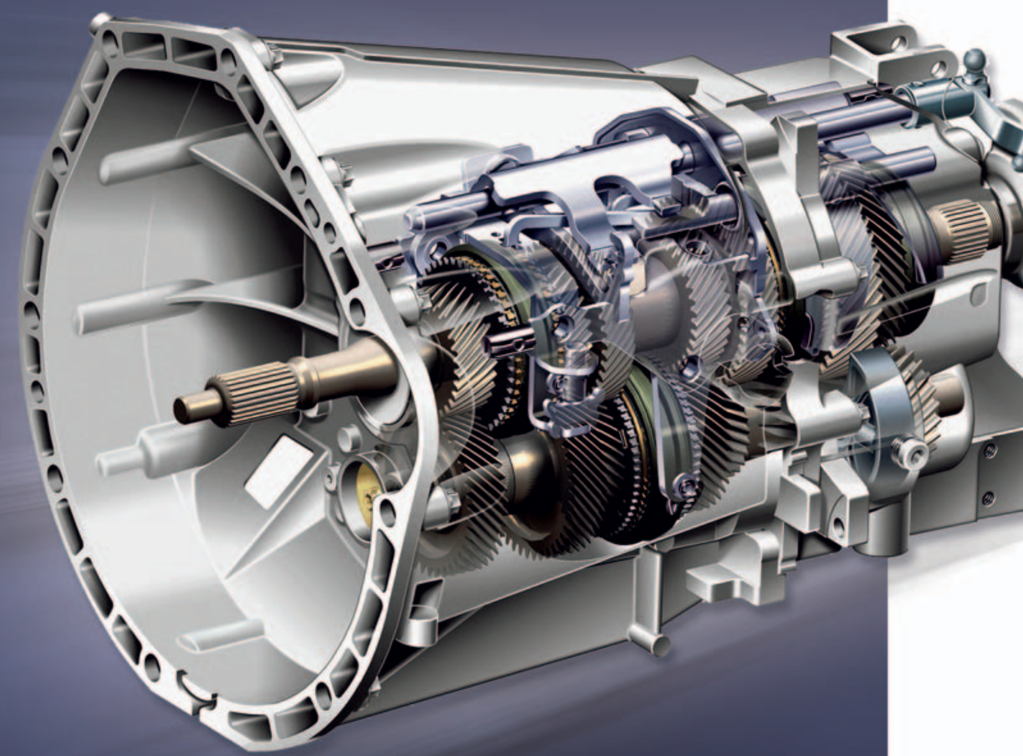

Drive Trains Under Test

Rotational Vibrometers Help Determine the Transmission Behavior of a Dual Mass Flywheel

Vehicle drive trains equipped with a combustion engine experience torsional oscillations caused by the crankshaft. Considerable amplitudes can occur at various positions of the crankshaft affecting the mechanical stability and acoustic properties of the drive trains. To provide a design that avoids or minimizes such phenomena, engineers need knowledge of the dynamic properties of the drive train components. Using Polytec Rotational Vibrometers, a dual mass flywheel can be characterized, demonstrating how the dynamic transmission behavior can be determined on a test rig for drive elements installed at the University of Kaiserslautern.

High-dynamic Test Rig for Drive Elements

A sophisticated dynamic test rig for drive elements (Figure 1) is available at the Institute for Machine Elements, Gears, and Transmissions at the University of Kaiserslautern. This system allows the vibrational testing of drive trains and their components under the special influence of torsional excitations and the derivation of the dynamic transmission behavior at various loads, rotational speeds, excitation frequencies and amplitudes.

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The test rig uses a twisting motion produced by a high-dynamic electric machine that drives a braking motor via the test item. The braking motor is operated as a generator so that a torsional momentum is generated that loads the drive element under test. The driving torque can be superimposed on a well-defined oscillation momentum at an excitation frequency $f_{exc} > 450$ Hz. With a high-resolution measurement of both torsion angle and torque momentum, the dynamic response behavior can be determined.

Measurement of Torsional Vibration Using Rotational Vibrometers

For the measurement of the torsional vibration, two rotational laser vibro-

Figure 1: Dynamic test rig for drive elements.

meters are used. The measurement procedure is highly precise, robust and mobile. The setup allows the measurement of drive speed n, dynamic fraction of the rotational speed $\Delta\omega$, and dynamic oscillation speed $\Delta\varphi$ without contact during operation. A detailed description of the operating principle of the Rotational Vibrometer can be found at **www.polytec.com/rotvib**.

Example: Dual Mass Flywheel

In every combustion engine, a fly wheel is used as energy storage to keep the piston motion running even when there is no work cycle. At the same time, it smooths out the torsional excitation of the crankshaft and avoids vibrations. In the majority of cases, this is accomplished solely with flywheel mass. An alternative method is to use a dual mass flywheel (DMF). In the DMF, the flywheel mass is split into two masses that are torsional linked by elastic springs. By varying the ratio between inertias and spring stiffness, a desirable low Eigenfrequency can be found. The DMF acts as a mechanical low-pass filter at the transition to the drive train.

In the title image, the test setup for determining the dynamic transmission behavior under various conditions is shown. The DMF is driven from the left side by a motor at stationary speed while superimposing a torsional oscillation. On the right side, it is loaded by the generator with a constant torque momentum. Between specimen and electric machines, the momentum is measured by the torque sensors

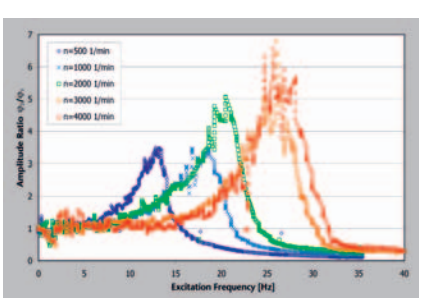

Figure 2: Rotational vibrometers and dual mass flywheel on the test rig.

and the dynamic oscillation angle is measured by the two rotational laser vibrometers.

The experimentally acquired response behavior of the dual mass flywheel at various revolution speeds during a frequency sweep between 0 Hz and 40 Hz is shown in Fig. 2. The excitation was done with a constant angle amplitude. A speed of 500 rpm corresponds to an Eigenfrequency of 13 Hz at a maximal amplitude ratio of $\varphi_2/\varphi_1 = 3.5$.
The Eigenfrequency moves to higher frequencies with higher speeds.
The amplitude amplification also grows with higher speeds.

Assuming that the modal masses are constant, the increase of the Eigenfrequency is due to a stiffening of the existing springs. The reason for the change in stiffness is supposed within the radial deformation of the spring. Apparently, this deformation presses the spring to an external contact surface so that friction is induced at the contact points, decreasing the effective number of springing turns and increasing the stiffness. The increasing amplitude at higher speeds shown in Figure 4 is caused by a decrease in system damping, a fact that could be confirmed by further investigations.

Conclusions and Prospects

The potential to investigate torsional vibrations with the institute's drive element test rig in combination with rotational laser vibrometry is exciting. Because of the flexibility of the test facility and data acquisition equipment, it is possible to gauge other drive train components such as torsionally stiff and flexible couplings, cardan shafts, and vibration dampers and absorbers. It is also possible to perform acoustic investigations of gearboxes (e.g. rattle behavior) and to acquire knowledge about the dynamic stiffness and frequency attenuation of gears. The equipment is mobile so that measurements can also be made on-site with customers' test rigs and running engines.

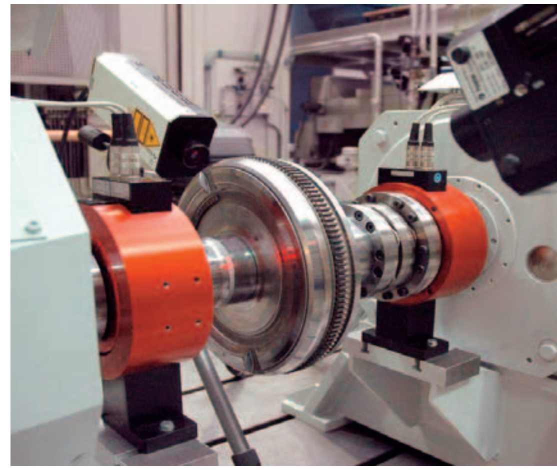

Figure 2: Dual mass flywheel on the test rig.