical example may help explain how total energy is calculated. The sampling scope records the waveform as 2500 individual voltage measurements taken during the time of the trace displayed on the scope. In the first waveform the scope displays 50 µsec of time[5] so one sample is recorded every 20 nanoseconds[6]. The first peak is about -13 kv. That would produce an instantaneous power into the resistor of $\frac{v^2}{R}$ or $\frac{-13000^2}{10000} = 16.9\ kw$, but it only lasts a 20 nanoseconds at that level, so for the duration of that sample the total energy contribution would be only $16.9\ kw\ \times 20ns = 0.338\ mjoules$. The total energy from the pulse is the sum of all 2500 samples. Fortunately, all sample data from the scope can be downloaded into an Excel spreadsheet and all calculations are automated.

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[4] Low pass filtering was required to suppress high frequency oscillations to avoid saturating the scope.

[5] The last 5 µsec was clipped off this picture in the editing process.

[6] $\left(\frac{50\times10^{-6}}{2500} = 20\times10^{-9}\right)$

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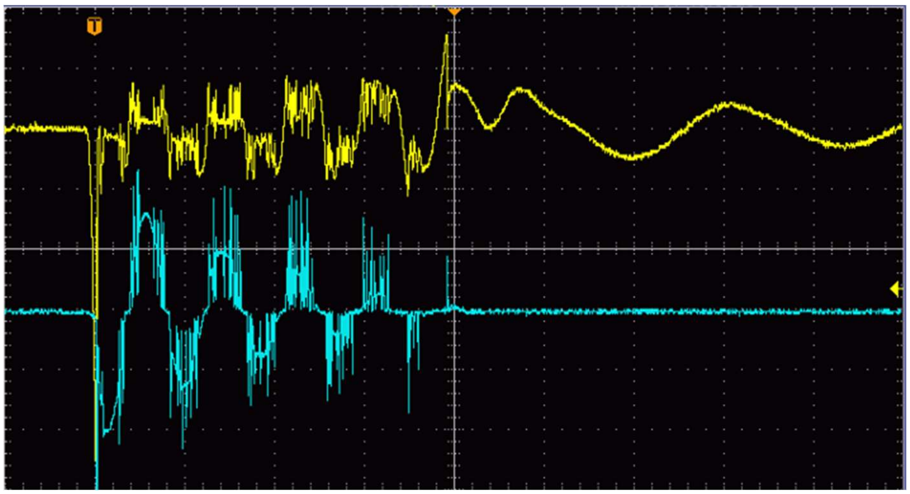
Spark Plug Waveform

Spark Plug Voltage and Current



Upper Trace: Voltage 500 v/cm;
Lower Trace: current 200ma/cm;
10µsec/cm; 0.63 mjoule to arc (calculated)

There are several points of interest on the voltage and current waveforms. First, the current and voltage oscillate positive and negative for a few cycles, just as the voltage waveform did in the resistive load. The current flow here still resembles the damped sine wave of the CDI module output, but the voltage is much more complex. The voltage is controlled primarily by the arc, not by the driving module. Instability in the arc drives the obvious oscillations on both waveforms, but looking through those, you can see a definite tendency toward lower voltages when the current is high, and that voltage tends to go up when the current is lower. You can also see that at current peaks higher than 0.5 amp the arc tends to stabilize, and the oscillations disappear.

There is a high voltage spike (off the display, negative) at the beginning that strikes the arc. After that, at the zero crossings of the current waveform, enough ionization lingers in the arc so that no further re-strike voltage spike occurs. You can also see that the arc decays and quits suddenly after about 40 µseconds, and the voltage waveform dissipates its remaining energy in a decaying sine wave.

Calculation of spark energy uses the same procedure as the resistor discharge example above, except that the instantaneous power computation is $P_n = v_n \times i_n$.