Pressure waveform analytics

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At Autoinform Live in Cork last April, Frank Massey's presentation was on compression evaluation. Frank recently attended a presentation by Brandon Steckler on pressure waveform analysis, and here reflects on how this can help you in mechanical diagnosis.

Let's first explore the reason and need to apply pressure sensor analytics to everyday diagnostic challenges. Two words explain this, Cost and Risk.

Given the technical evolution of engine design, and the difficulty of accessibility, diagnosing engine faults by traditional non-intrusive methods is difficult, if not impossible. Always measure your decision by the golden standard of diagnostic process, evidence-based evaluation.

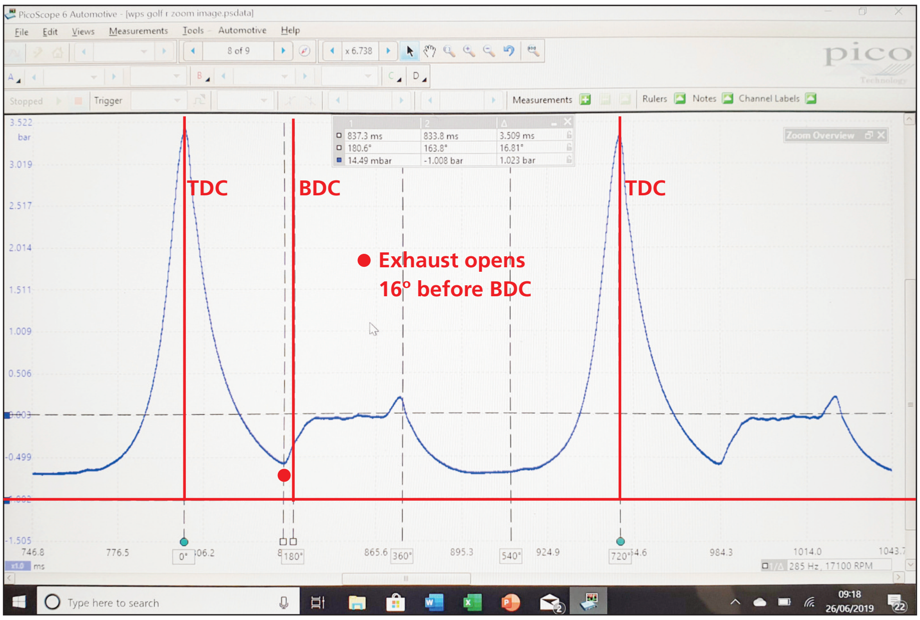
The challenge is to accurately plot the position of the piston crown against inlet and exhaust valve operation, whilst measuring the cylinder pressure differential. In making this task easier, you must accept that vacuum does not really exist. It is an expression to describe a pressure below atmospheric pressure. When a pressure differential exists, there will be a flow from high to low.

This statement embodies the very principle of the Otto Cycle, and describes the effects of pumping losses perfectly. Further to this statement, I suggest you study the effects of Boyle's Law, which describes the behaviour of gas under pressure.

Let's apply the physics and simplify as much as is possible, to the theory of efficient combustion principles. The process I apply here is focused on petrol engines, as diesel engines do not demonstrate the same characteristics, due to not having a throttle controlling the fresh air intake mass. The measurements are taken from individual cylinders using a pressure transducer in place of the sparking plug, hence no ignition.

The compression tower should be symmetrical with values around 3.5 bar at idle, asymmetrical profiles are due to cylinder leakage. The next consideration is the expansion pocket, where pressures drop below atmospheric. Discrete cylinder leaks will reduce the pressure differential.

The next part in the process involves the effects on cylinder pressure by the opening and closing of the exhaust and inlet valves. Exhaust valve opening should occur before bottom dead centre (BDC) of the power stroke. At this point, the pressure in the exhaust system is higher than in the cylinder, so flow will be from exhaust into the cylinder, indicated by a rise in pressure. During the exhaust stroke, the cylinder pressures should not rise above atmosphere by 100mb.



A pressure waveform from a Golf R EN888 engine, which has variable cam timing on inlet and exhaust and variable lift on exhaust

Just before Top Dead Centre (TDC) on the exhaust stroke the intake valve opens, the intake manifold pressure is lower than atmosphere, so the pressure should drop indicating the exact inlet timing.

The period of exhaust and inlet operation, with reference to BDC and TDC is critical to correct timing, valve lift and tappet clearance.

Fresh air intake is the biggest resistance in the cycle, also known as pumping loss, and reflects the volumetric efficiency of the entire intake and exhaust system. Consider the effects of early and late valve operation on the cylinder pressures during the Otto Cycle and consider the effects of the other cylinders within the ignition order.

This brings me to the next consideration how are the pistons and valves connected? Traditionally, this was solely by a timing belt or chain. Now have a computer that can vary the angular timing and lift profiles. So it's imperative that known good profiles are compared with the cylinder under test.

I am not suggesting this method is the first to be applied, quite the opposite. Evaluate serial data first, followed by a relative compression test, remembering the complexity of components within the intake and exhaust modules which can affect these results.