October 2014

Technical Newsletter

Automotive Electronic Control Systems

AECS
Training, Equipment and Data for Automotive Diagnostic Specialists

P(r)oxy Voxy

*This article is a true description of an **AECS** technical help desk problem and how it was solved.*

Vehicle

2003 Toyota Voxy 2.0 Ltr direct injected petrol 1AZ-FSE D4 engine.

Problem presented to the Helpdesk

The vehicle has a bad surge at light throttle below 2500 RPM, and intermittently at idles.

It only happens when the vehicle is at operating temperature and in ECO mode. There are no fault codes, and in live data on the Launch scan tool, we see that all values match the values as printed in the repair manual.

We have done what you always say, record ignition over injection and to us it seems that the ignition pattern is really strange at the same time when the problem occurs.

Lots of trouble

Well we have dealt with a large number of problems on direct injected Petrol Toyota D4 engines in the past. Many cases ended up being unresolved or too expensive to carry on (DNFs). This case certainly started to fit into the DNF category. It had been sold as a Jap import by a respectable car dealer. He had the vehicle looked at several times in different garages before the decision was made to buy the car back.

It was passed on to a number of different work-shops over a period of more than a full year, before it was handed to a diagnostic workshop who has AECS equipment and Technical support. With all the best will and patience, we were not able to come to a conclusion in the time available.

AECS HQ

A decision was made to transport the vehicle to AECS headquarters, something which we always

Did you Know?

RLNZ + AECS - We have teamed up with RLNZ (Refrigerant License New Zealand) and we can now offer the RLNZ Air-Conditioning Filler & Handlers course at the end of our 2 day air-conditioning training.

When you enrol with us for our air-con course, let us know if you wish to enrol on the Fillers & Handlers course and we can arrange the enrolment for you.

AECS Training

Taking enrolments for:

EMS1-3
Engine Management systems
20 & 21 October 2014
Auckland

ECAC-1
Air–conditioning training
22 & 23 October 2014
Auckland

ECAC-1 rescheduled
Air–conditioning training
~~15 & 16 September 2014~~
3 & 4 March 2015
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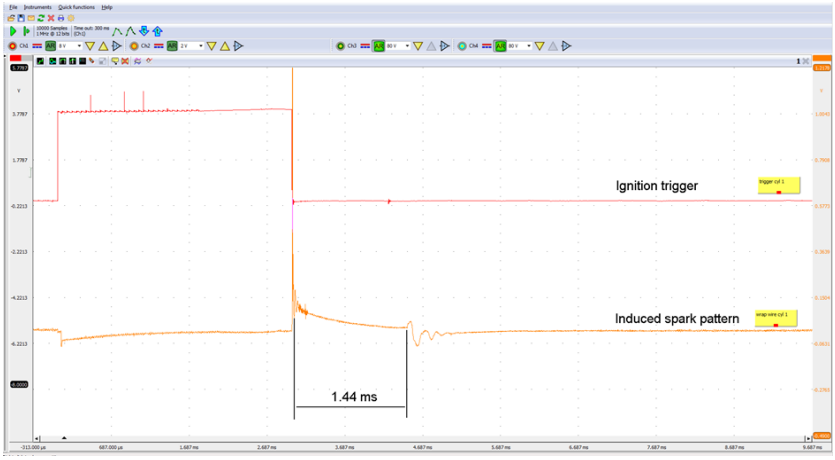
discourage as we do not want to be in competition with our customers (garages). However in this case it was beneficial for AECS to have first-hand experience and patterns to strengthen the new EMS 1-3 (direct injection, variable valve timing/lift, current proxy switches, multi-layer CAN, etc.) training seminar.

Scope recording

We started from scratch, first check spark and fuel. Each of them needs its own attention. However, you simply cannot get to the injectors, so we first measured and analysed the ignition pattern by itself.

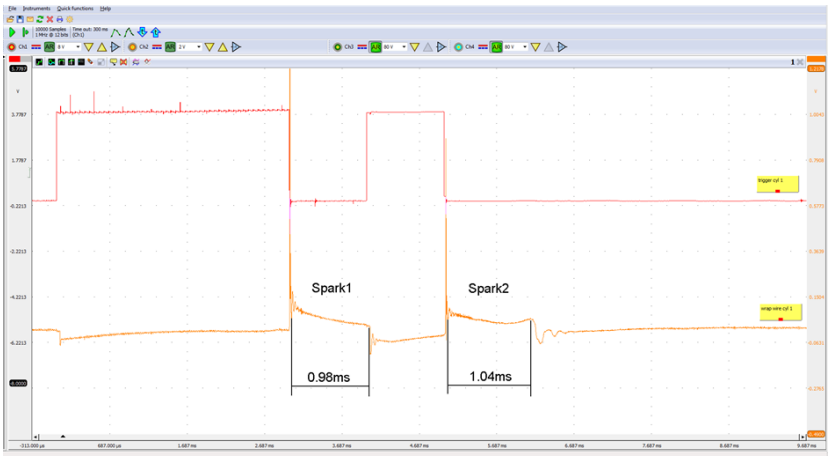
Spark, MSD??



Picture1 : ATS scope recording of ignition while the engine is running normally

The measurement is of the Ignition trigger (IGT) and the induced voltage around the coil to see what the spark quality was. The pattern above was the same on all cylinders and looking absolutely great, 1.44 msec is more than enough to make this vehicle run fine. However as soon as we revved the engine (at operating temp) the engine felt as if it was randomly misfiring.

In the pattern below, we saw and MSD (multi spark discharge) ignition like pattern. I had never seen that on any Toyota yet. A number of other vehicles have MSD at idle and just above idle (e.g. BMW and Ford).

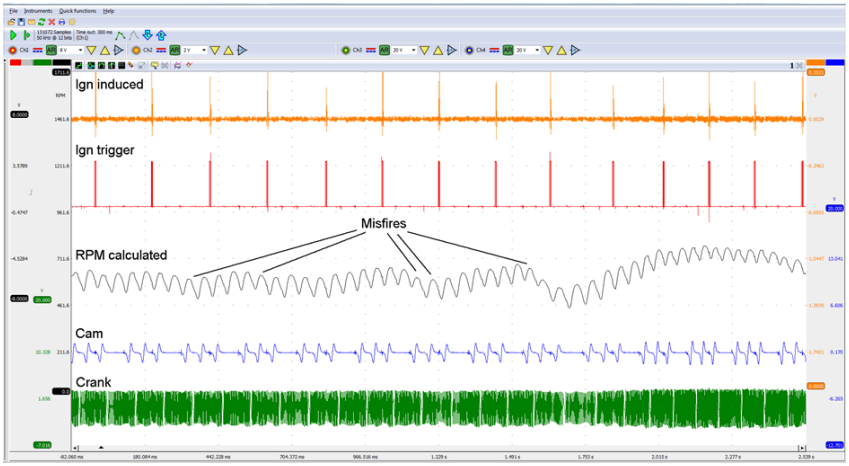


Picture 2 : ATS scope recording of Ignition at raised revs

The MSD stayed present while raising the revs, up to around 2500 RPM, after which the ignition pattern became normal AND the misfire disappeared….

Found the fault?

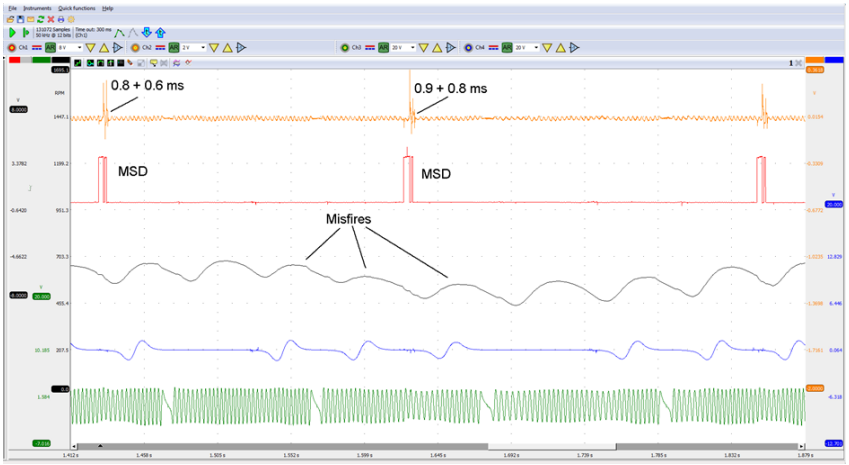
Could this be the problem? That was quick! Let us look at why the MSD was there and on all cylinders. In my view if it was not supposed to be there, this could only be the result of cam/crank sensor issues.



Picture 3 : ATS 5004d recording of induced ignition, IGT, cam shaft and crank shaft sensor.

The RPM trace is calculated from the crank shaft sensor signal and CLEARLY shows where the engine misfires.

The recording where we can see the misfire clearly in the RPM signal zoomed in reveals that the cam and crank signals are almost perfect!



Picture 4: 5004d recording of induced ignition, IGT, cam shaft and crank shaft sensor zoomed in.

It also shows that the ignition is present when the misfire occurs. That tells me that the problem is not with the MSD ignition.
With the aid of the RPM line, we could determine TDC of the piston, through which we could calculate the actual ignition timing (and later the injection timing).
We found that the first ignition pulse started 35 degrees BTDC and the second ignition started around 25 degrees BTDC. Yet the scan

tool was showing 23 degrees BTDC in live data.
Hmm… not sure about that one.

Next, Fuel

For this, we needed a wiring diagram to make sure that we were measuring on the injector of Cyl 1 so we could clearly see the injection phase shift of this engine. (Picture 5)
The first recording we did straight away showed us that the misfire was also present if there were no double ignition pulses, even though we were not looking for that anymore! This told us for sure that the problem was not in the ignition. It also showed (when zoomed in) that the injection duration did not alter much while misfiring (+/-1.1ms).

Scan tool and Emission analyser

What we did see when we were concentrating on the fuel delivery was that the fuel pressure dropped from +/-12kPa (running fine) down to +/- 9kPa (misfiring) at idle on the Launch scan tool. This happened at the same time that on the scan tool the ignition timing changed from +/- 7 degrees to +/- 24 degrees BTDC.
Also on the emission tester, we saw that the air fuel ratio changed from Lambda 1 (stoich) to Lambda 2.1 (very lean). This while the idle speed remained about the same, with a hardly changing throttle angle.

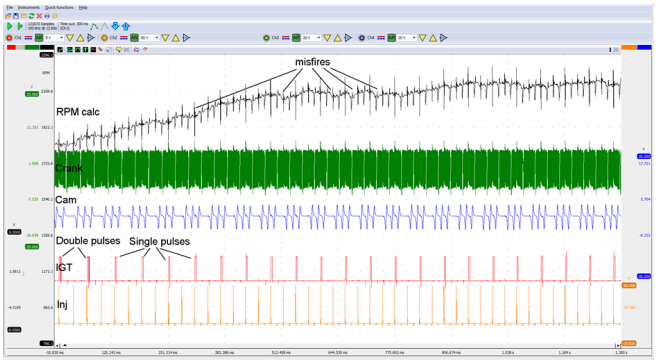
Manipulate with scope signal generator

With so little change and such a massive change in running, something had to be wrong in my view with the fuelling.
To increase the fuel quantity on an engine with a MAP sensor, all you have to do is place the signal generator in between the MAP sensor and ECU, so you can increase/ decrease the MAP sensor's voltage. This, on all engines, has an immediate effect on the injection duration. It had no effect on this engine, not on the fuel pressure nor on the injection duration??

We started to think that the pump timing was perhaps incorrect. The pump used on these engines is a spill valve type pump, where the fuel into the pump comes through the same valve as the valve that controls the rail pressure. This pump runs of the variable intake cam. We checked the cam timing and spill valve timing when running good and bad. (Picture 6)

In the yellow comment boxes, are the count of the crank-shaft teeth, please study in detail (by clicking on the picture)!
This simple measurement led us to conclude that:

a. the cam shaft was in exactly the same position when in lean running mode or in stoich mode, and
b. that the spill valve timing was ending at exactly the same crank position but starting a 10 crank degrees later (one tooth), which caused the lower pressure.



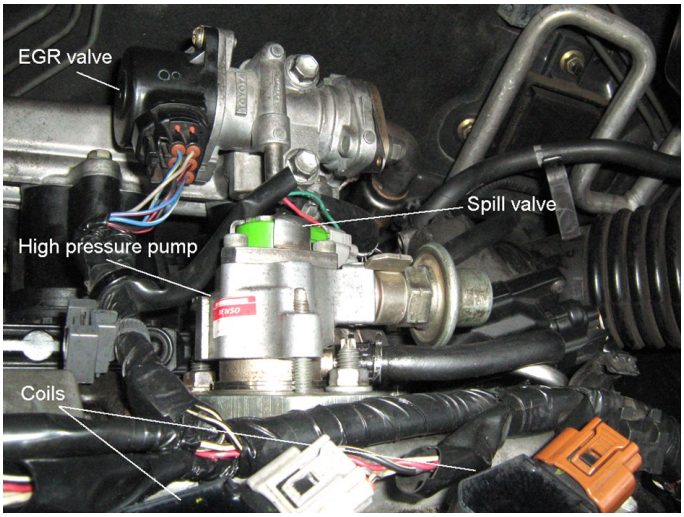
Picture 5: ATS scope recording of Crank, Cam, Ignition trigger, Injector power supply and RPM calculated, fully zoomed out.

Picture 6: ATS 5004d recording to check cam and pump timing. Running good traces are grey, running bad are coloured.

We concluded that in lean running mode this engine runs obviously in 'double open loop'.
It already does not look at the O2 sensor when in lean running mode, but also not looking at the MAP was a surprise to me.

Circles

We placed the signal generator of the ATS 5000 scope in between the fuel pressure sensor and the ECU to try to manipulate the fuel quantity when the engine is running bad. When we generated -0.67V (in fact dropping the signal voltage from the rail pressure sensor) we got the actual pressure back to the 12 kPa, while the ECU sensed 9kPa at idle.
Result: no difference in running!!



Picture 7: Picture of EGR valve and high pressure pump

We started to redoubt the ignition timing, maybe 24 degrees BTDC was just too much. We simulated knock to see if the timing would come back to normal values, which also had absolutely no effect. We were running around in circles!

Fuel Spark and Air

Therefore, we had done all we could with the fuel and with the spark and cam timing, what is left?
We had to look at air flow, boy! we were in deep now. We spend already more than 2 days on this job! Thankfully, the owner of the vehicle was understanding, as we kept working up to set points he determined. Every time we reached that point, we e-mailed him a report of what we had done and where we wanted to go.
What could possibly be wrong with the air flow? These engines need accurate air swirl into the combustion chamber during lean running mode. They use EGR to 'up' the quantity of gas flow and close a set of intake runners to increase the speed of the gas flow, to get the rich mixture 'ball' inside the combustion chamber, directed to the spark plug.

EGR and Swirl valve

We looked at EGR flow and removed first the EGR plug from the EGR stepper motor, which brought the car into limp home mode (Lambda 1). We removed the stepper motor of the EGR valve while electrically connected. We made sure that the valve was manually operational, by pushing on the valve with the engine running. With the EGR valve shut firmly the engine was still misfiring, opening the valve manually only made it worse.
We studied the activation of the swirl valve control solenoid, and found that every time the vehicle entered lean running mode, the valve was activated.
Just as a try, we decided to deliberately interfere with the air flow in the manifold by activating the solenoid valve manually, by overriding the ECU control.

This had an absolute and immediate effect! At idle you could hear the difference straight away. However, at higher revs the swirl valve did not want to move, so say you hold the revs at 1500 rpm while misfiring and activated the swirl valve, no difference in misfire.

However if you activate the swirl valve at idle and then took the revs up to 1500 the misfire was gone. With the air cleaner removed, you could hear the intake noise change with the swirl valve activated or not; as confirmation that the swirl valve actually moved.

Intake manifold removal

The next step we took was to remove the intake manifold and cylinder head to de carbonise the intake runners and intake ports in the head. In addition, to carefully inspect the swirl valves.

A common fault on these vehicles is totally carbon caked intake runners, in some cases obstructing the movement of the swirl flaps, or at least interfering with its operation.

We found the following:

Picture 8: Intake valve port with cylinder head and intake manifold removed.

This blew me away, hardly any carbon and the intake manifold was absolutely spotless! I would say somebody had been there before me in the year of trying, preceding this job.

After a thorough clean of all the ports and pistons, the engine was put back together again, still running virtually the same, bad.

ECU?

This is where I hit the brick wall (DNF coming close). There was nothing left to try, or was there?

Let us look at all data again in great detail. The swirl valve was actuated in lean running mode low load and during full load. That are two opposites of the load spectrum. The swirl flaps need to be open in my view during full load, as else there is not enough air entering the engine to rev out. We verified this by activating/deactivating the valve manually. No top end power and also no upshift in kick down mode!

We activated and deactivated the valve during lean running mode low load, watching the ignition timing and MSD ignition and could make the car run beautiful and bad at will.

Costs too high

After deliberation, we decided against trying a $1750 new ECU. Manually activating the valve set a fault code, as if the ECU was actually trying to activate and deactivate it when it did, meaning in our book that the ECU tried to do the incorrect thing. A new ECU would not necessarily solve this if it were programmed the same way.

With our team, here at AECS we decided to build a small kit to override the ECU control of the swirl valve and let it kick in when we deemed necessary. We tested this kit thoroughly with all tools at our disposal (emission tester, scanner, scopes, temp probes, etc.) and believe that we have cured the running problem of this D4 engine forever!

Conclusion

We have not often had a troublesome engine that gave us such headaches. We also do not think that we can better the design of the car, over what the manufacturers do. However, in this case, which was far more complex than what is written down, we had to alter the design. The end result is there. Since this support case, it has come to our attention that there are many more D4s in the country with the same or similar problems.

If you are subscribed to AECS tech support, get in touch with us so we can help you analyse this problem much simpler than how we got to the finish.

Choose you technical partners wisely. For equipment and training, deal with people who know their stuff. Automotive technical matters are your and our lives.

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P.S

*To view the pattern pictures in **High Definition** - **click on the pictures***