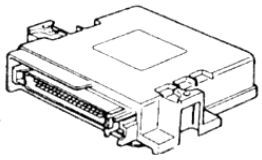
February 2011
Technical Newsletter

Automotive Electronic Control Systems



AECS
Training, Equipment and Data for Automotive Diagnostic Specialists

Prius practical problem

This article is a true description of an AECS technical help desk problem and how it was solved. The story turned out to be very expensive for the customer, even though it was a very simple problem.

Vehicle
2000 Toyota Prius NHW11 1.5ltr Hybrid

Problem presented to the Helpdesk
The Prius has developed a very loud knock in the engine. The engine is diagnosed by a garage as having dropped a bearing on the crankshaft. The owner is told it is not worth repairing even though a brand new HV battery had been fitted about a year prior.
Please do read the whole story in detail; you might get this in your workshop yourself!
The car finds its way to a customer of AECS, where we were able to call in and assist with this *truly remarkable story*.

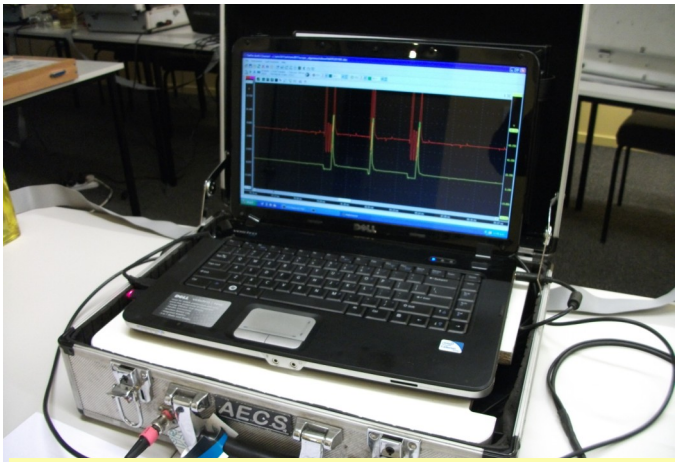
Vibrations
The car was un-driveable, the drive train vibrated madly, the noise the engine made was horrendous, to me it sounded like a broken conrod rattling around inside the crankcase.
Where do you start? Well, the garage before us scanned it for codes but found none. Since the workshop did not use the Launch we decided to scan it again.
We found that the code P3190 Poor engine power was logged, but this could have happened when we stalled the engine during testing.

Hybrid drive train
The NHW11 Prius has a very simple gearbox, only one planetary gear set, which serves as all gears forward and reverse. There is no clutch so we could not confirm if the problem was perhaps in the planetary gear set, or transmission damper between the gearbox and engine.

AECS deals with the exact details on how the drive train works and its diagnostics, in the EMS 1-4 training.

Scope
We decided to use the scope to see if we found any problems in for example ignition or injection, just as a matter of course, it could be a misfire.

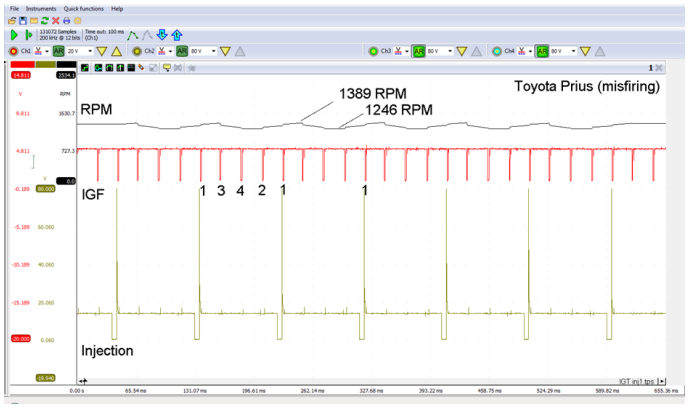
On Toyota coils, it is not possible to record primary ignition, which has our preference over any other type of ignition pattern, so we opted for the IGF (Ignition Feed Back) signal vs. injection.



A 2-channel ATS scope which comes with ATIS software to help diagnose all electronic faults. Scope packages start from $3,650+gst.
AECS takes care of making you proficient in diagnostics with its highly valued training seminars.

RPM variations
To see if the knocking noise and rattle came from the engine or from the drive train we added to the recording a calculated RPM signal which uses IGF signal to calculate the RPM every 180 crankshaft degrees.

We recorded the following pattern just as the engine started and knocked really loud.



IGF vs injection with calculated RPM trace.

MGs?

The fact that the engine RPM stays low every time after cylinder 4, and the fact that the RPM fluctuations ran beautifully in synch with the engine position made us think that the problem was in the engine, transmission damper or shaft going to the planet carrier in the gearbox. But that it had nothing to do with the Motor Generators (MG1 or MG2), as the MG's run at different RPMs to the engine.

Ignition misfire?

We preferred to measure the ignition pattern as discussed, it could be a simple ignition misfire, but the IGF indicated that there was no problem with the ignition system. So we checked with the scope's second channel the injectors.

Injection

All injectors measured identical, even the little hump was visible on the inductive spike of all injectors', indicating injector needle movement.

Emission test

After a few minutes running the engine started to smell badly, so to make sure the engine was getting fuel at about the correct quantity we used an emission tester, see Brainbee printout for the results.

The printout was made when the engine had been running for a few minutes, the fuel control was in closed loop. Look at the values:

- Lambda was close to 1 which means that the air fuel ratio is almost correct, think about the effect of the oxygen sensor.

- O2 is extreme! Far too high, this should be near zero, indicating that a lot of air moves through the engine unused.

EXHAUST GAS ANALYSIS

BRAIN BEE

Type:		AGS-688	
GARAGE DATA:			
AECS			
VALLEY RD			
HASTINGS			
MEASURED VALUES			
CO	:	1.29	[%Vol]
CO2	:	10.2	[%Vol]
HC	:	4280	[ppmVol]
O2	:	5.20	[%Vol]
Lambda	:	1.036	[-]

Date and time

08.02.2012 08:59

- HC is also extremely high. This should be more like 40ppm, indicating that a lot of fuel moves through the engine unused.
- CO is also high, should be near zero, this indicates to me that the cat is burning some of the raw fuel, but that it is not properly lit.

The emission test indicated to us that there was enough fuel and air, but that it simply did not react with each other (it was not igniting inside the combustion chamber).

Combustion

For proper combustion, we need atomised fuel, compressed air, and quality ignition. We more or less checked the ignition, we looked at the injector pattern on the scope. At this stage, we felt like doing a compression test; think about the broken conrod noise which the engine still made.

How do you perform a compression test on a Hybrid Prius?? Spark plugs are deeply recessed into the head, no starter motor and electronic throttle… The scan tool has a special hybrid compression test procedure, but this feature was not available on this car.

Disconnecting one coil at the time made all injection stop through the IGF signal, so that did not get us any further too. Disconnecting injectors had a marginal inconclusive result as the Atkinson engine used in this Prius pushes a lot of air and fuel back into the manifold so all cylinders receive fuel no matter which injector is still operating.

Conrod

We took the spark plugs out and placed a screwdriver on top of the pistons. Moving the crankshaft minute amounts back and forth, had immedi-

ate movement of the screwdriver as result on all cylinders. We looked with a bore scope into each cylinder and found nothing bad. Therefore, we thought that the compression must have been at least reasonable. We even took the cam cover off to look at cam timing and valve lift and clearance.

Injector test bench

To make sure that we did not have one injector spraying badly ('hosing' the fuel in), we took the injectors out and put them on the test bench. We had beautiful spray patterns and less than 1% difference in delivered volume under variable injection rates, which is good.

Brainbee injector test

So what is next?

Maybe it was the transmission damper or planet carrier after all.

Well to be frank, this is where I got unsure, just like how you would be.

There is not a lot that can go wrong in the gearbox, so what is next?

Back to basics

As so often in many workshops, it is the attention to or even skipping of the basics, which makes the whole job very expensive.

Where was anything assumed in this whole story? Ignition!

At this stage (should have been much sooner) we needed to see spark duration and quality, no matter what.

With the ATS scope, it is often, enough to hold a simple probe above a coil to get a good ignition pattern on the screen. The scope is more than sensitive enough to get a pattern without any special probes or amplifiers.

Some of the scope patterns discussed in this article are studied in great detail in EMS1-1.

There is still places in the EMS1-1 training on the 8th & 9th March 2012. in Auckland .
Ring Christine to enrol ph: 06-874-9077

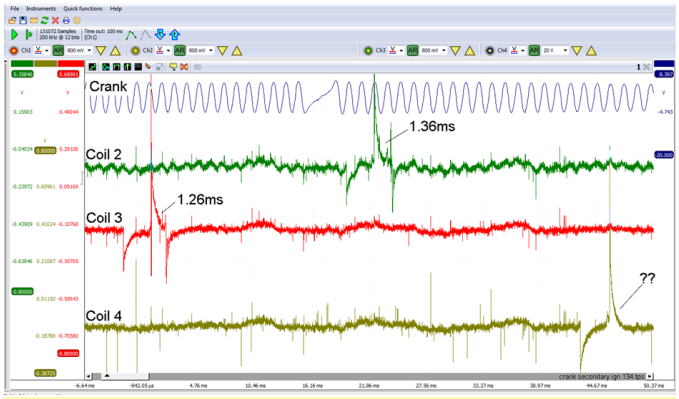

Probe on top of the coil, no signal

We had to try to pick up the magnetic field around the coil inside the cylinder head as that is where the iron core of the coil is.

By simply wrapping, a thin wire around the coil and holding it in place with masking tape gave us what we needed.

We recorded with the ATS 5004d 4-channel scope connected to the wires wrapped around 3 coils and the crank shaft sensor.

Coil with wrap wire

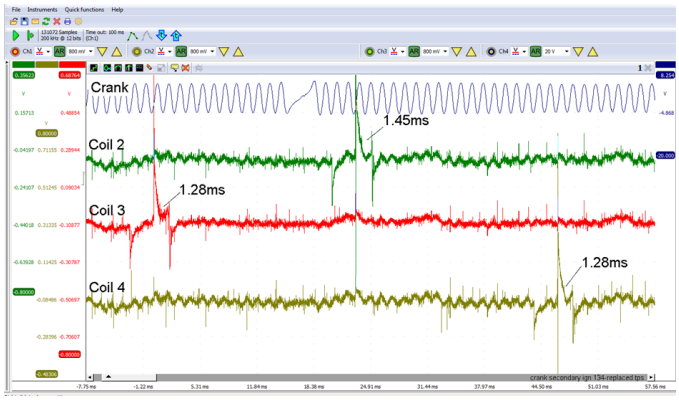


Recording of a very loud knocking engine

Bingo!

Found the fault! There is was. Cylinder 4 had no ignition at all. What about IGF then? Maybe a faulty coil. We replaced the coil and closed the sparkplug gap of the not too bad looking sparkplug. The engine knocked still exactly the same and the pattern was still exactly the same …

We replaced the sparkplug and recorded the following pattern:



Recording with 1 new spark plug at #4

Did it

That solved the problem; the engine was running fine in every respect, no knock, or what so ever. We were all stunned, especially because there was nothing odd visible on the spark plug, no discolouration cracks or tracking. We even put the old coil back on, and the engine still ran absolutely fine. We put the old plug back in and the knocking was back again.

Why the knock

What was causing the terrible knock? The hybrid drive train works with very precise position sensors. The management system needs to anticipate where the rotor of the electric motor is going to be every 65353'st part of a third of a rotation. This so it can power up each of the coils in the stator with the appropriate amount of current; - do not make the magnetic field too strong as you get over shoot of the rotor and also - do not give it too little.

The engine is connected to the rotors of the MG's via the planetary gear set.

Any misfire in the engine gives an MG rotor under-shoot, so the MG ECU is going to compensate for this incorrect rotor position by increasing current to the next MG coil. This will be aided by the next cylinder firing, causing overshoot, which needs to be compensated for…. Please do not think that when the engine is running the MG works just as a generator. The MG's both do use current, also when charging, as this is how the MG ECU controls the charge voltage to the battery.

There is in any drive train free play, even in the big ends on the crankshaft. Move all the free play of every item in one direction and immediately in the opposite direction, and presto there is your noise!

Like it
Like it or not, this is your world. Every manufacturer has hybrids now, It is only a matter of time before this ever changing world of technology enters your workshop if you haven't dealt with this already. Yes! this job took me by surprise too.

What I do know is that this job would not have been solved without

the emission tester,
the scope,
AECS Hybrid Training (EMS 1-4) and
AECS tech. support.

Unless of course some lucky b..strd had changed the spark plugs just as a matter of course.

Conclusion
How expensive can finding a faulty spark plug be? The owner sold this fine car for scrap price. It took the workshops involved days of time to come to the conclusion it was an engine bearing (which it was not). A new spark plug….
Again, please read the whole story to appreciate what you will get in your shop sometime soon!
Prepare for this with appropriate training and equipment.

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Next courses coming up in your area:

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SCAN 1 - Scan tool course

AUCKLAND: 8th & 9th March 2012
EMS1-1 - Engine Management

HASTINGS: 19th & 20th April 2012
Air-conditioning training

TAURANGA: 1st & 2nd May 2012
DMS1-3- Diesel Management Systems 1 –3

HAMILTON: 3rd & 4th May 2012
SCAN 1 - Scan tool course

For enquires or to register for any one of these seminars contact AECS:

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