

Measuring with Lasers

Optimizing Valvetrain Dynamics at Porsche Engineering

Laser vibrometry has established a firm place in the automotive sector over the past few years. This non-contact process is used at Porsche Engineering to investigate and improve the dynamic behavior of valvetrains during engine development.

Valvetrain Design

Top performance with optimum fuel consumption requires a perfectly tuned engine. The valvetrain, at the foundation of such tunings, always has the potential for improvement. Heavy demands are placed on these components, particularly in the case of sports car engines, by offering the largest possible opening cross-section in combination with short valve opening periods at high rpm. It is for this reason that developers in this area are constantly striving to improve the properties of valvetrains.



Fig. 1: View of the valves of the test sample, mounted to the cylinder head mock-up. In the foreground is the laser vibrometer.



Fig. 2: Pre-validation of a valvetrain layout on a single-valve test bench.

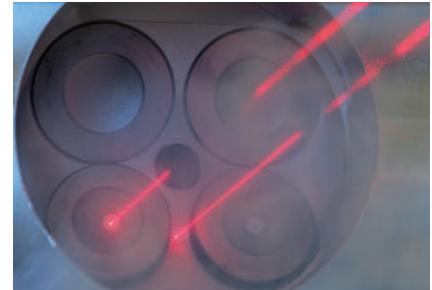


Fig. 3: Measurement and reference laser beams of the vibrometer.



A test bench (fig. 1) can be used during the early stages of development to ascertain whether or not the valvetrain can actually offer the characteristics indicated in a specification document, and whether it will be able to withstand the demands placed on it as a result. The engineers at Porsche Engineering use special lasers to examine valvetrain dynamics without physical contact and therefore no interference. This allows the behavior of the valve to be measured at different speeds. The title image reveals the measurement and reference beams using smoke.

Measurements on the Test Bench

To take measurements, the cylinder head is pressurized with oil just as in normal operation on a mock-up test bench (fig. 2). Oil temperature and expansion can be adjusted accordingly. These parameters are specified in an electronic database and are monitored.

A high-performance electric asynchronous motor drives the entire timing assembly and can be programmed to simulate actual operation.

The chain drive is replicated in full with all intermediate gears, guides and tensioning rails, including the chain tensioner. In this way valvetrain dynamics can be examined along with all the external influences and reactions, such as the chain drive polygon effect, damping influence of the hydraulic chain tensioner, and variable camshaft moments.

Before taking measurements, the laser beam is positioned to strike the valve head perpendicularly. A second laser beam is positioned as a reference beam parallel to the first and adjacent to the valve seat. In fig. 3, both measurement and reference laser beams can be seen as they have been made visible by smoke. With the reference established, the relative movement between the two points is then measured and can therefore show the isolated movement of the valve without the influence of sprung mass. In this way, valve lift and valve speed can be recorded exactly.

Data Acquisition and Evaluation

Porsche Engineering uses a Polytec HSV-2002 High-Speed Vibrometer that was developed especially for measuring Formula 1 engines. It can record speeds of up to 30 m/s as well as displacements (strokes) up to 160 mm.

The data acquired are recorded and saved in a time-synchronous manner. The Rotec RAS system used by Porsche Engineering can record analog signals at a resolution of 16 bits and a sampling rate of 400 kHz. Speed signals up to a frequency of 1 MHz and a resolution of 40 bits can be recorded. An integrated software package enables rapid analysis of the data obtained (fig. 4).

Deploying this system enables Porsche to measure the effects of different cam contours, spring stiffnesses, spring progressions and valve drive masses, for example. The influence of these modifications can then be assessed by examining valve closure speeds (fig. 5) and valve accelerations and by calculating contact power processes and Hertzian stresses. Additionally, analyses of torsional vibrations can provide further information on operational behavior.

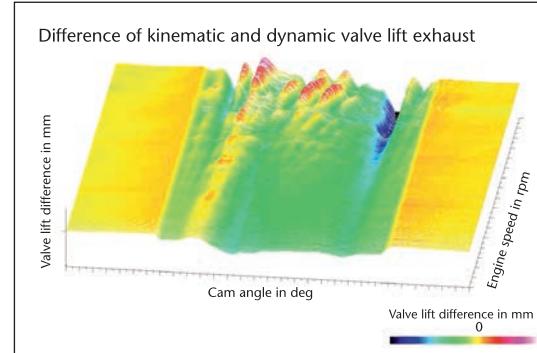


Fig. 4: Differences of kinematic and dynamic valve lift due to dynamic effects.

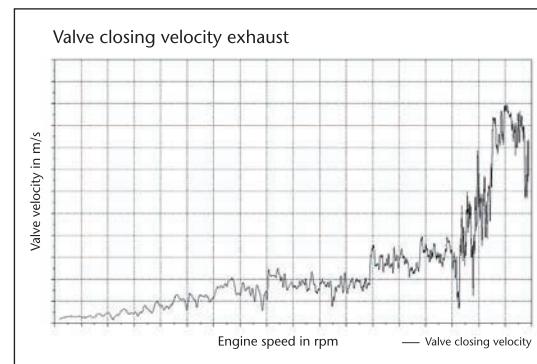


Fig. 5: Increasing valve closing velocity with rising engine speed.

Owing to increasingly complex valvetrains now being produced with ever shorter development periods, valvetrain analysis is gaining more and more significance. By using laser vibrometry at an early stage of development, Porsche Engineering is examining the valvetrain for kinematic properties, dynamics, and stress in the desired RPM range. The necessary valvetrain development modifications were targeted and evaluated on several projects through the use of laser vibrometry, and thus avoided costly and time-intensive development loops.



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