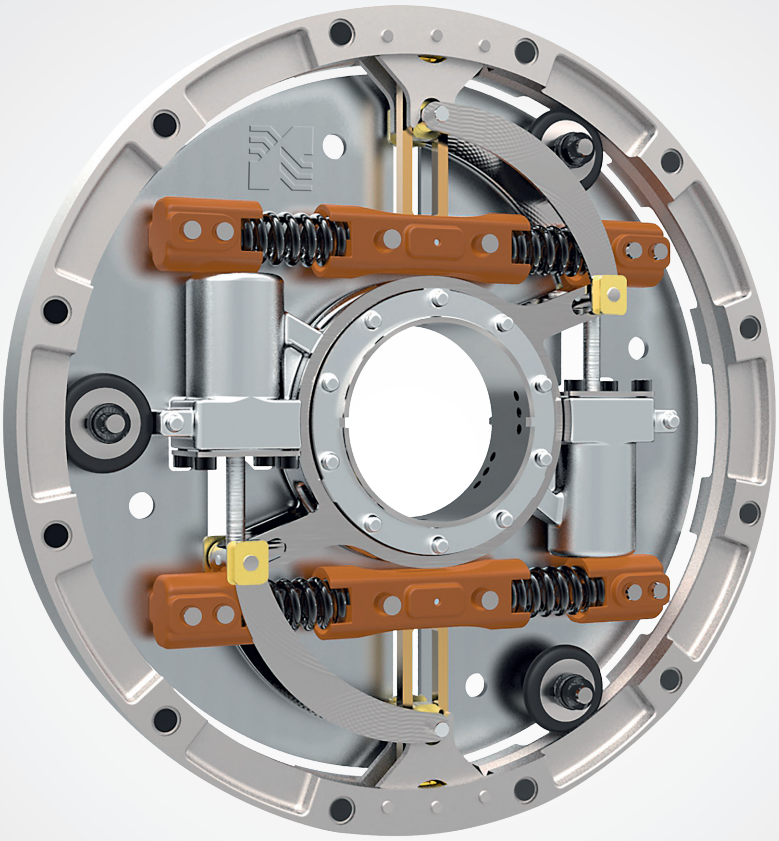

Combustion Hybrid

Keeping it smooth: BorgWarner's variable spring absorber

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By efficiently absorbing different levels of torsional vibration during operation, BorgWarner's innovative vibration damping system allows extreme downspeeding and cylinder deactivation as well as an unparalleled degree of downsizing. The system enhances driver comfort and fuel efficiency while also reducing emissions by providing the precise amount of absorption needed, regardless of cylinder count or engine speed.

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Preface

Modern vehicle powertrains feature highly complex designs designed to follow the trends of downspeeding and downsizing alongside a reduced number of cylinders as well as a high degree of turbocharging. These measures present a substantial challenge for the abilities of current torsional vibration damping systems. In addition, they contribute to reducing emissions and enhancing the engines' fuel efficiency. Yet more complexity is added by introducing cylinder deactivation, as the damping systems now need to cope with shifting levels of torque fluctuation - and thus torsional vibration - in one and the same drivetrain. To approach tasks of this kind and support automakers in the construction of fuel-efficient, clean and powerful cars in the future, BorgWarner is working on a state-of-the-art active torsional vibration absorber solution. The system's extraordinary damping performance was proven by component tests and driveline simulations. Featuring a variable torsional stiffness that can be changed actively to provide maximum isolation, the technology further reduces damper noises caused by engine cranking. The latter is considered as a principal advantage for engines with stop-start systems.

Enhancement of comfort and efficiency

Located in between the transmission and the engine, dual mass flywheels have achieved their damping limits for modern engines with reduced cylinder counts and high specific torques. These engines offer adequate torque for nearly all driving conditions, even at low rotational speeds. Nonetheless, high torsional vibrations are brought about in the drivetrain by driving in higher gears at high torques and low engine speeds. Using a spring-mass or pendulum absorber system in addition to the dual mass flywheel, which uses torque fluctuations to generate an opposing torque, provides an effective solution to minimizing said vibrations. The resonance frequency of the absorber system is engineered to match the torque fluctuation frequency. As the absorber vibrates in opposite phase to the engine torque fluctuations, it efficiently reduces torsional vibrations in the drivetrain, shown in Figure 1.

Innovative set-up

Installed on the secondary side of the dual mass flywheel in front of the transmission input shaft, BorgWarner's variable spring absorber consists of an absorber inertia ring. A tilt lever connects

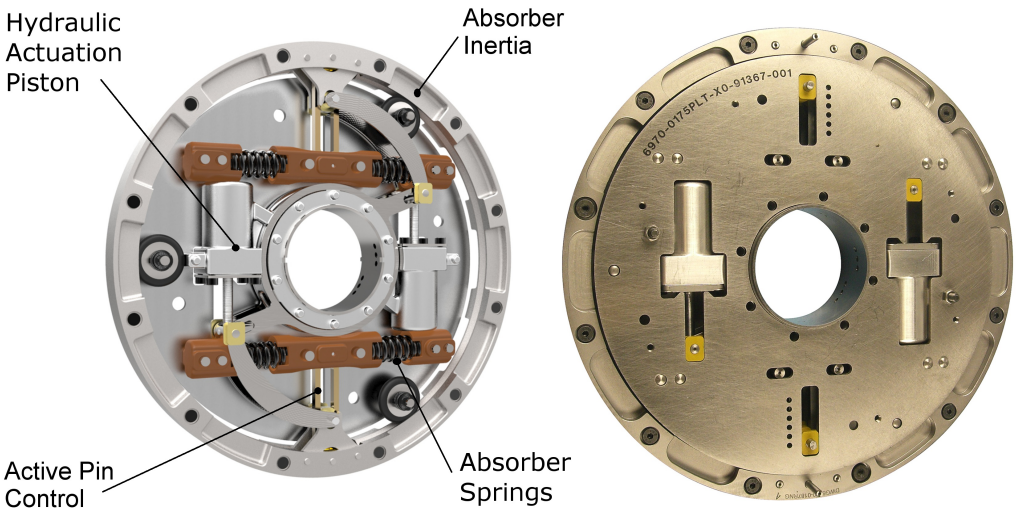

Figure 1. BorgWarner's latest innovation for automatic transmissions: the variable spring absorber.

this ring to coil springs on the secondary side of the dual mass flywheel. The actuation system enclosed within the ring, see Figure 2, operates with hydraulic oil pressure. Also, the inertia ring and the springs form a rotational spring-mass system. To alter the resonance frequency of the spring-mass system, the variable fulcrum of the tilt lever can be repositioned to change the effective spring stiffness acting on the absorber ring. The absorber system frequency is set to match the torsional vibrational frequency of the powertrain during ongoing operation, allowing the absorber to vibrate in opposite phase and cancel out vibrations on the secondary side.

A high amount of vibrational energy can be stored in a small space with no major influence of temperature and rotational speed by using mechanical coil springs. The absorber is equally effective at low as well as high engine speeds. In addition, the same absorber can be utilized for different applications with various cylinder counts and for engines with cylinder deactivation, as active changes can be made to the absorber frequency independently of the engine speed.

Absorber systems are susceptible to "clonking" noises occurring during stop-start manoeuvers. This is due to the fact that the absorber masses hit their end positions when subjected to high torque peaks. To prevent unnecessary noise generation, BorgWarner's variable spring absorber system stays blocked mechanically for as long as the engine speed is below idle. The absorber system unblocks once the engine starts and idles or runs at higher speeds and the correct absorber frequency is set.

Fuel-saving potential

Allowing automakers to develop fuel-efficient vehicles while simultaneously maintaining or even

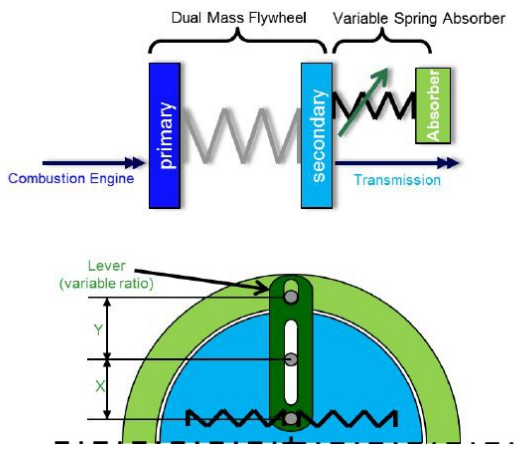

Figure 2. The variable spring absorber's vibration frequency can be modified on the fly and is located behind the dual mass flywheel.

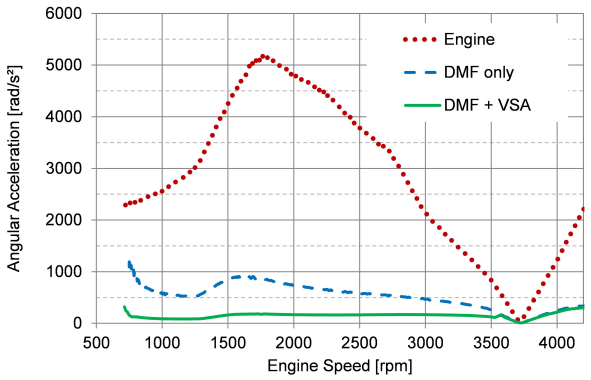

Figure 3. BorgWarner's variable spring absorber significantly lowers torsional vibration when combined with a dual mass flywheel.

enhancing comfort as well as driving performance is the main reason for developing a new torsional vibration damping system. BorgWarner's variable spring absorber supports this in multiple ways. For example, the absorber's adaptability to various resonance frequencies allows cylinder deactivation. In addition, BorgWarner's innovative solution assists in reducing the lowest engine speed at which cylinder deactivation is viable by improving the vibration isolation for numerous cylinder counts on the fly. Depending on the deactivation strategy as well as the drive cycle, fuel savings of 3 to 7 percent can be achieved. Apart from that, the variable spring absorber facilitates extreme downspeeding, which is currently limited by comfort requirements. These high degrees of downspeeding potentially improve fuel economy by up to 3 percent while allowing the use of 2- and 3-cylinder engines with an acceptable torsional vibration performance. This would facilitate their use in premium vehicles, as 4 cylinders are the lower limit there at present.

Performance assessment

To assess the system's isolation performance, BorgWarner conducted simulations for drivetrains equipped with the variable spring absorber. A 4-cylinder turbocharged diesel engine was selected for these tests, as turbocharged diesel engines are more susceptible to torsional vibrations. It was evaluated under full-load conditions in a high gear and equipped with the variable spring absorber as well as a suitable dual mass flywheel. The test results confirmed the technology's enormous potential to allow much slower engine operating speeds than are possible today. Delivering maximum torsional amplitudes of 180 rad/s^2 for engine speeds between 800 rpm and 3,500 rpm, the system supports significant reductions in CO_2 emissions and fuel consumption.

These extraordinary findings were reinforced and verified by multiple tests performed on a torsional vibration test bench. When torsional vibration was introduced into a 4-cylinder engine's drivetrain with the absorber system active, but in blocked mode, a vibration reduction of around 75 to 80 percent was observed behind the damper, shown in Figure 3. A total isolation performance of over 95 percent can be attained by having the dual mass flywheel and the innovative variable spring absorber work in tandem.

The bottom line

With the variable spring absorber, BorgWarner presents an innovative technology for reducing torsional vibrations in combustion powertrains of the future. The system's potential to facilitate extreme downspeeding and cylinder deactivation has been shown by various thorough tests and simulations. To widen the development approach, BorgWarner will examine the advantages of this innovative solution's integration into electrified powertrains such as those used in hybrid vehicles and pure electric applications equipped with range extenders.

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