Using Software to Aid in Engine Mechanical and Electronic Failure Diagnosis

In this article, we'll show how a modern oscilloscope or engine analyzer along with software can greatly enhance engine mechanical and/or electronic failure diagnosis.

The investigated script is called the Px script (V3) and uses a pressure transducer installed in place of a cylinder's spark plug. The script allows for checking the characteristics of the cylinder, intake system, exhaust system and the timing system in order to evaluate the relative impact of these systems on the engine and each other.

Figure 1: Pressure and synchronization transducer installation.

The script allows:

- To evaluate cylinder leakage. Cylinder leakage is affected by a number of items such as piston ring wear and/or ring gap, cylinder wear, intake and/or exhaust valve damage or clearance, head gasket, cracks in the combustion chamber, in the piston or in the cylinder.
- To measure compression ratio. Compression ratio is affected by the presence of large amounts of carbon deposits on the piston top or crown and, in the combustion chamber, bent connecting rods due to hydrolock. The compression ratio can also be affected by the use of a replacement crankshaft, piston or piston rod.
- Automatically measure the actual valve timing (intake and exhaust valves opening and closing angles).
- To use animations to show the real process of gas exchange that occurs in the cylinder during the measurement. This takes into account the effect of the measured valve timing and the characteristics of the intake and exhaust system, etc.
- To identify insufficient filling of fresh mixture into the cylinder (volumetric efficiency), and to determine the cause. Non-optimal valve timing, or the geometry of the intake system, air filter restriction or throttle opening, poor exhaust gas scavenging from the cylinder due to exhaust system restrictions.
- To assess the effect of systems used to force extra air into the combustion chamber. Turbocharger, supercharger, variable valve timing system (Vanos, VVT, etc.), changing the height of timing valve lift (VTEC, etc.), changes in the intake system geometry such as variable length intake runners, and intake system resonators.
- To evaluate the efficiency of the turbo or supercharger turbine. (Balance between extra resistance created by the turbine wheel of the turbocharger and the supercharged air produced by the compressor wheel of the turbocharger.)
- To identify excessive cylinder pressures due to control system malfunction of the mechanical or turbocharger, which can cause piston and cylinder damage.
- To identify power loss from scavenging exhaust gases from the cylinder including the loss from the turbocharger. (Exhaust system flow limitations from, for example, clogged catalytic converter or muffler, the exhaust valve closing too early, insufficient exhaust valve lift or an improper exhaust system installation.)
- To check the ignition timing advance angle and identify modes of engine operation, in which the measured timing advance angle is later or earlier than optimum. This takes into account the measured geometric compression ratio and cylinder fill.
- To check whether the diagnostic test is performed correctly.
- To conduct this test it is sufficient to install the pressure transducer in place of the spark plug, then connect a spark tester and synchronization transducer to the high-voltage wire of this cylinder, as shown in **Figure 1**.

Documentation Produced by the Script:

The Px script produces a report that consists of multiple pages or tabs with the measurement results shown in text, table, graphical and animated forms. In addition, the script analyzes the measurement results and independently identifies diagnosis, which can be found in the "Summary" of the "Results of analysis" tab, see **Figure 2** on page 4. This tab can be printed for inclusion with the customer documents.

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Figure 2: Summary with conclusions from the "Results of analysis" tab.

Figure 3: Audi engine with compression loss.

Cylinder Leakage

Let's take a look at an example of excessive cylinder leakage on an Audi A6 equipped with a 2.4 V6 engine (AGA). **Figure 3** shows the summary conclusion from an engine with compression loss. Note that the summary is listed as incomplete. The failure is such that a complete engine test cannot be performed until the cause of the failure is repaired.

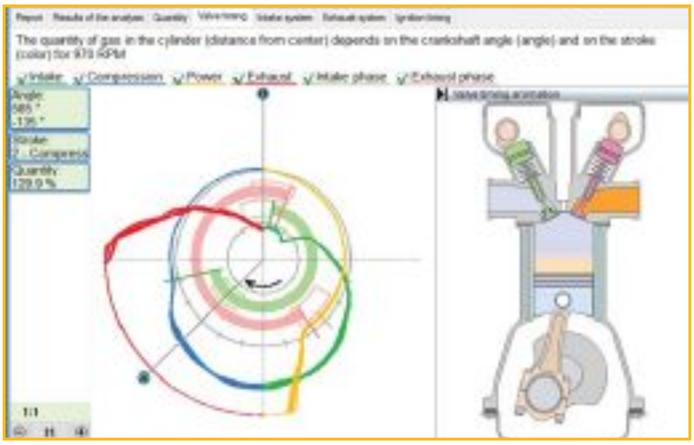

Figure 4: Valve timing diagram from an engine with valve timing problems.

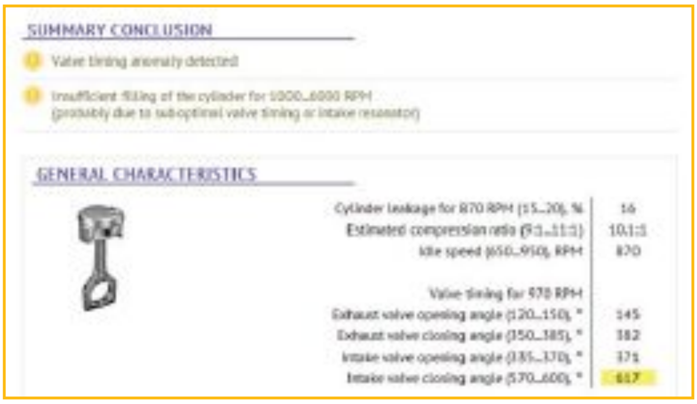

Figure 5: Summary conclusion on an engine with late valve timing.

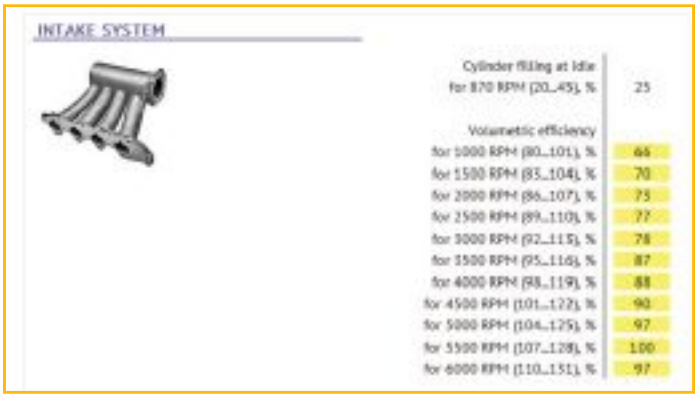

Figure 6: Summary conclusion for the intake system.

The amount of gas losses here is 66% and has gone far beyond the typical range of 15-20%. As a result, the script diagnosed "The cylinder is losing compression."

In addition, the script can identify some causes of the leaks. In this case, the reason is the exhaust valve clearance is too small.

Valve Timing

The Px script measures and displays the actual valve timing by calculating and then automatically analyzing a diagram depicting the amount of gas in the cylinder. The diagram has an interactive animation that demonstrates the real process of gas exchange in the cylinder. During calculation/construction of the diagram, variables such as the initial installation of the camshaft, stretch and slack of timing chain/belt, valve clearance, the shape and the wear of cam lobes and variable valve timing system are automatically taken into account. **Figure 4** is an example of a valve timing diagram from an engine with late valve timing.

During day-to-day usage of the script, it is not necessary to examine the diagram manually because the script automatically calculates the valve opening and closing angles and assesses their impact on the operation of the engine. Primarily, the filling of fresh air/fuel mix into the cylinder (volumetric efficiency) is estimated because this parameter limits the maximum power and torque of the engine.

For the engine diagnosed in **Figure 5**, the script diagnosed "Insufficient filling of the cylinder..." and found the cause of this as "Valve timing anomaly detected" – namely, the measured closing angle of the intake valve has gone beyond the typical range of 570-600°. **Figure 5** is the script's summary conclusion based on the diagram in **Figure 4**.

A diagnosis of late valve timing often points to an incorrect camshaft installation. In this case, the evidence points to an incorrect intake camshaft timing, either a problem from installation or something such as the timing belt or chain slipped. Too late closing of the intake valve results in a substantial part of the air/fuel mixture being pushed back from the cylinder into the intake manifold as the piston starts on the compression stroke. As a result, there is considerably less air and fuel in the cylinder after the closing of the intake valve than it could be. In practical terms, this causes a loss of effective compression ratio. Because of this, the engine power is significantly reduced.

Thus, only one tab "Results of analysis" shows that the engine efficiency throughout all of the rpm ranges is lowered, and immediately determined the cause of this to be suboptimal valve timing.

If necessary, the results of filling the cylinder are available in table and graphical form. For example, for the engine discussed above, the

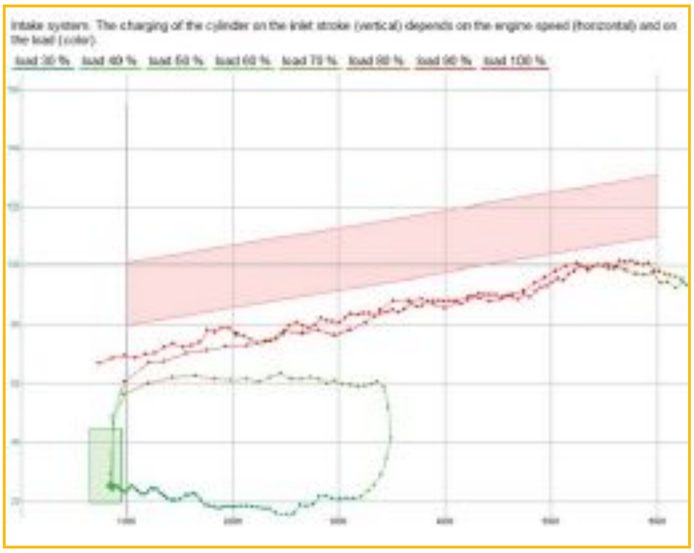

Figure 7: Cylinder filling in graph form.

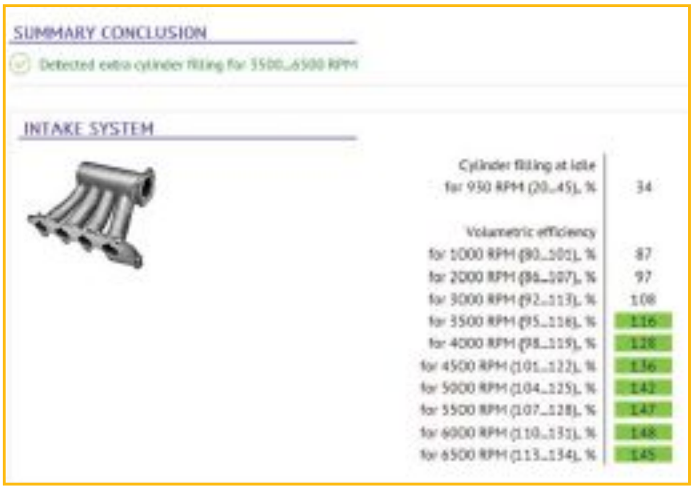

Figure 8: Summary conclusion on volumetric efficiency on a turbocharged engine.

Figure 9: Graph depicting above 100% volumetric efficiency due to use of a turbocharger.

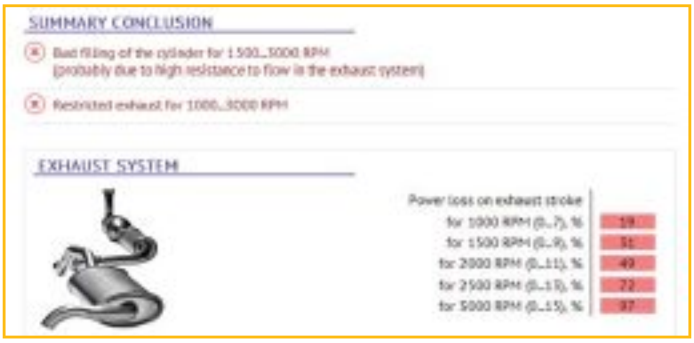

Figure 10: Severe exhaust system restriction.

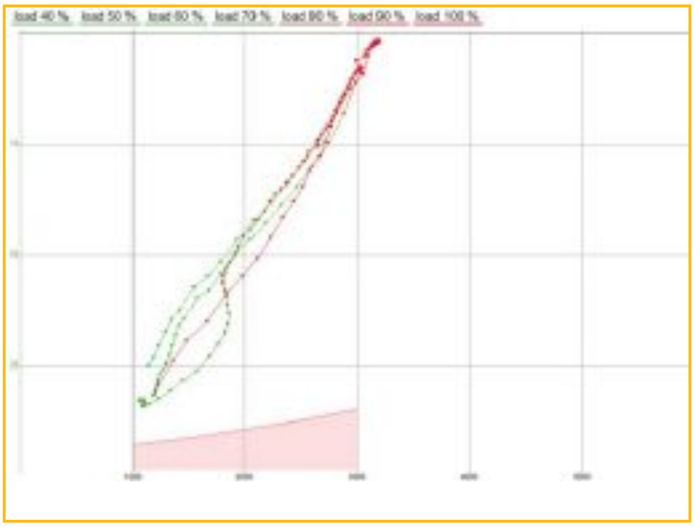

Figure 11: The engine is unable to go above 3,300 rpm, due to severe exhaust system restriction.

Report tabs data are shown in **Figures 6 and 7**.

In the table shown in **Figure 6**, it's clear that at all engine speeds the measured values of the cylinder filling are below typical range. In **Figure 7** it is shown in graph form that the filling diagram in red, corresponding to snap throttle, is located below the limits of the standard areas.

Forced Induction

The following is an example of the test results from a turbocharged engine on a Ford Focus. **Figure 8** clearly shows a volumetric efficiency above 100% in higher rpm ranges. **Figure 9** shows above 100% volumetric efficiency on the same engine as in **Figure 8**, but in graph form. The results clearly show that the turbo adds significant fill at engine rpms above 3,000, and the extra fill increases drive torque by approximately 20% between 4,000 and 6,000 rpm.

Exhaust System Testing

The script is testing one more important engine system – the exhaust and potential exhaust system restriction(s). **Figure 10** is an example from a vehicle where the exhaust system is restricted, causing power loss.

Here, from the script report, it is seen that the blockage of the exhaust system not only led to an increase of power losses on the exhaust stroke, but also negatively affected the filling of the cylinder (volumetric efficiency) with fresh mixture. Due to insufficient cylinder scavenging there is less room for a fresh air/fuel mixture on the intake stroke. The cylinder is completely filled, but the density of the charge is reduced (inert gas takes up room, allowing less air and fuel to enter). Loss of fill density in turn reduces the power of the given cylinder. The result is that at engine speeds just above 3,300 rpm, all the power developed by the engine cylinder is spent on cleaning the cylinder from the exhaust gases on the exhaust stroke and the engine speed cannot be increased more. **Figure 11** shows this clearly.

Ignition Timing

If the synchronization transducer is used during the measurements, then the ignition timing angles are also checked. This method of measurement is the most accurate, because the real ignition event as measured by the synchronization transducer is compared with the actual top dead center (TDC). (In the vast majority of cases, peak pressure in the cylinder will coincide with TDC.) The ignition timing advance angle is measured during different engine rpm and load modes.

Figures 12 and 13 show an example of late ignition timing. This example shows incorrect initial ignition advance angle. Ignition timing is not adjustable on this particular engine because it does not have an adjustable distributor. Diagnosis and tear down found the reluctor wheel for the crankshaft position sensor incorrectly installed. *TS*

Figure 12: Summary conclusion showing late ignition timing at various rpm ranges.

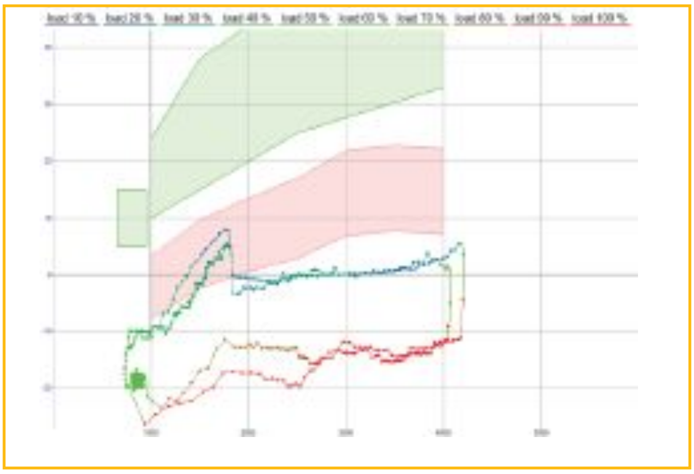

Figure 13: Graph showing late ignition timing.