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Composite Intake Manifold Backfire Testing

Introduction:

RAETECH has created a test procedure to simulate backfire events in an intake manifold. As the industry has moved from metals to plastics for intake manifolds, burst pressure has become an important issue. Certain circumstances arise which could potentially create a high-pressure impulse inside the manifold.

The backfire condition being simulated is a worst case scenario. The intake manifold and a cylinder volume are saturated with fuel vapors. Ignition is provided by a mistimed spark event. A high-pressure impulse is created in the intake manifold. Peak pressure will be in the range of 75-100 psi (5-7 bar). The increase in pressure will lift the intake valves off their seats allowing some gasses to escape through cylinders that have open exhaust valves. The following test procedure is designed to test the integrity of the intake manifold when subject to this type of a backfire event.

Burst pressure requirements should be unique to each manifold design. Pressure rise rates are influenced by turbulence and acoustic effects. Manifold geometry is a factor in the magnitude of a backfire event. Simple four cylinder log type manifolds at atmospheric pressure typically generate pressures of approximately five bar. Pressures of eight bar have been seen with complex manifolds incorporating long runners and multiple plenums under the same conditions. Whenever possible Raetech recommends qualifying the backfire event by testing a pre-production, possible aluminum, manifold on a complete engine assembly. Based on those results, the minimum burst pressure requirements including the desired safety factor can be specified. A single value burst requirement can lead to unnecessary manufacturing cost for one design that generates lower backfire pressures, while not providing the desired safety factor for another design that creates higher pressures.

Material properties of nylon vary widely with temperature and moisture content. RAETECH prefers to test dry as molded parts as a near worst case condition. As nylon absorbs moisture the elongation increases and the stiffness decreases leading to an improvement in backfire performance. Some customers have supplied heat-aged parts to simulate long term exposure at elevated temperatures. Parts that have been warehoused for long periods may require a conditioning procedure. Tests are normally conducted at room temperature. Improvements in backfire performance have been noticed when component temperatures increase above 27°C.

Procedure:

An engine backfire is being simulated by igniting a combustible air/fuel mixture inside the intake manifold. The manifold being tested is attached to a machined test fixture. The throttle body flange is blocked off with a plate containing a port to introduce the fuel mixture into the manifold and sensors to monitor pressure. All other holes in the manifold are sealed off.

Propane is used as the fuel due to its similarity in characteristics to gasoline including energy density, burn rate and flame temperatures. The major difference between the fuels is that propane is a gas at room temperature and therefore much easier to distribute within the manifold in a consistent repeatable manner.

The rate of pressure rise in the manifold is influenced by the distance from the igniter to the pressure sender, the volume and the elasticity of the manifold. Generally the time from spark to peak pressure, or ignition delay is 20 to 40 ms. The rise time is defined as the time from 5 psi above the dynamic pressure transducer's initial pressure to peak pressure. Rise times typically are 5 to 15ms. Actual values are dependent on the individual part geometry.

The test procedure for an unfamiliar manifold starts out with the fixture valves set to their standard position and a backfire event initiated at atmospheric pressure. The initial pressure for each subsequent event is incremented up in small steps until a failure is created. At a condition below the failure threshold, a sensitivity study is conducted to compare pressure impulses initiated at the cylinder head end of different inlet runners. Peak pressures and pressure rise rates are compared. The location, which produces the most severe conditions, is used for subsequent testing. Once the burst pressure range for the part design is estimated, the majority of lower intensity impulses are eliminated from the procedure.

To validate a manifold design, a statistically significant sample, typically 6-10 manifolds needs to be burst tested. Smaller sample can be used to identify trends due to design modifications but are not suitable for estimating a standard deviation for the population.

Test objectives are up to the discretion of the individual customer, as is any safety factor they wish to include to compensate for manufacturing variability, material degradation and other unusual circumstances.

Sample Data:

Pressure traces are attached from a manifold test. 19 impulses are included on the plot. The first 18 impulses were created on the test fixture. Impulse severity was incrementally increased raising the peak pressure from 75 to 90 psi. (5.2 – 6.2 bar). The final impulse that failed the manifold was created on an engine. Ignition delay times for this group of impulses was 28ms. Pressure rise times were 6.4ms.