VARIABLE DAMPING SYSTEM FOR INCREASED RIDE COMFORT AND AGILITY

The new, integrated variable damping system from ThyssenKrupp extends the variable damper portfolio with an infinitely variable, fast switching, pilot-controlled pressure relief valve. The wide damping force range in the rebound and compression stage as well as the high adjustment dynamics resolve the conflicting aims of ride comfort, driving safety and agility even better. A pilot valve actuated with a magnet precisely controls the pressure for the two independent main valves for the rebound and compression stage. This approach also enables a wide range between the soft and hard characteristic in the compression stage.

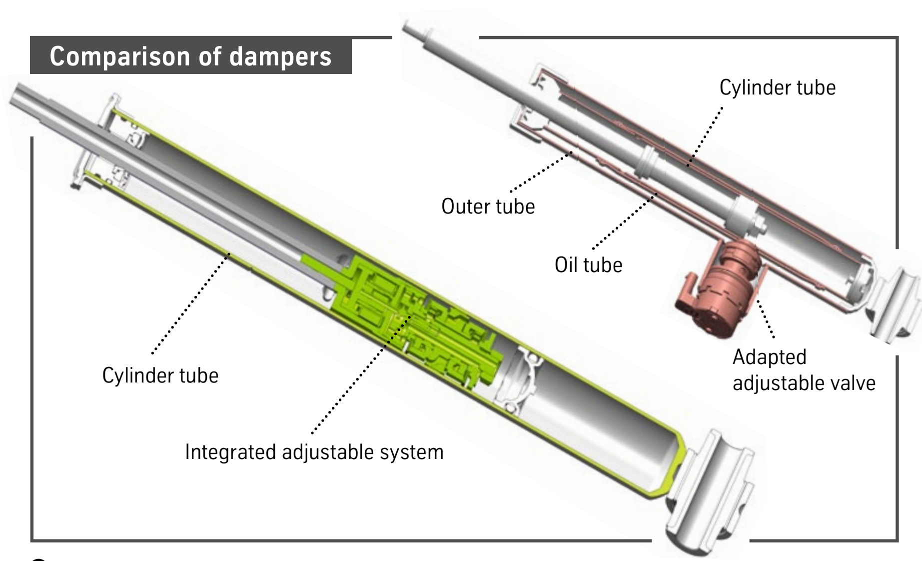
Variable damping systems are now available in compact class vehicles and offer drivers better ride comfort with increased agility and driving safety at the same time. To achieve this, the chassis control system's control unit can individually adapt the damping forces for each wheel in a few milliseconds using data from the acceleration and travel sensors, etc. A corresponding control strategy keeps disturbing road excitations away from passengers as far as possible and simultaneously actuates the dampers so that body movements are stabilized as well as possible. To optimally meet the different requirements of various vehicles and OEMs, both piston-integrated control valves (valve is located at the end of the piston rod within the damper) and control valves mounted on the outer damping tube are used, ❶.

PILOT-CONTROLLED PRESSURE RELIEF VALVE

In InCar plus, ThyssenKrupp has developed a new, infinitely adjustable damping valve. A control valve integrated into the piston offers significant potential for reducing the weight of the damper in comparison with the outer tube solution. Firstly, the oil guide tube required to channel from the damper's working chambers to the external valve is omitted; secondly, the inner tube of a twin-tube damper is no longer required if the valve in the mono-tube damper is used. Both ensure a weight reduction of up to 600 g as against comparable dampers.

With its compact dimensions, the proportional control valve is suitable for use in tubes as of an inner diameter of 36 mm. This enables integration into a variety of McPherson struts. A variant with a diameter of 40 mm is available for a higher damping force level, which is often required for unfavorably linked dampers. Due to the control valves' modular principle, both variants only have a few different parts. Thanks to high functional integration, the length of the valve is less than 100 mm, as a result of which it can be used in numerous axle concepts.

Before defining the control principle, ThyssenKrupp discussed the specific



❶ Comparison of a piston-integrated control valve (left) with a control valve mounted on the outer tube (right) weighting of individual functional characteristics with the OEMs in workshops. The map design, switching time and controllability requirements which were determined led to the development of a pilot-controlled pressure relief valve. This control principle preferably enables the generation of a damping force map in which the damping force is independent of the damper speed due to very flat pressure limiting gradients over wide ranges, ❷.

This behavior is reflected in extensively linear damping force-current behavior and significantly facilitates regulation of the proportional control system. One other important requirement which the new valve meets is the wide pressure stage force spread. As the pilot control principle is also applied in the pressure stage, low damping forces are possible in the soft characteristic and high damping forces in the hard characteristic.

PILOT STAGE CONTROLS MAIN STAGES

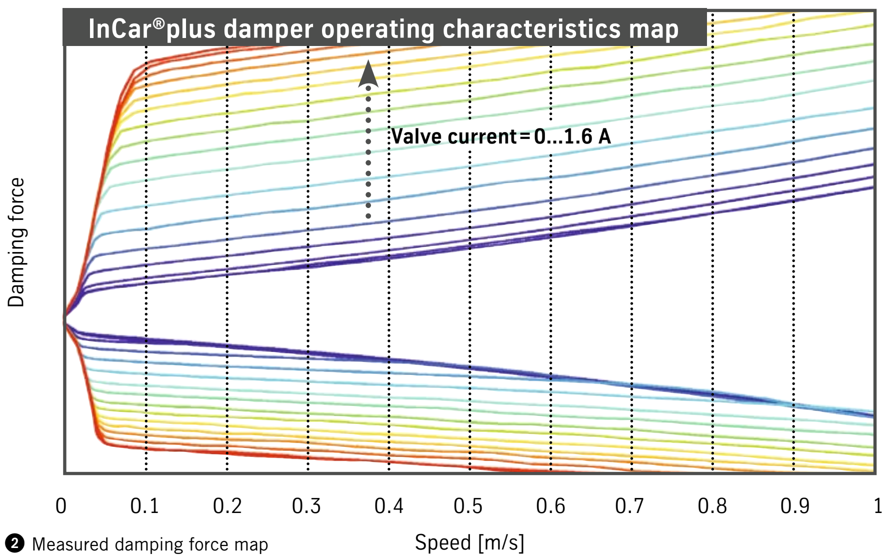
Depending on electrical current, the magnetic force-actuated pilot stage controls the pressure for the main stages, ❸. Several challenges have to be resolved on use of this valve principle in the damper. In the vehicle, the damper moves in both the rebound and compression direction. This means that the damper oil flows through the valve integrated into the piston on alternate sides. As a common pilot stage is available for both directions but is only effective on one side, the volumetric flow has to be rectified. This is undertaken by check valves in the form of spring loaded or clamped shim valves. With their low masses and large pressurized surfaces, both designs offer the required high switching dynamics. As there is no external pressure supply and the pilot stage is supplied with pressure generated by the damper itself, this function must also be guaranteed at lower pressure. This is the case during operation in the soft characteristic or at low excitation speed.

To minimize the system's energy consumption, the proportional magnet is designed such that it exercises no force on the pilot stage in currentless condition. The damper is therefore in the soft characteristic. During vehicle operation, the damper is primarily operated in the low damping force range and thus at low current, e.g. during smooth travel over a relatively level road surface. Low damping forces then ensure good superstructure insulation against road surface excitation. High damping forces, e.g. to stabilize the superstructure during dynamic driving maneuvers, are only set temporarily. At maximum damping force, a valve current of 1.6 A flows, leading to maximum power output loss of 13 W. An electrical power output loss of approximately 2 W per damper arises depending on road surface condition and the vehicle dynamics requirements.

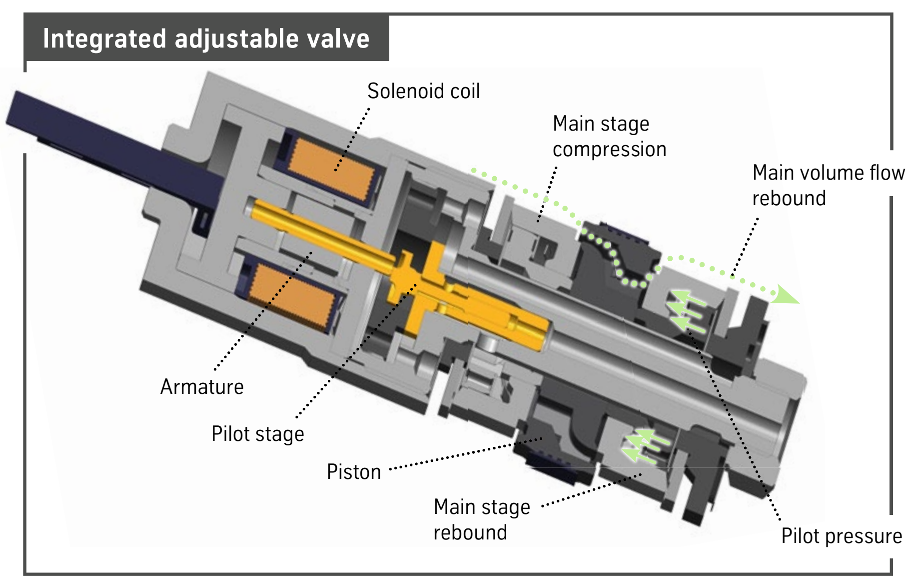
An optional failsafe function can be implemented in the control valve; in the event of an electrical fault, it sets a firmly defined mean damping force characteristic. In currentless condition, which, for example, could arise due to a line defect, an additional, passive pressure relief valve regulates the pilot stage pressure for the rebound and compression stage.

REBOUND AND COMPRESSION STAGE EXTENSIVELY INDEPENDENT

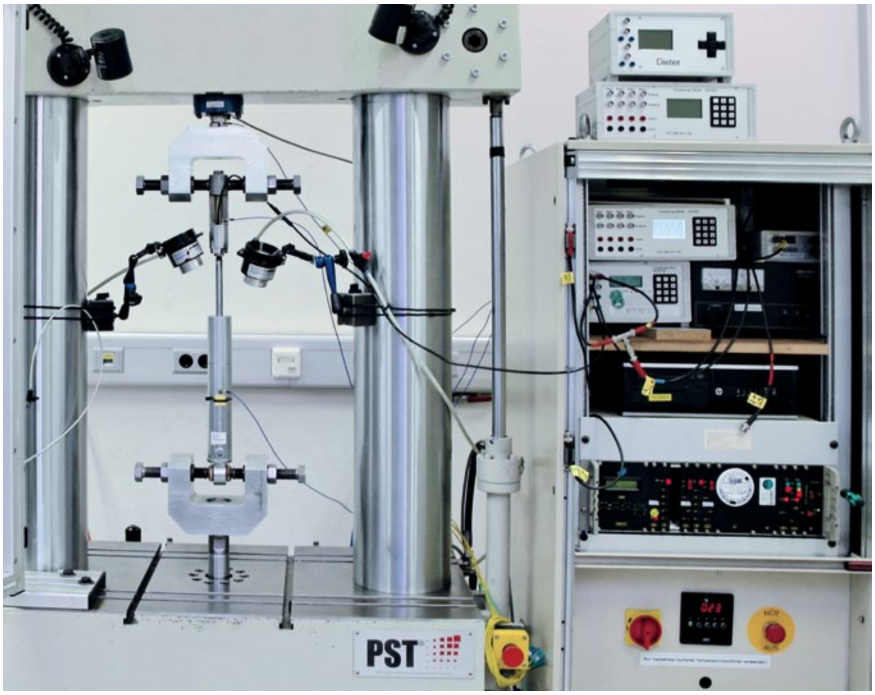
The main stages are defined as pressure chambers, which the pressure regulated by the pilot valve reaches via channels. Via the precisely dimensioned, pressurized surfaces, the pressure leads to



❷ Measured damping force map



❸ Cross-section through the valve



❹ Function and lifetime testing

defined pre-tensioning of the main stage pistons on the valve seats. The main valves remain closed until the damping pressure on the opening surfaces exceeds the pre-tension. Only then do the main valves for the rebound and compression stage assume their pressure control function.

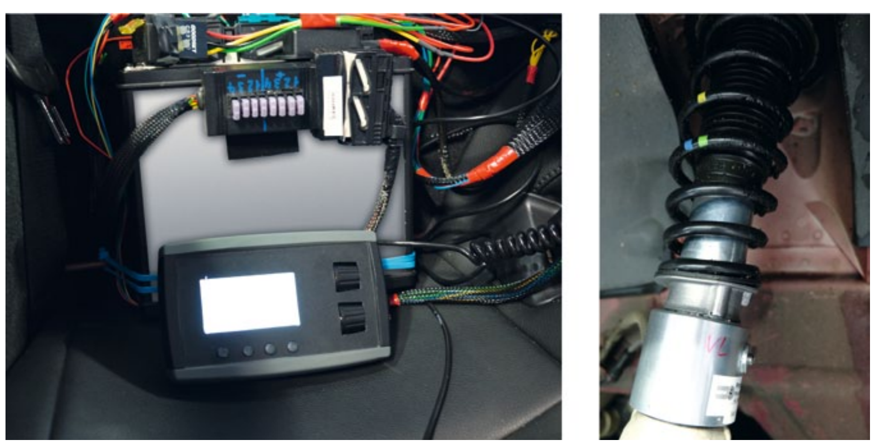
The valve's stable function is based on corresponding coordination of surface ratios, inflow and outflow resistances and further important valve characteristics. Special requirements arise for the valve's soft characteristic. To achieve good disturbing force insulation from the body, the damping forces should be as low as possible. A variable soft characteristic is required to enable a response to specific events such as wheel imbalance even without controller intervention. Large flow cross-sections and sufficient main stage lift travel ensure the soft damping characteristic potential. The characteristic is set using an adjustable disc spring package and is therefore based on the tried-and-tested setup of conventional dampers.

Hydraulically, the piston-integrated control valve design offers the advantage that the rebound and compression stage can be designed very independently. This is a major advantage, particularly in the case of the soft characteristic, in comparison with twin-tube dampers which operate according to the uni-flow or re-pumper principle with an adapted valve.

The innovative InCar plus piston-integrated control valve is predestined for use in mono-tube dampers. It offers the option of adapting the ratio of maximum rebound to maximum compression stage force to the vehicle setup over wide ranges. However, these characteristics also enable high setup flexibility under hydraulically restrictive boundary conditions in twin-tube dampers and McPherson struts.

In addition to extensive testing on the test rig, ❹, the valve is already undergoing successful testing in various concept vehicles, ❺. Valve actuation is also adapted to exploit the advantage of the high adjustment potential and the system's high control dynamics. To achieve this, ThyssenKrupp is continuing to extensively develop its own chassis controller. This is already fitted as standard in various vehicles. The interaction between the control valve and damper regulation offers the driver noticeably more ride comfort and agility.

The advanced development status of this damper system is laying the foundation for rapid production development in cooperation with the OEM.



❺ Testing in the concept vehicle