Strength Testing of Parking Lock Mechanisms in Car Transmissions

Cessation as a special form of motion, is a very apt description of the task of the transmission parking lock – a powertrain component often underestimated in its importance. In order to prevent personal injury as well as damage to property, a flawless function of the parking lock throughout the vehicle's life time has to be ensured. Therefore, Bertrandt put their focus on comprehensive test procedures early in and throughout the product development process.

PARKING LOCK MECHANISMS ARE ESSENTIAL IN EVERY PARKING SITUATION

In section 14 paragraph 2 of the German Road Traffic Regulations (StVO), car drivers' duty of care when leaving and parking their vehicles is described as follows: "A person operating a vehicle must take the necessary measures to avoid accidents or traffic disruption when leaving the vehicle. Motor vehicles must also be secured against unauthorized use."
In some cases international regulations [1] place much more detailed obligations on drivers and car manufacturers.

The comfort features of the latest generation of cars include a range of software functions which are responsible for preventing parked cars from rolling away or being stolen. Alongside the handbrake, which is often electronically operated, cars with automatic gearboxes and torque converters, dual-clutch transmissions or electric drives often have an automated transmission locking mechanism (referred to here as a parking lock). In the torque path of the car powertrain, the parking lock forms a frictional connection between the tires, which are in contact with the road, and the body and powertrain suspension system. In order to ensure that this locking mechanism

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functions reliably in every parking situation, a ratchet lock, **FIGURE 1**, that takes into consideration the gear ratios is generally positioned so that it has positive impact on the speed at which the mechanism is engaged, the rolling distance, the material stresses and the reliability of the unlocking function.

When developing a parking lock, powertrain engineers have to ensure that the software, the electronic functions and the mechanical locking mechanism in the gearbox are designed to last for the service life of the vehicle and are comprehensively tested.

CONVENTIONAL TESTING AND VALIDATION PROCESSES

The final vehicle test is an essential part of the functional validation of the parking lock. It is the only test that can provide accurate and reliable results.

However, this means that the testing takes place in the later stages of the product development process, when any problems relating to the functionality or durability of the system may be identified too late to be resolved before the scheduled start of production. The parking lock can also expose people, the environment and the vehicle body to risks. Examples of the kind of test currently carried out include a fatigue test lasting several weeks and involving 30,000 engaging and disengaging cycles on an incline and a misuse test to evaluate the safety mechanism that prevents the ratchet lock from engaging at high speeds.

The development and test procedures that are currently used at an earlier stage on component test rigs make it difficult to take into consideration the interaction between all the components in the powertrain from the perspective of phenomena such as elasticity, inertia and backlash throughout the entire vehicle system. Given the fact that when the locking mechanism engages all the remaining kinetic energy in the spring, the mass system can die away or cause the locking mechanism to disengage when this is not required, the functional development process at the lower engagement speed (rolling to a stop or starting to roll) requires an investigation of the entire powertrain, including the mass of the car and the road contact.

THE ROAD ON THE TEST BENCH

The special feature of the test bench concept described here is the application of force to the test specimen via the contact patch of the original tire. An asphalt pad is pressed onto the surface of the tire, **FIGURE 2**, to represent the tire contact

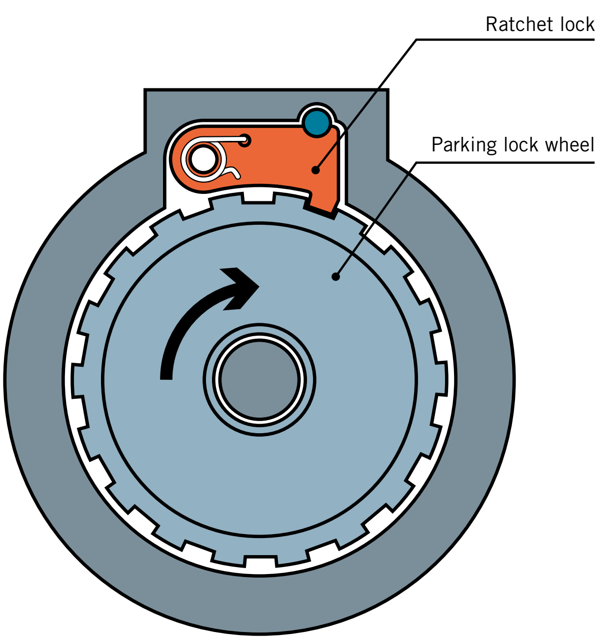


FIGURE 1 A ratchet lock is generally used as a locking mechanism in passenger car gearbox parking locks (© Bertrandt)

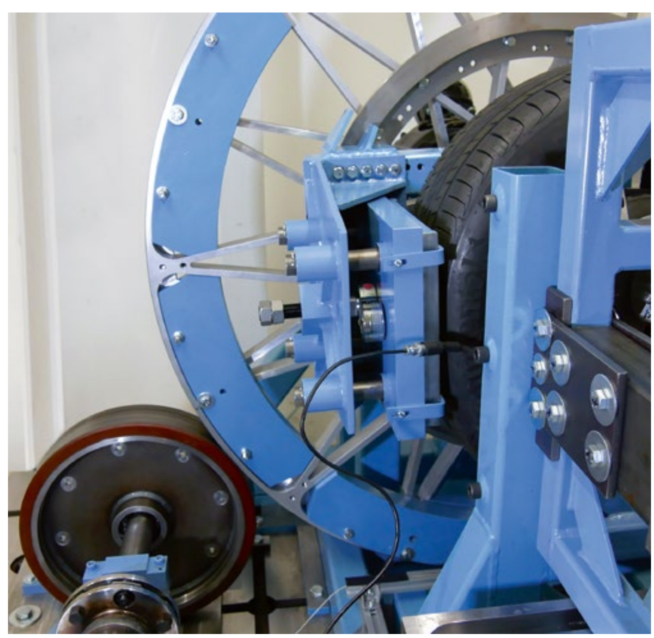


FIGURE 2 An asphalt pad is pressed onto the surface of the tire to recreate the tire contact patch with the correct axle load, wheel camber and tire pressure (© Bertrandt)

patch with the correct axle load, wheel camber and tire pressure. When the test is running, this asphalt pad drags the wheel with it at the same speed using the existing frictional grip on the tire contact patch, ensuring the road to turn with the tire. This means that the road turns with the tire. The maximum torque is restricted to the slip limit of the asphalt pad on the tire contact patch, which ensures that no more torque is ever applied to the test specimen than can be built up by a tire gripping the road in a real-life scenario.

The rigid connection between the entire test rig drive system and the right-hand and left-hand wheel of the vehicle ensures that the wheels turn in synch, producing the same results as a vehicle traveling in a straight line on the road (road/wheel connection).

The entire test rig is installed on a vibration-damped base consisting of an 8 m² grooved steel plate with a total weight of 14 t. The test rig is driven by a 30-kW three-phase electric motor with speed and torque controllers and an integrated transfer box (bevel gearbox i = 7.54) which divides the test speed and torque symmetrically between two drive shafts. These shafts use a pair of friction wheels to drive a large flywheel (i = 3.2) that the asphalt pad is fixed to. This allows the test rig drive system to develop maximum torque from a standstill up to 4500 Nm.

The vehicle wheels are fitted to the gearbox using the original drive shafts, wheel bearings, brakes, bolts and plug connectors. The gearbox is attached to the test rig at special mounting points using the original anti-vibration mounts. The connections for the wheel bearings, brake calipers and gearbox bearings are extremely rigid. The parking lock is activated by the original actuator. When the parking lock is engaged, the test torque applied via the vehicle tires is transferred to the gearbox housing and then via the gearbox mounting points to the test rig, which closes the torque path, **FIGURE 3**. In the case of cars with electric drives, a mass equivalent to the rotor is attached to the gearbox input shaft to accurately represent the spring mass system.

If the parking lock is engaged when the system is rotating, the entire test set-up will suddenly be stopped from turning any further. At this point the existing rotational energy can only be dissipated by the frictional swinging of

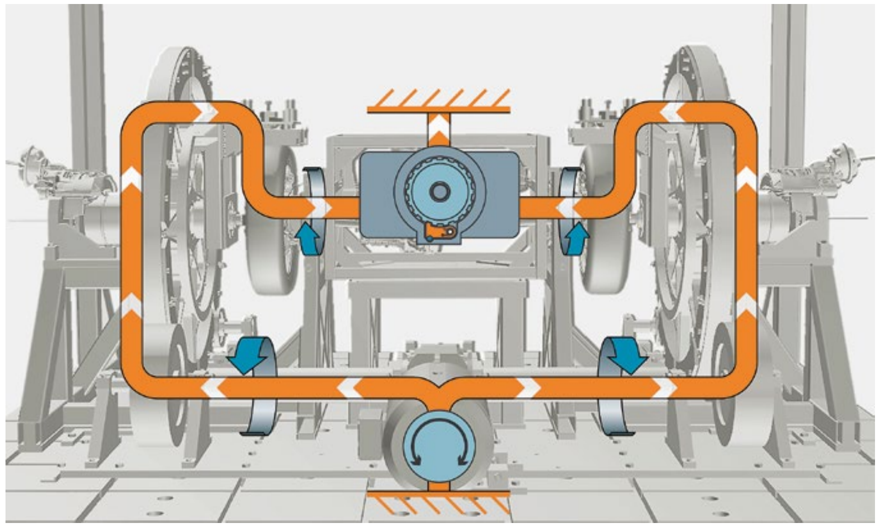


FIGURE 3 Test rig for gearbox parking locks: When the parking lock is engaged, the test torque applied via the vehicle tires is transferred to the gearbox housing and then via the gearbox mounting points to the test rig, which closes the torque path (© Bertrandt)

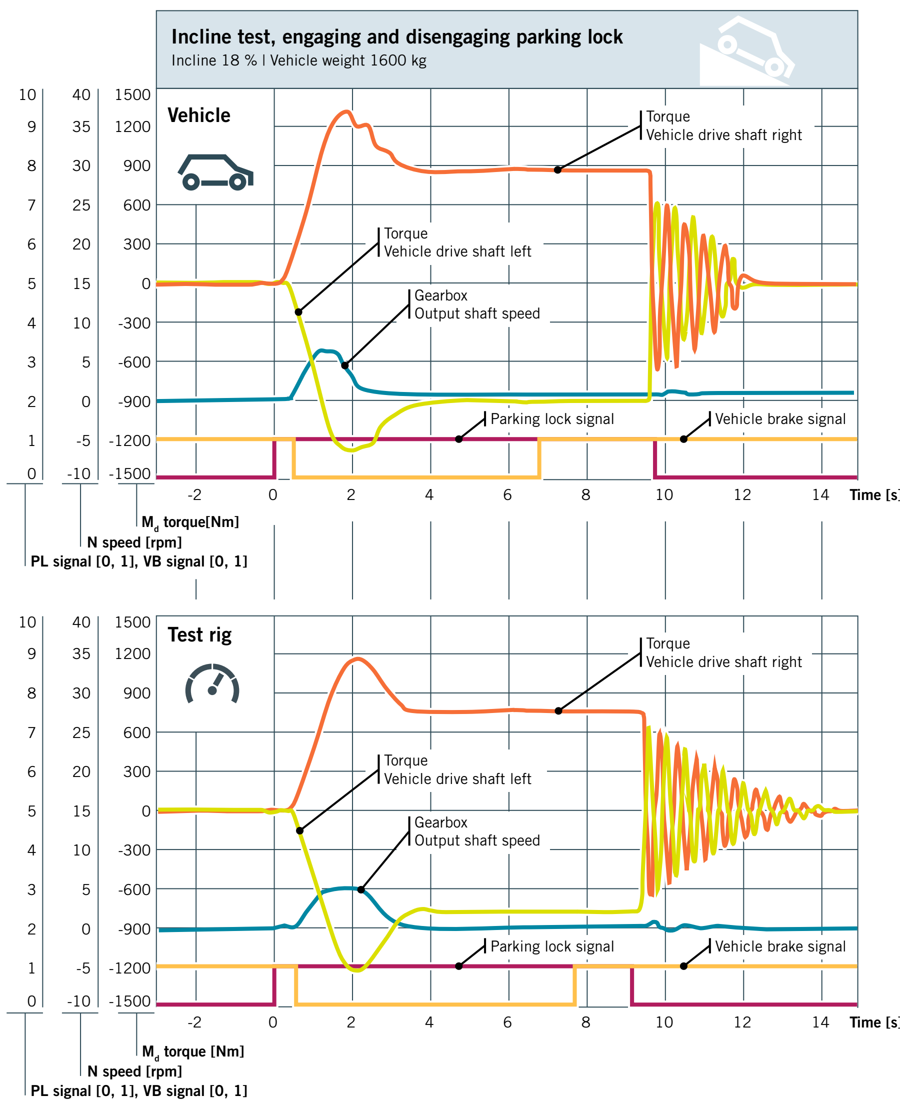


FIGURE 4 The test shown describes a situation involving parking on a slope and pulling away again (© Bertrandt)

the test set-up, the plastic deformation of a component transmitting the force, which may subsequently break, or the sliding friction on the tire contact patch. In order to represent the forces generated by a real vehicle maneuver on the road, the translational energy of the total vehicle mass is applied in the form of rotational energy to the outer edge of the test rig flywheels using additional weights. With a maximum load of hundred 4.5 kg weights, it is possible to represent a vehicle weighing up to 5000 kg.

The torque generated in the powertrain is measured using strain gauges fitted to the two vehicle drive shafts and the results are transferred to the measurement amplifier using telemetry. The test speed and direction of rotation are recorded at several points and at high frequencies using inductive speed sensors. This allows a speed/torque curve to be produced. In addition, the temperature of the cooling air, lubricants and components such as bearing seats, circuit boards etc. is also measured. High-speed cameras and stroboscopes can be used for special functional investigations of bearing points, actuators or the parking lock itself. An external cooling unit allows the test specimen to be examined at ambient temperatures ranging from -30 to +125 °C.

LOAD CASES FOR THE PARKING LOCK

The static and dynamic load cases enable the following test scenarios to be reproduced. The first involves the application of a static force to the lock

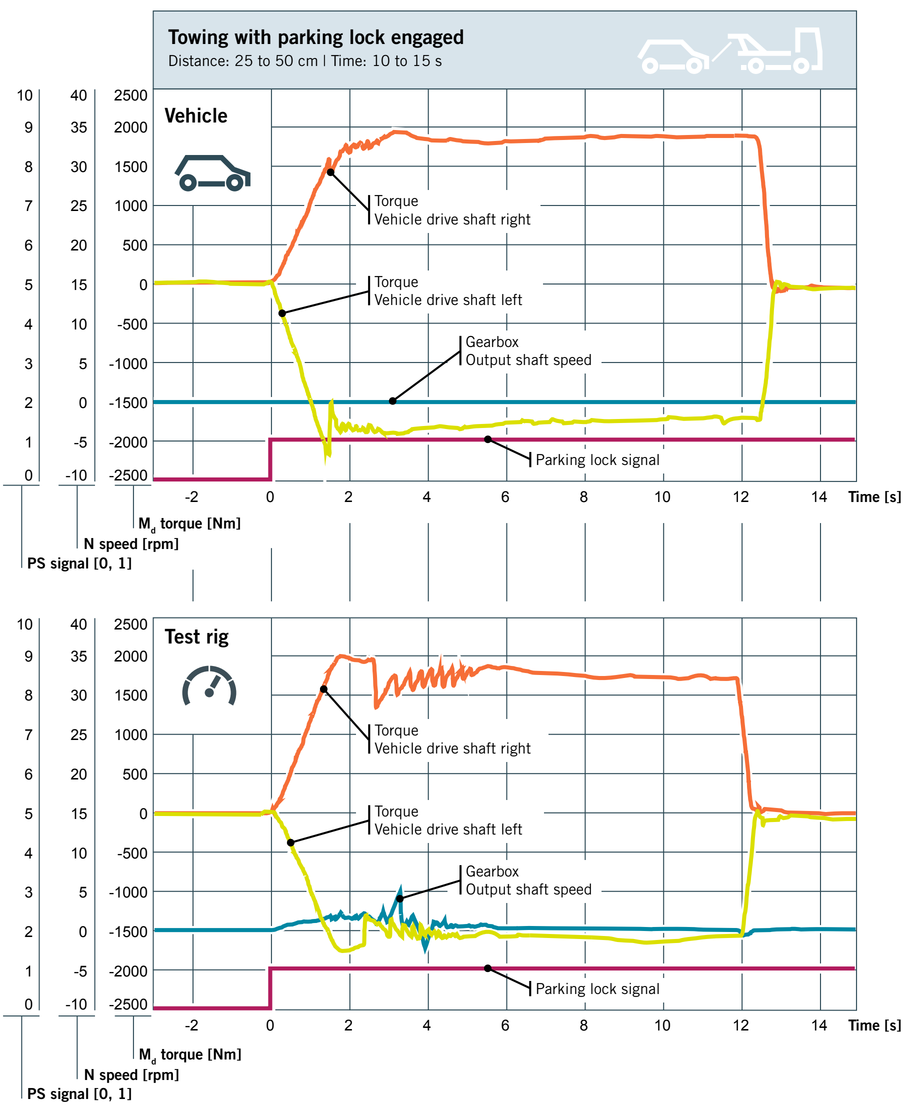


FIGURE 5 The test shown describes a towing situation with the parking lock engaged (© Bertrandt)

mechanism when it is engaged. This includes parking on an incline, **FIGURE 4**, stacked parking, minor impacts when parking, transporting or towing the vehicle, **FIGURE 5**, or borderline cases, such as parking on a road surface which is slippery on one side of the vehicle.

The second involves the locking process in the moving vehicle. The lock mechanism is engaged within the permitted vehicle speed range, for example when rolling to a stop on a level surface, **FIGURE 6**, or pulling away on a hill. It also includes testing malfunctions such as engaging the parking lock at a high speed.

In order to verify the test rig results when simulating real-life load cases, an identical powertrain is tested first in a car on the road and then on the test rig.

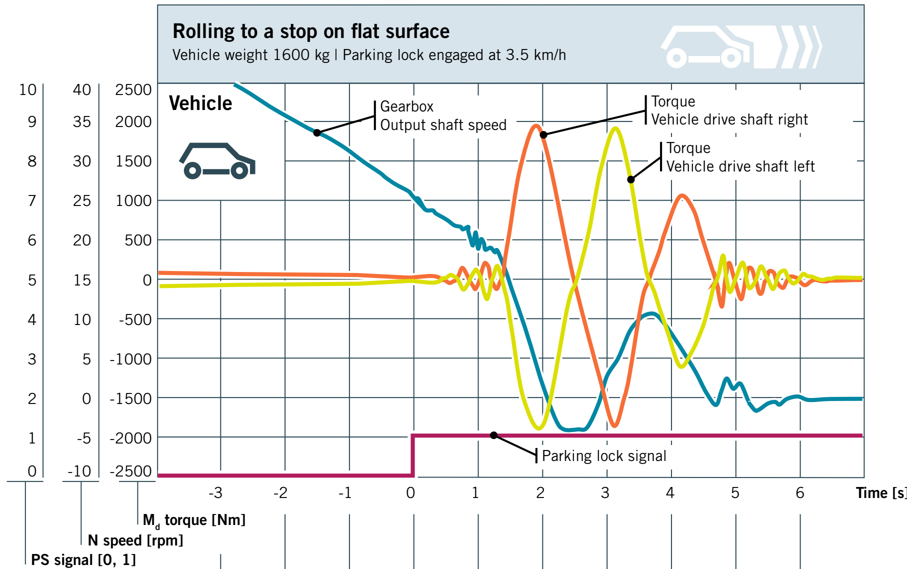
TEST RIGS THAT CAN BE USED ANYWHERE

This test rig allows the simulation of realistic operating conditions for a gearbox parking lock, including the accompanying vibration from the entire powertrain and nearly equivalent to road use.

The tests give an insight into the static and dynamic behavior of lock mechanisms when subjected to a variety of stimuli. This allows the functions to be accurately validated by testing the strength and durability of individual components. The high level of automation of the test procedures combined with the specially designed acceleration cycles offers huge potential for improving the efficiency and speed of the development process. Remote diagnostics and the real-time transmission of images and measurement data to other teams involved in the development process under secure data protection conditions improve cooperation during product development. In this way, the testing results can directly be incorporated into the design of individual components or be used for multi-body simulation. In order to provide test rigs serviceable worldwide, the next generation of these test rigs for evaluating parking locks and diffential locks will be constructed in moveable containers, so that they can be used anywhere, **FIGURE 7**.

REFERENCE

[1] United Nations (ed.): See Annex I point 2.1.2.3 of European Commission Directive 98/12/EC. UN Vehicle Regulations – 1958 Agreement (ECE R 13 H), most recently amended by E/ECE/324/Rev.2/Add.12H/Rev.3/ Amend.2 v. 22/02/2017; CFR Title 49 Subtitle B, Part 571.114



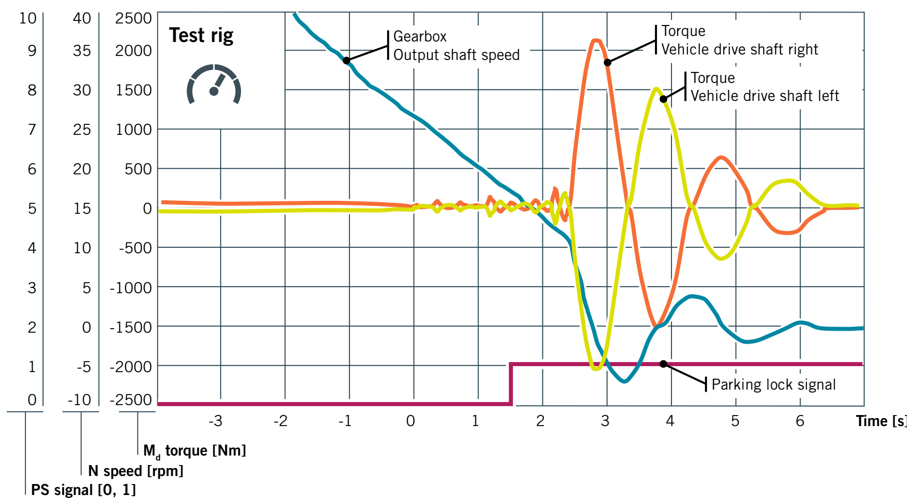


FIGURE 6 The graph shows the locking situation resulting from the driving situation (© Bertrandt)

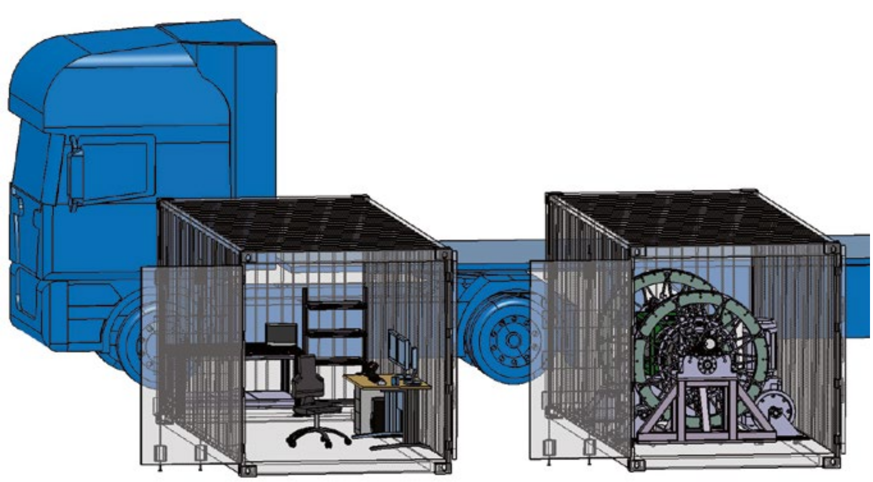


FIGURE 7 Future prospects: a mobile test rig for gearbox parking locks with a control room (© Bertrandt)