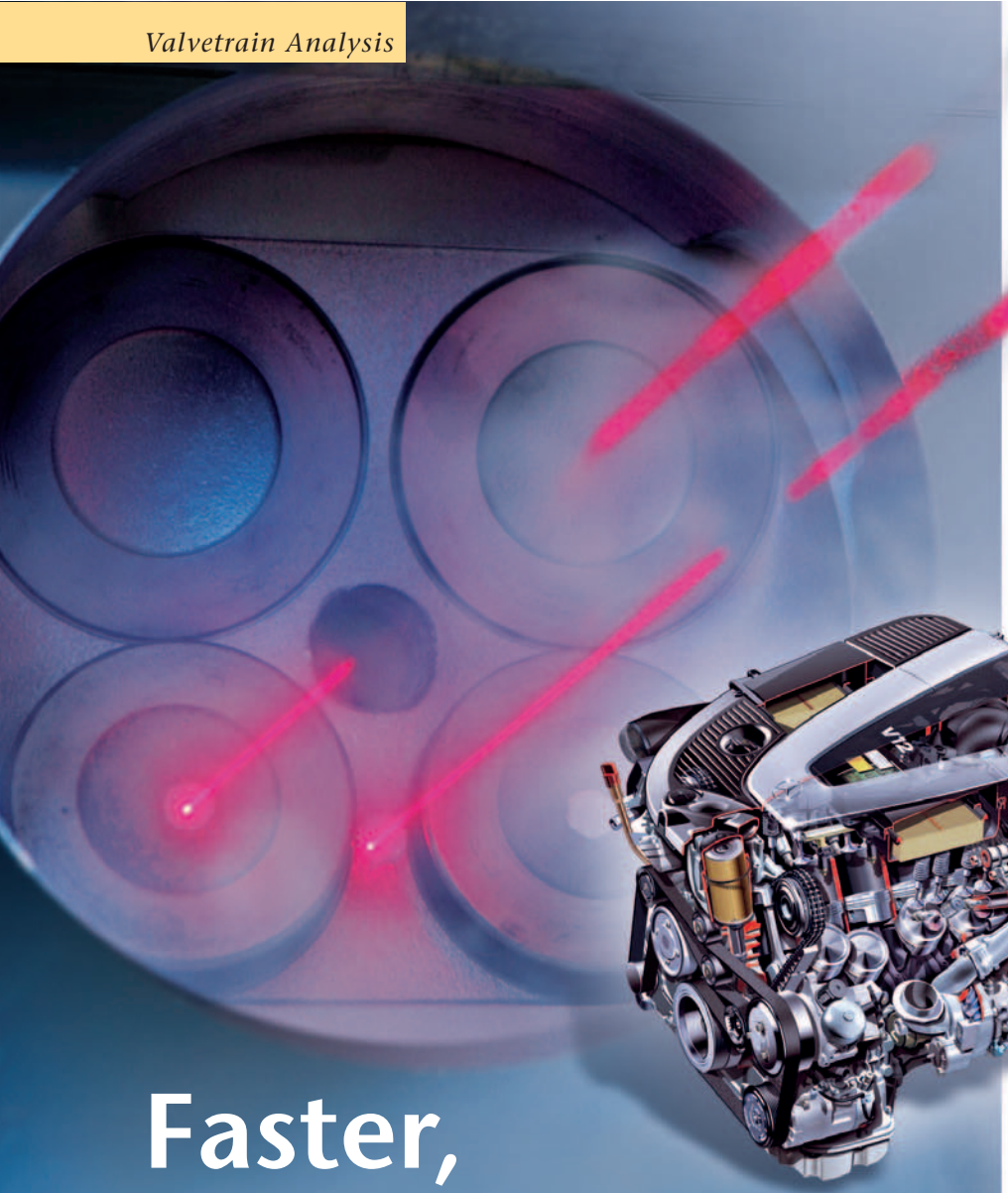


Faster, Higher, Stronger

Dynamic Valvetrain Analysis with Rotec's Rotational Analysis System and Polytec's High Speed Vibrometer

By combining Rotec's Rotation Analysis System and Polytec's High Speed Vibrometer, development engineers can measure and analyze dynamic and high-speed valvetrain motion, even on racing engines, ensuring that valvetrain components satisfy strength, durability and accuracy requirements.

Introduction

Modern valvetrain systems must provide both large cross sections for the gas exchange process and high-speed opening and closing of the valves. This combination results in high structural excitation and component stresses from the fast changes in valve velocity and acceleration combined with large lift values. Development programs must assure that valvetrain components satisfy strength and durability requirements and that they operate within tight specifications and tolerances.

With the increasing complexity of valvetrain systems, the requirement for comprehensive valvetrain testing can be addressed through application-specific test and analysis protocols in customized valvetrain motion software. In response to this need, Rotec GmbH has developed a PC-based Rotation Analysis System (RAS) to perform signal acquisition and noise and vibration analysis on engines and transmissions. A large number of these systems are used worldwide by automotive testing and development departments.

Measurement Setup

In Figure 1, a typical measurement setup for valvetrain testing is shown. Camshaft speed and angle are measured by either fitting an incremental encoder to the shaft or by scanning a toothed wheel with a magnetic pickup. On both fired engines and non-fired test benches the valve lift is generally measured with inductive or capacitive displacement sensors.

Polytec's High-Speed Vibrometer (HSV) system is an excellent sensor to measure valve velocity on motored test benches. The advantages of the HSV include non-contact, high-resolution measurement up to 30 m/s and linear output signals. Valve velocity is measured at frequencies up to 50 kHz and valve lift can be

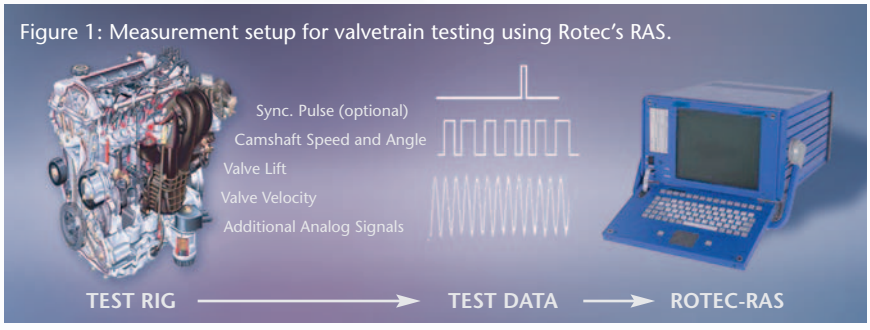


Figure 1: Measurement setup for valvetrain testing using Rotec's RAS.

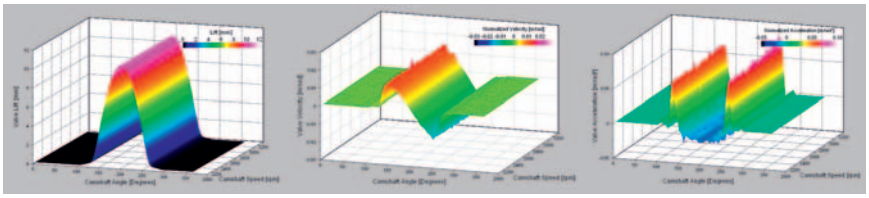


Figure 2: a) Valve lift versus cam angle and speed; b) Valve velocity versus cam angle and speed; c) Valve acceleration versus cam angle and speed.

measured up to 250 kHz. Differential measurement compensates for unwanted vibration and movement (see information box).

By combining both the RAS and HSV systems, engineers can make demanding dynamic measurement and analysis of valvetrain motion, even on high performance racing engine test rigs. Synchronous to the camshaft speed and valve lift and velocity signals, additional test data such as valve spring loads can be acquired.

The RAS rotational speed channels require square-wave TTL level signals as input. The time interval between rising (or falling) edges for each pulse period is recorded using a 10 GHz/ 40-bit high-speed counter/timer. The RAS analog channels sample at 400 kHz with 16-bit resolution. In valvetrain testing, the speed signal is used for transforming the time equidistant sampling of the lift and velocity signals into angle equidistant data. Consequently, a toothed wheel and proximity probe (instead of rotary encoders) may be used for measuring camshaft speed and angle. Signals from gear wheels with missing teeth may also be processed, a significant advantage of the RAS software.

Exemplary Results

The RAS valvetrain software offers a variety of options for analyzing valve motion versus speed and angle. In Fig. 2, a speed run-up measurement is plotted in 3-D. The valve lift signal which determines the valve lift versus cam angle and speed is measured by the Polytec HSV and shown in Fig. 2a. The valve velocity (Fig. 2b) is also measured by the HSV. However, since the camshaft speed changes over the course of the measurement, it is more meaningful to represent valve speed in m/rad instead of m/s. This option is integrated into the RAS software. The normalized valve acceleration in m/rad² is shown in Fig. 2c. This is the 1st derivative of the measured valve velocity (HSV) sampled by the RAS. The software allows for low-pass filtering before differentiating.

There are several methods of calculating valve closing velocities and closing angles. In general, a threshold value of lift during the closing sequence is specified. Then, beginning at maximum lift and looking along the cam angle, the closing velocity and angle are found when the valve lift falls below the threshold lift. Alternatively, having located a specified lift threshold and looking along the cam angle, the first local maximum of valve acceleration is found. The valve closing velocity and cam angle are then determined at this position (Fig. 3).

The contour plot (Fig. 4) shows valve velocity versus cam speed in the closing angular range where valve bouncing is apparent. The valve seats at approx. 288 degrees cam angle. The alternating red and green colors show the valve impacting the seat before finally coming to rest.

Figure 3: Valve closing velocity (green) and closing angle (blue) versus cam speed.

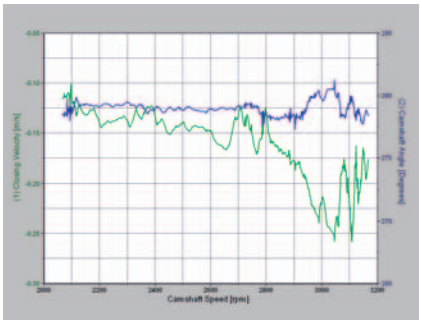
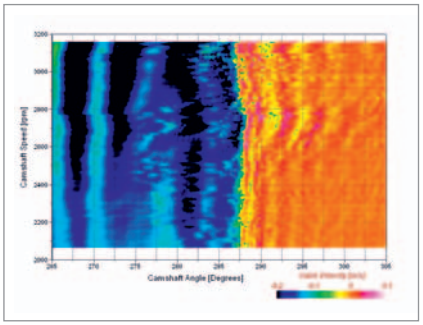


Figure 4: Valve bounce while impacting the seat.



Conclusion and Outlook

The RAS valvetrain software offers many other capabilities such as comparing measured 3-D plots with theoretical curves or determining lift loss normalized to angle during the opening and closing phases. Valve open and close duration is also of interest. Valvetrain material and geometrical parameters may be used to investigate cam and tappet component strains (Hertzian stress). In conclusion, the use of high-resolution measuring equipment and application-specific analysis software help satisfy the demands for meaningful results and shorter development cycles.

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Polytec Product Information

HSV High-Speed Vibrometer

The HSV copes with high vibration speeds up to 30 m/s and provides single or differential velocity and displacement measurement capabilities for high-speed applications like valve train testing on performance engines, power tools and impact testing.

www.polytec.com/highspeed