

Overview of Measurement Technology for Valve Lift and Rotation on Motored and Fired Engines

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ABSTRACT

In the last decades the operational requirements to control the gas exchange of an internal combustion engine increased immensely. The gas exchange is mainly controlled by the valve train system affecting the combustion behavior and power output of the engine. The necessary valve lift curve must be ensured within the whole operation range of the engine. Moreover, a minimum friction has to be achieved. On the one hand engine speeds and loads of the valve train components have increased and the weights of the components have decreased, on the other hand the demands regarding durability increased as well. The engine development department has tried to find out optimization potentials of valve train dynamics to get along with these challenges. During an engine development process analysis tools together with measurements of the dynamic valve train behavior on motored cylinder heads using Laser Doppler Vibrometry are applied. However, influences caused by the gas exchange process, thermal effects and additional issues of a complete engine under fired conditions are neglected with this approach. Therefore the differences between the ideal and real valve opening and closing together with real valve timing as well as detailed information about the gas exchange and the dynamic behavior of the valves need to be assessed. Taking care of these mentioned issues, dynamic valve train investigations on a fired engine using Magneto-Resistive (MR)-sensors have to be performed.

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INTRODUCTION

The target of this paper is to give an overview of various test set-ups used to investigate valve train systems. At first, the differences between dynamic valve train measurements on motored cylinder head mock-ups and fired engines will be explained. Then details about the test set-ups and the parameters will be described. Afterwards, the measurement technique for the valve lift and rotation measurements on fired engines using steel and titanium valves, respectively, will be introduced. To give a better understanding of the dynamic behavior of the valve train charts of valve lift, velocity, acceleration and rotation explain the dynamic behavior depending on the different boundary conditions.

VALVE TRAIN INVESTIGATIONS ON MOTORED TEST RIGS

The analysis of the dynamic behavior of the valve train on motored test rigs has taken a firm position in the development of valve train components [1], [2]. An engine mock up can be build up in an early phase of the engine development, and thus avoids cost and time-intensive development loops. In order to measure the valve lift and velocity, typically a Laser Doppler Vibrometer (LDV) is used. The function of the LDV is displayed in [Figure 1](#). Based on the measured valve lift and velocity, kinematic properties, dynamic effects, valve closing velocity and Hertzian stresses can be calculated. Additionally, analysis of the camshaft torsional vibrations can provide further information on operational behavior. Changes to the components such as different cam contours, spring stiffness, spring progression and valve train masses can be assessed, for example.

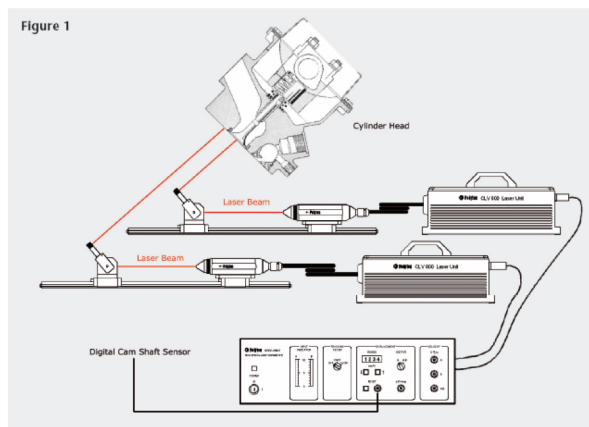


Figure 1. Valve lift measurement by Laser Doppler Vibrometer [3]

OVERVIEW

A motored test rig offers the possibility to reproduce the behavior of an engine under fired conditions only up to a certain level. Boundary conditions like oil pressure, temperature and the gas content of the oil can be adjusted to the specifications of the engine and will be monitored. Other parameters like the influence of the gas pressure are not considered. The comparability of the motored test rig is also affected by the availability of test parts and the geometry of the mock up. With regard to these aspects, motored test rigs can be separated in two kinds of set-ups:

- Single valve test benches to assure the functionality of a preliminary design.
- Common cylinder head test benches to carry out all tests which are necessary to release the new products.

SINGLE VALVE TEST BENCH

In the concept phase of the development a single valve test bench is used for the assessment of the function of single valve train components without having any serial part. Figure 2 displays the good agreement between experimental and calculated valve dynamics.

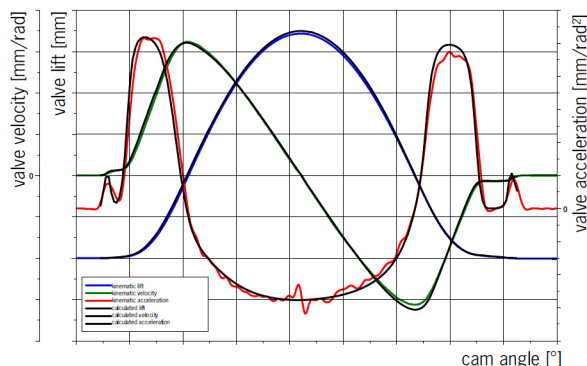


Figure 2. Calculated and measured valve dynamics

The assembly has to be done separately for every valve that has to be measured. The single valve mock up consists of several plates and adapters, which allows building up a valve train in a simplified way with high flexibility in the set-up. The main dimensions, for example valve angle, valve seat diameter and the position of the camshaft are taken over from the concept. If changes of main dimensions are to be made as a result of the tests, these can be done easily. All parts which have an influence on the functionality of the valve train can be tested in interaction with the other parts, what gives a better understanding than testing the parts individually. The high flexibility of this system gives the direct benefit in development time since a lot of tests can be performed in early stages of the development phase. Due to this, cost intensive tests on the engine test bench can be avoided. The CAD-drawing in Figure 3 shows the main components of this concept (camshaft, roller finger follower, valve spring and the hydraulic lash adjuster). The valve angle and the axis of the hydraulic lash adjusters can be adjusted in this mock-up.

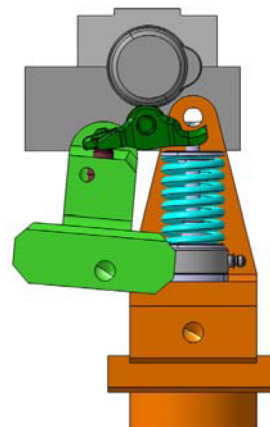


Figure 3. Main components of a single valve train mock up

The same mock-up is displayed in Figure 4 as a fully functional single valve train mock up. The mock-up is built with massive aluminium plates, similar to single cylinder research engines for combustion analysis.



Figure 4. Fully functional single valve train mock up

VALVE TRAIN INVESTIGATIONS ON FIRED ENGINES

Although the results of valve train tests on motored mock-ups are close to reality, it is necessary in some cases to measure the valve lift on a fired engine. This gives the opportunity to examine all parameters which can't be investigated on a mock-up such as the monitoring of the valve clearance for engines without hydraulic lash adjusters, for example.

The rotation of the valves is necessary during the operation with reciprocating piston engines to avoid problems like local overheating, oil carbon scaling on the valve seat, gas-leakage and possible heat-distortion.

In order to measure the valve lift as well as the valve rotation, Porsche Engineering uses Sensors based on the magneto resistive effect [4], which are applied to the valve guide. [Figure 6](#) gives an impression about the small dimensions of the sensor.

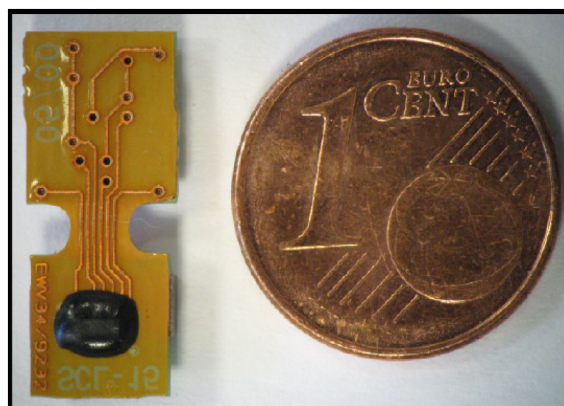


Figure 6. MR-Sensor

CYLINDER HEAD TEST BENCH

In contrast to a single valve train test bench, the cylinder head test bench has the function to demonstrate this system within the entire engine in order to get results which reflect the reality as good as possible. Therefore, the chain drive is applied fully with all intermediate gears, guides and tensioning rails including the chain tensioner. In this way, the valve train dynamics can be examined along with additional external influences and reactions such as polygon effects caused by the chain drive, damping influence of the hydraulic chain tensioner, and variable camshaft torque. A high-performance electric asynchronous motor drives the entire timing drive assembly and can be programmed in order to simulate real engine operation. To take measurements, the cylinder head is pressurized with oil just as in normal operation on a mock-up test bench. The oil temperature and oil aeration can be adjusted accordingly. These parameters are specified and monitored in an electronic database.

In combination with durability tests, the results of the cylinder head test bench allow the release of the valve train components for serial production. [Figure 5](#) shows a cylinder head test bench with fully equipped cylinder head mock up and LDV.

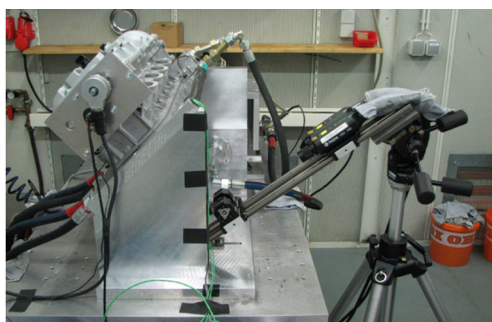


Figure 5. Motored cylinder head test bench

OVERVIEW

Magneto resistive sensors are ideal for position, speed and angle detection. The signal of the sensors is generated by an external magnet field with changing direction. This leads to a change of the sensor's electrical resistance. If the sensor is mounted between a permanent magnet and a tooth structure of ferromagnetic material, the movement of this tooth structure deflects the magnetic field. The signal period represents the movement of the tooth structure, and with a given tooth spacing, a linear relationship between the movement and the signal is set. The working-principle of the sensor is displayed in [Figure 7](#). The sensor itself is a standard-sensor, no changes have to be done in order to use it for the detecting of the valve lift. Further information about the working principle and technical details can be taken from the product-data-sheet [5]