

Testing piezoelectric injectors

When you squeeze quartz an odd thing happens, it will produce a current. When you apply current to quartz, it will rapidly change shape and stay in that new shape. Piezoelectric injectors use this characteristic to provide fast, precise control of injection timing, while eliminating all other moving parts. Joe Clarke, from DIT, makes it simple to sort out problems with these injectors.



Joe Clarke, D.I.T.

Fundamentals

The electromagnetic type injector is controlled when its solenoid is energised, enabling a controlled leak-off resulting in a pressure difference within the injector leading to its opening. The closing of this type of injector occurs when the electric current is cut, the solenoid becomes de-energised, resulting in the closing of the control chamber valve via a spring. Because of the design, there is an unavoidable delay in the time taken for this spring to close the control chamber valve. The Piezo-electric controlled injector can operate up to four times faster than the electromagnetic type, as the control valve is driven closed instead of relying on a spring. This extremely rapid open/close time has enabled up to 5 injections per cylinder per cycle (2 pilot injections, split main injection & post injection) according to running conditions. As a result, use of this technology has increased since the introduction of ever increasing emission control standards.

Operation

The mechanical principle of operation is similar to the electromagnetic solenoid injector. The controlled leak off, used to assist in the opening of this type of injector, utilises the “inverse Piezo-electric effect”. The injector contains a control actuator, consisting of

several hundred thin layers of Piezo crystal material, (normally quartz). When a voltage is applied to the quartz it will either expand or contract, according to the polarity of this voltage applied. The Electronic Control Unit (ECU) will continually alternate the polarity of the voltage, enabling precision opening/closing of the injector as required.

Note: When an electromagnetic type injector is disconnected from an electrical signal, it closes immediately due to the solenoid valve spring action. If a Piezo-electric type injector is disconnected from an electrical signal when the engine is running, the injector may remain in its open state for a period of time, which could lead to over fueling and possible engine damage.

Identification

The majority of piezoelectric injectors may be recognised by the location of the leak off pipe, located at the side of the injector and not on the top as seen on the electromagnetic type.

Safety Precautions & System Protection

- The operating fuel pressure within modern common rail systems may exceed 1,800 bar, or 26,100 psi. Therefore, before any work is carried out on the high pressure

circuit, it is imperative that the system is depressurised after the ignition has been switched off. This depressurisation may involve a procedure using the diagnostic tool, or waiting a specified time for the pressure to drop naturally.

Note: Recently developed injection systems as used on hybrid vehicles may retain their pressure for longer periods of time, to enable immediate restart of the engine.

- If a high pressure pipe is loosened, disconnected or removed, it should not be reused as its integrity cannot be guaranteed. These pipes should always be replaced and tightened to the manufacturer’s recommended torque.

- The working clearances within the injector are in the region of 3µm, many times smaller than that of a human hair. For this reason cleanliness must be ensured and all openings must be sealed following component disconnection.

- If a Piezo-electric injector is dropped or receives an impact, its internal crystals may be damaged resulting in faulty operation.

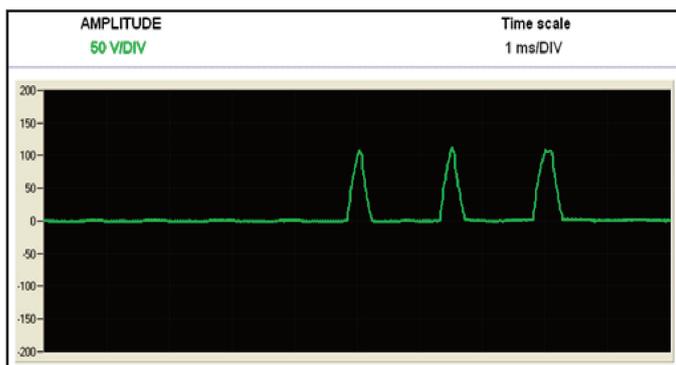


Figure 1 - A scope trace from a Euro 5 compliant diesel engine

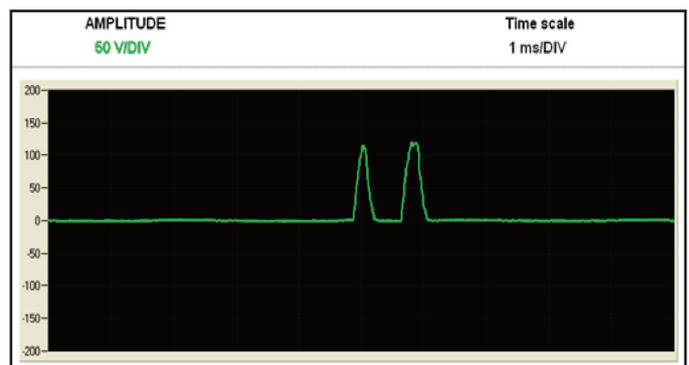


Figure 2 - This injector was triggered twice in about 1 millisecond

Testing

Unfortunately there is no single check that can be applied to diagnose a faulty injector, aside from substitution with a known good component. This is not recommended, as a faulty wiring circuit could lead to damage to the new injector.

The following tests may be carried out on Piezo-electric injectors. The values obtained may vary according to the injector and the injection system variant.

• **Test 1 - Resistance Test:** The resistance of the control actuator may be measured by connecting an ohm meter across the two injector electrical pins, when the injector is disconnected from the wiring harness.
Result: The resistance should be in the region of 200KΩ.

• **Test 2 - Capacitance Test:** This test is carried out by connecting the multi-meter in the same way as during the resistance check, except the capacitance test is selected on the multi-meter.
Result: The capacitance should generally be between 6µF and 8µF.

• **Test 3 - Injector Leak-off Test:** All injector leak-off pipes must be disconnected and blocked to prevent leakage. A separate pipe is connected to each injector, with the free end in a graduated cylinder. This test normally consists of holding the engine at high idle for a duration of 2 minutes and observing the quantity of fluid contained in each graduated cylinder afterwards.

Result: The quantity of diesel contained in each graduated cylinder is normally less than 30ml, with nearly identical leakage in all of the cylinders. A faulty injector control chamber may be identified by excessive diesel in the corresponding container, while some faults can lead to a reduced leak off quantity.

• **Test 4 - Electrical Control Test:** An oscilloscope is connected across the two pins

of the injector, with the engine running or being turned over using the starter motor.

Note: Do not display two injectors at the same time using an oscilloscope with a common earth between channels, as this could result in an injector being held open and causing engine damage.

To display the voltage pulse from the engine ECU, the following oscilloscope settings should be selected:

- Amplitude: 50V/Div
- Time scale: 1ms/Div
- Trigger threshold: 40V.

Result: Figures 1, 2 & 3 scope traces are taken from a Euro 5 compliant diesel engine equipped with the Continental SID807 injection system.

Pilot injection is used to reduce engine noise and emissions at low to medium engine speeds. Above 4,500 rpm, the engine tone will change as pre-injection is no longer carried out and the Exhaust Gas Recirculation (EGR) valve will be closed.

Some systems require a learning programme to be carried out in order for pilot injection to function. This involves driving the vehicle within specified parameters to learn injector drift. When injector current is displayed using the oscilloscope, the value may range from 5 to 10 amps positive and negative as the current flow changes direction.

• **Test 5 – Injector Flow Correction Test:** With the engine at idle, the ECU will observe the acceleration of the crankshaft during each power stroke and determine an average value. If one cylinder under-performs, compared to the average, the ECU will inject slightly more fuel into that cylinder to compensate. This can be viewed using the diagnostic tool in the live data section. This correction may be displayed as a percentage, the injected fuel quantity (in mg/stroke) or the value for each cylinder may be given in relation to the average, as shown i

n Figure 4. If an excessive difference is observed between cylinders, then an injector fault could be the cause.

Note: An engine mechanical fault resulting in reduced compression could also lead to excessive fuel being injected to compensate. This can be identified by swapping the injectors between cylinders. If the imbalance stays with the cylinder, the injector is not the fault. If the imbalance moves with the injector, then the injector is faulty.

Conclusion

In order to efficiently diagnose a Piezo-electric injector fault, a detailed knowledge of the injection system's strategies and characteristics is required. A systematic approach must be taken, involving the skilled use of various specialised tools and equipment, all while ensuring personal and system safety.



A Delphi piezoelectric injector

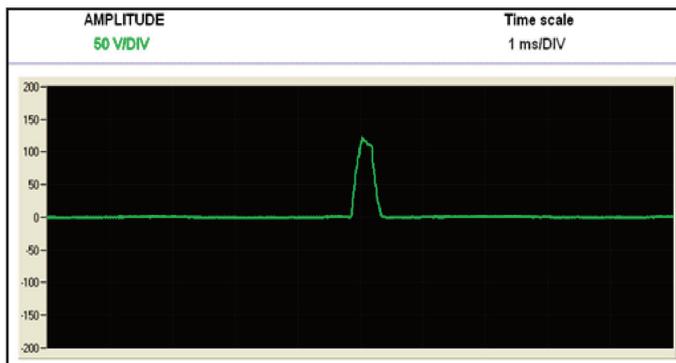


Figure 3 - This injector was triggered only once during this event

Cylinder 1 injection time	09.66	ms
Cylinder 2 injection time	09.69	ms
Cylinder 3 injection time	10.08	ms
Cylinder 4 injection time	09.38	ms
Injector opening correction strategies	Active	
Cylinder 1 injector flow correction factor	0.860	
Cylinder 2 injector flow correction factor	1.098	
Cylinder 3 injector flow correction factor	1.072	
Cylinder 4 injector flow correction factor	0.970	

Figure 4 - data from the ECU can be used to find a faulty injector