High-Revving Motorcycle Engines

Acquisition of Irregular Rotational Speed Patterns in a Four Cylinder Sports Motorcycle Engine

Because of a combustion engine's discrete firing process, irregular rotational speed patterns of the crankshaft occur. These excite components of the driveshaft, causing rotational vibrations which in turn can cause undesired noises and vibrations. On typical motorcycles, the engine and driveshaft are not acoustically encased. Consequently, analysis to reduce undesired noises and vibrations is given high priority. Acquiring the rotational vibrations induced on motorcycles can be done directly on the vehicle when placed on a roller dynamometer. For the special case of high-revving motorcycle engines (>10,000 cycles/min), it is best to use Polytec's RLV-5500 Rotational Laser Vibrometer.

Introduction

The design goal of modern, high performance motorcycle engines is to optimize efficiency and lightweight construction. At the same time, there is the customer's desire for smooth power delivery and comfortable characteristics from the driveshaft. This means a drive that is free of resonances and does not jerk. In addition, the stress caused by irregular rotational speed patterns, hard load and gear changes, and misuse requires precise calibration of the individual components in the vibrating driveshaft. Using dynamic simulation, the spring and damping elements of the driveshaft (Fig. 1) are designed to suit the type of vehicle – from giving a sporty to giving a comfortable ride. As however, there are lots of things that influence the drive of a motorcycle, it is vital to analyze and test the whole driveshaft in detail. This is done by making measurements and correlating to real test drives which are especially important for determining subjectively perceptible and annoying vibrations and knocks. The vibration behavior of the total driveshaft can be examined in detail with the aid of special rotational vibration measuring setups.

Experimental Setup

The analysis of the vehicle's drive vibrations on an acoustic roller dynamometer has many advantages, apart from the rotational vibrations, the acoustic radiation can be examined at the same time. The vehicle setup on the dynamometer reflects real conditions extremely well, and offers the advantage of reproducible driving conditions for the various loads and RPM ranges in an ideal way.

Specially manufactured measurement adapters which are resistant to rotation and are fixed on to the respective end of the crank and gear shaft, leading out of the crank housing, form the measurement objects that can be acquired by the Rotational Laser Vibrometer (Fig. 2). For this purpose, the vibrometer is set up at an appropriate distance (the operating range of the RLV-5500 is approx. 200 mm) and is aligned so that both of the laser beams emitted hit the measuring shaft at right angles and are set to be in line with the direction of rotation (Fig. 3 and 4). Applying a diffusely reflecting self-adhesive film improves the measurement signal-to-noise and thus reduces any fluctuations in the signal. The measurement principle of laser vibrometry is based on the Doppler effect. This measurement methodology is very effective and works without making contact and is thus non-reactive (zero mass loading), allowing it to be used independently of the material properties and temperature. With the recently released RLV-5500 Rotation Laser Vibrometer, it is easy to make high resolution rotational measurements on high-revving motorcycle engines with a maximum RPM of well over 10,000/min.

Results

Measurements made on initial prototypes generally showed excellent correlation with simulation results. However, within the framework of comprehensive analyses and test drives, there were special driving conditions which under certain circumstances were perceived by drivers as uncomfortable vibrations in the vehicle. Such effects are often missed during construction and simulation and can only be detected and classified by selective examination of the rotational vibration in the driveshaft (Fig. 5 to 7). Using carefully calibrated variations of the spring package for the clutch torsional vibration damper, optimizing the rubber packages of the rear wheel jerk damper and taking measures to limit the play in the driveshaft, it was possible to selectively influence and remedy these resonance vibrations.

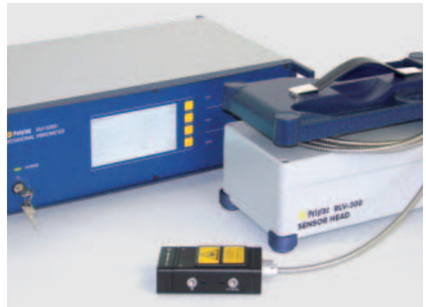

Fig. 2: RLV-5500 Rotational Vibrometer.

Conclusions and Outlook

The comfort requirements made of modern motorcycles and their power drives are continuing to increase. This leads to additional technical challenges to make sure that the driveshaft of future motorcycles is sporty and dynamic, yet comfortable. For this purpose, the described measurement methods to acquire rotational vibrations are very important and form a comprehensive process for gaining a better understanding of complex vibration systems and to reach the design goals.

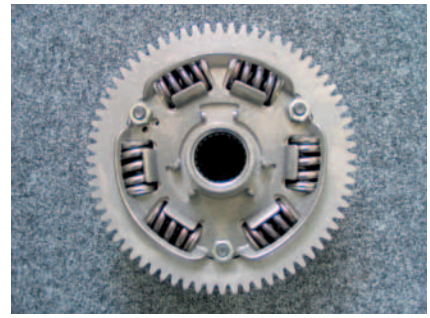

Fig. 8: Spring package for the clutch torsional vibration damper.

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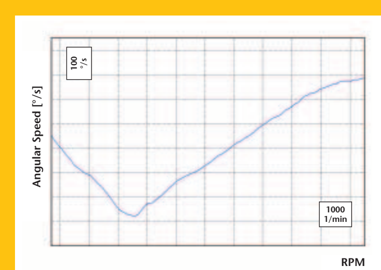

Fig. 5: First irregular rotational speed pattern vs. RPM.

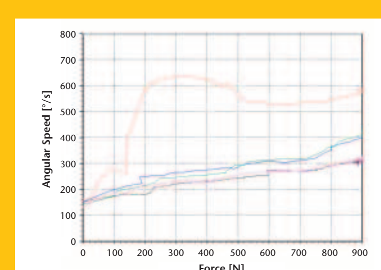

Fig. 6: First irregular rotational speed pattern vs. load.

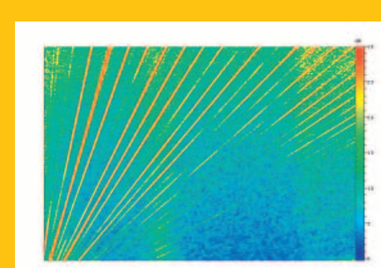

Fig. 7: Campbell diagram of a run-up measurement.

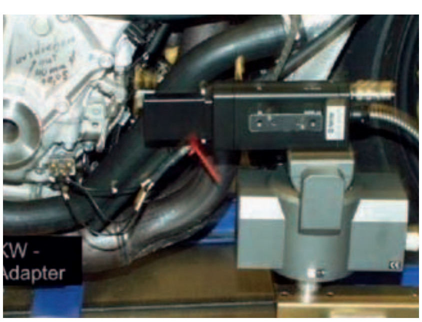

Fig 3: Measurement of torsional vibrations on the crank shaft using the RLV-5500.

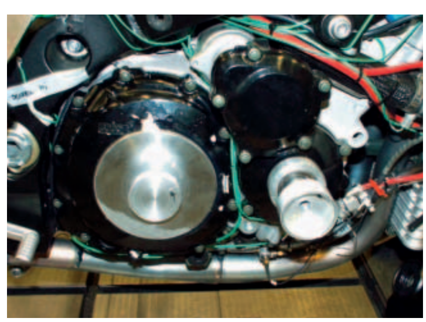

Fig. 4: Measurement points at the crank shaft and at the gear shaft.

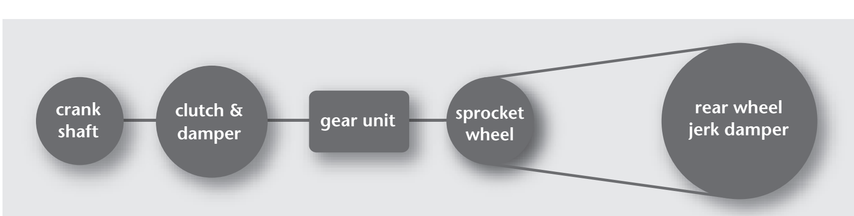

Fig. 1: Schematic of a motorbike's driveshaft.