3

The clutch system of the future

More than disconnecting and connecting

Jürgen Freitag
Friedrich Gerhardt
Markus Hausner
Christoph Wittmann

Introduction

Hybrid models, electric cars and hydrogen locomotion are only a few of the drive concepts on which the automobile industry is betting for the future of personal transportation. Nevertheless, the classic combustion engine will, in the view of many automotive experts [1 to 5], remain the primary drive form for passenger cars, commercial vehicles and farm equipment for the next 10 to 20 years. With new combustion processes and other optimizations, the engines are becoming cleaner and more economical. And so the demand for manual transmissions, and the clutches and torsion dampers that go with them in the drive train, remains strong for the foreseeable future. Compared to present-day applications, the requirements for these components are increasing strongly, since engine technologies demand greater isolation potential for the downstream drive train.

The LuK line of clutch products meanwhile covers the full range, from components for subcompact cars to component groups for tractors to modules for commercial trucks, of automobile and tractor applications (Figure 1). The engine torques to be transmitted range from 60 to 3500 Nm.

Numerous application-specific optimizations, such as twin plate clutches for high-torque vehicles, double clutches, multi-stage dampers for diesel applications or dampers for CVT transmissions, make it clear how market-oriented components have continuously expanded the product portfolio in the past to the benefit of the customer.

The modules do much more today than just a few years ago. Developments to reduce CO_2 output, such as downsizing, reduce the number of cylinders or increase the efficiency in the drive train bring about increased rotary and axial acceleration with reduced damping. At the same time, the use of the components in ever more complex systems, such as double clutches or hybrid applications, means that the requirements for the clutch with respect to comfort, durability and reduced installation space are constantly increasing in both the passenger car and the commercial truck sector. Special NVH issues also create higher requirements in the development of advanced, more powerful systems.

Comfort

LuK SAC Always in tune with the times

For years the trend in engine development has been toward higher torques while keeping piston displacement nearly constant [6]. Because the space available has remained practically constant, this development has led to a clear rise in the per-

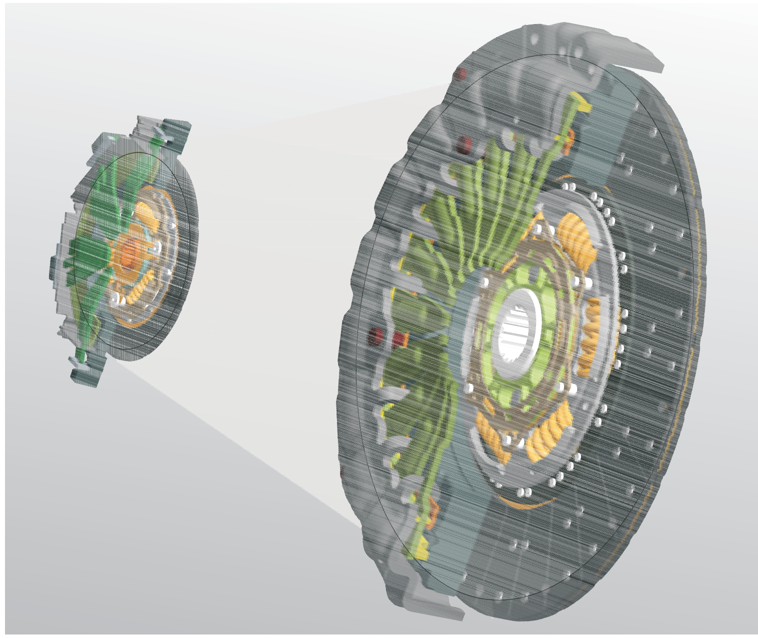

Figure 1 LuK clutches for 60 and 3500 Nm engine torque

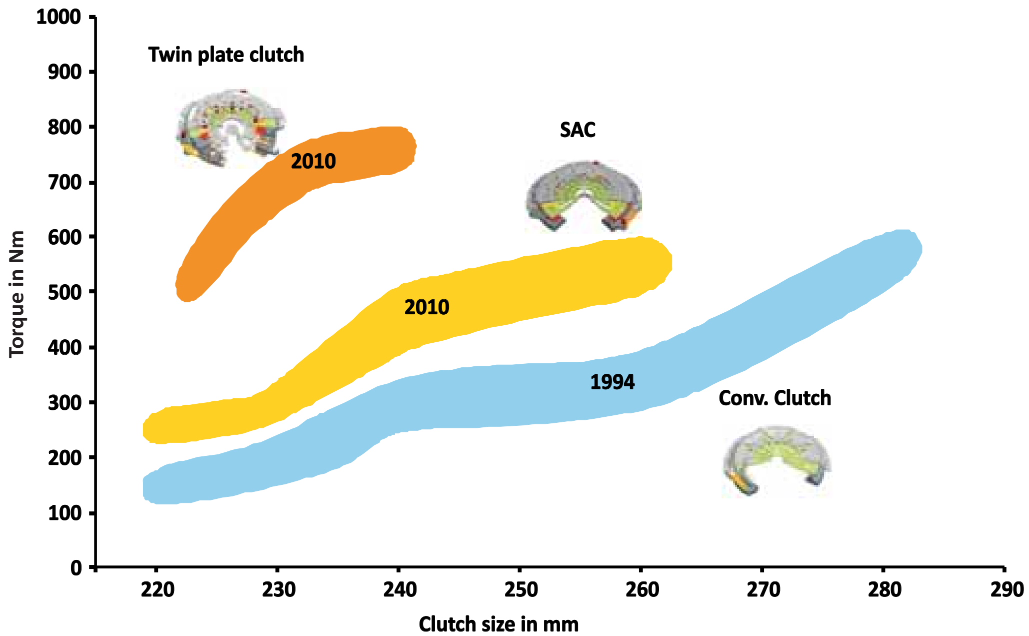

Figure 2 Development of torque and the clutch technologies adapted to it in 1994 and 2010

formance density of the clutch system. Torque capacity has thus increased by about 50 % while clutch size has remained steady (Figure 2). The loads on the power train and thus also on the clutch system have increased markedly. This trend necessarily leads to higher release loads during clutch operation.

One of the first responses to this development was the LuK SAC (self-adjusting clutch) with load-controlled wear adjustment. In the passenger car segment, SUV applications, off-road models and smaller vans in particular set high requirements for wear resistance. The use of the SAC has proven itself in these vehicles because of the high torques and the high running performance achieved in past several years. Despite rising torques, the SAC is also widely used in the area of passenger cars because of the moderate release loads.

The first development goals of the SAC were [6]:

- To increase the wear range (longer service life)
- To reduce the operating load (comfort)
- Downsizing
- To reduce the bearing stroke (reducing space and cost)

Increased torque capacity with continued moderate release loads, or, alternatively, the ability to reduce the difference between the maximum and minimum release load (drop-off) – these are the characteristics of the SAC2. This has been implemented by means of the degressive leaf spring to connect the pressure plate with the cover [7] and the sensor fingers on the main diaphragm spring. The sensor load of the degressive leaf springs is thus introduced via the pressure plate. At high axial excitation of the crankshaft – a common phenomenon in newer engines – the system can, however, be dynamically excited in connection with the mass of the pressure plate.

In the development of the newest SAC generation, these requirements have been taken on and the functions of degressive leaf spring and sensor finger replaced by functionally new components to further optimize the overtravel safety.

The sensor diaphragm spring is now actuated with each lift-off and introduces its load directly into the main diaphragm spring. In this way, the pressure plate mass exercises no influence on the sensor spring load. A support spring replaces the sensor finger in order to raise the total effectiveness with three additional diaphragm spring fingers.

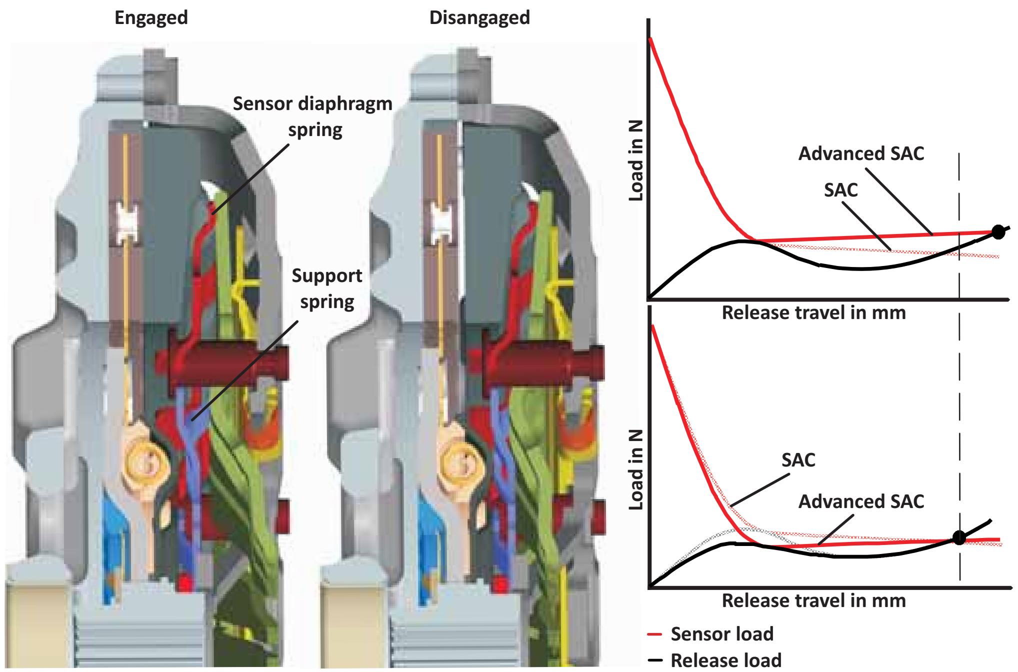

Figure 3 Further development of the LuK SAC

During the release process, the sensor, support and leaf spring load combine to increase the sensor load and thus expand the overtravel safety. Alternatively, the maximum release load can be lowered with the same overtravel safety (Figure 3).

A constant sensor load in the wear of the clutch disc is ensured by the tuning of the three spring components.

With this step, the LuK SAC is also equipped to meet upcoming demands.

Compared to the first-generation SAC, the release load has been reduced by some 30 % at the same engine torque. Minimum and maximum release load are now considerably closer to one another.

LuK TAC New roads for commercial vehicles

In general, a clutch system is designed for a lifespan of about 200 000 km for passenger cars and between 600 000 km (local distribution) and >1 000 000 km (long-distance hauling) for commercial vehicle applications. The lifespan depends on the cast masses (flywheel and pressure plate), the selected facing size and on the wear range of clutch disc and pressure plate. Especially in commercial vehicles, a variety of start-up and maneuvering processes, such as in construction traffic, result in a need for increased wear resistance so that a reasonable service life can be achieved.

The automated manual shift transmission with pneumatic operation frequently used in commercial vehicles also requires an ever-increasing release load characteristic. This lack of ambiguity in the load-travel characteristic curve is needed by the clutch control system.

The LuK TAC (travel adjusted clutch) has been developed for these applications (Figure 4).

The adjustment procedure is triggered in the TAC by the travel measurement of the distance between pressure plate and flywheel and the axial travel change then by a gear with a spindle directly coupled with the adjuster ring. The travel compensation takes place between the pressure plate and diaphragm spring with constant finger height. Distortion or potting has no effect on the adjustment quality because the complete adjustment unit is located on the pressure plate.

With this design there is a minimum available wear range of 6 mm. This makes the wear reserve nearly double that of other systems available on the market.

The positively actuated self-adjustment provides a consistent adjustment quality over the entire wear range. Depending on requirements, different release load characteristics can be drawn (Figure 5).

In principle, the TAC adjustment principle can be used for commercial vehicles, passenger cars, stamped and pressed clutch covers. The LuK TAC is a complement to the successful LuK SAC. With these concepts, LuK offers its customers nearly unlimited possibilities in selecting the release load characteristic and thus the pedal forces.

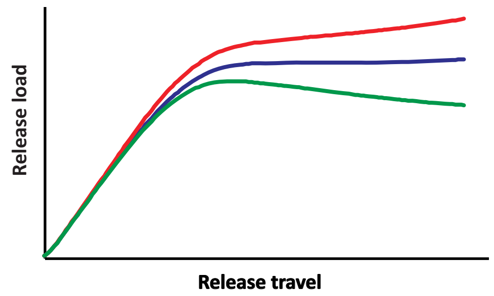

Figure 5 Possible release load curves for the TAC

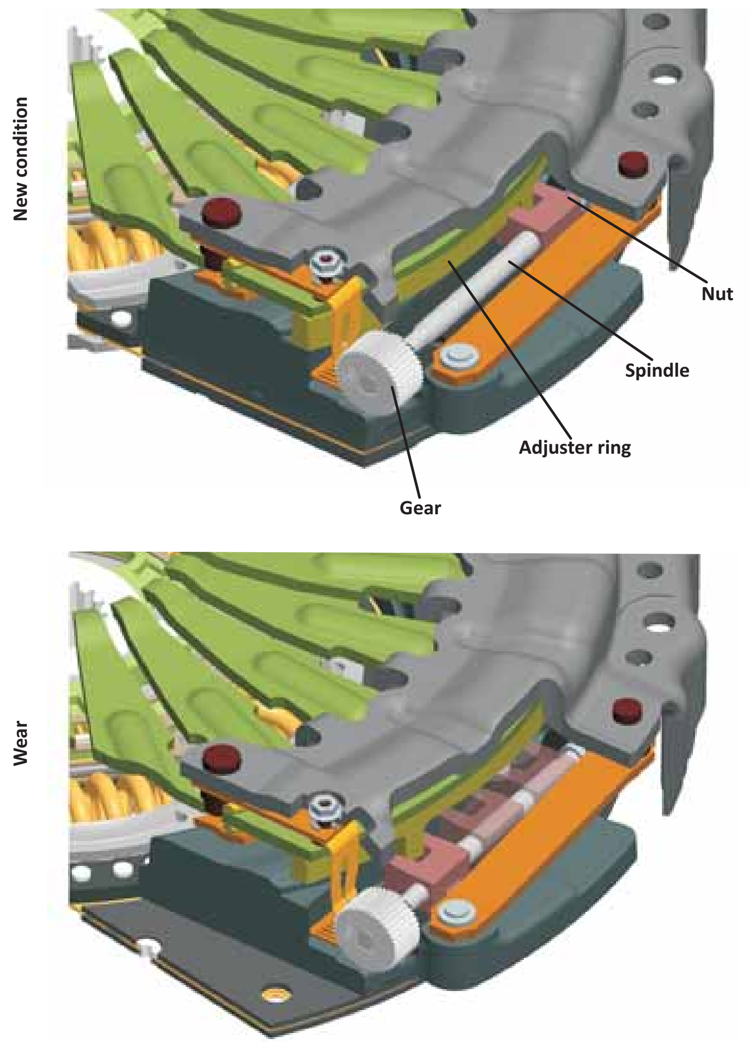

Figure 4 LuK TAC (push-type clutch) with minimum wear reserve of 6 mm

In principle, the release load level can be further reduced in all designs, even conventional clutches, by using a servo spring between the cover and diaphragm spring finger. This approach was described in [8].

Vision

New trails must be blazed in order to significantly lower the operating loads. One approach is the use of a booster clutch (Figure 6). This clutch system consists of an actuation clutch and a main clutch. These two elements are connected with one another by a ramp system using roll bodies. When the actuation clutch closes, the built-up torque rotates the ramps, thus closing the main clutch. The energy required to operate the main clutch in this system is provided by the combustion engine and the only external

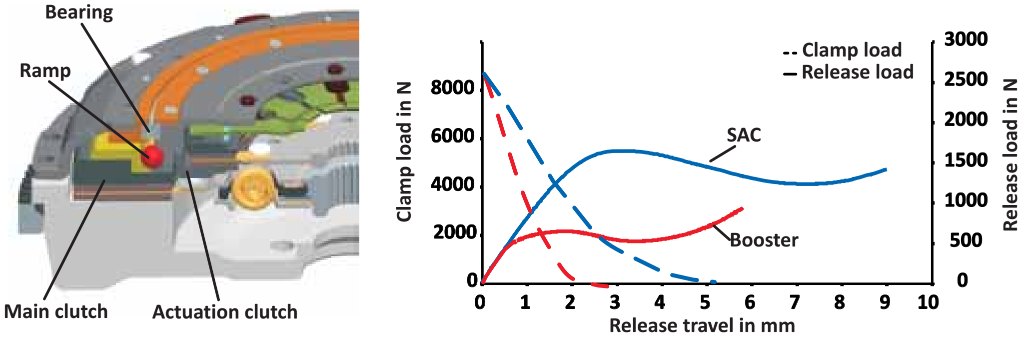

Figure 6 Booster clutch

force that must be applied from is that needed to close the actuation clutch. The critical transition from drive to coast is conquered with a suitable friction control device. Initial tests in vehicles are showing good results. The release loads can be reduced by a factor of 2 or 3 compared to present-day designs, thus offering great potential for the electrification of the clutch operation, for example.

Service life

Reducing wear in the torsion damper

Particularly in dampers with high coil spring mass, such as in commercial vehicles, but also increasingly in hybrid and automatic applications, the load

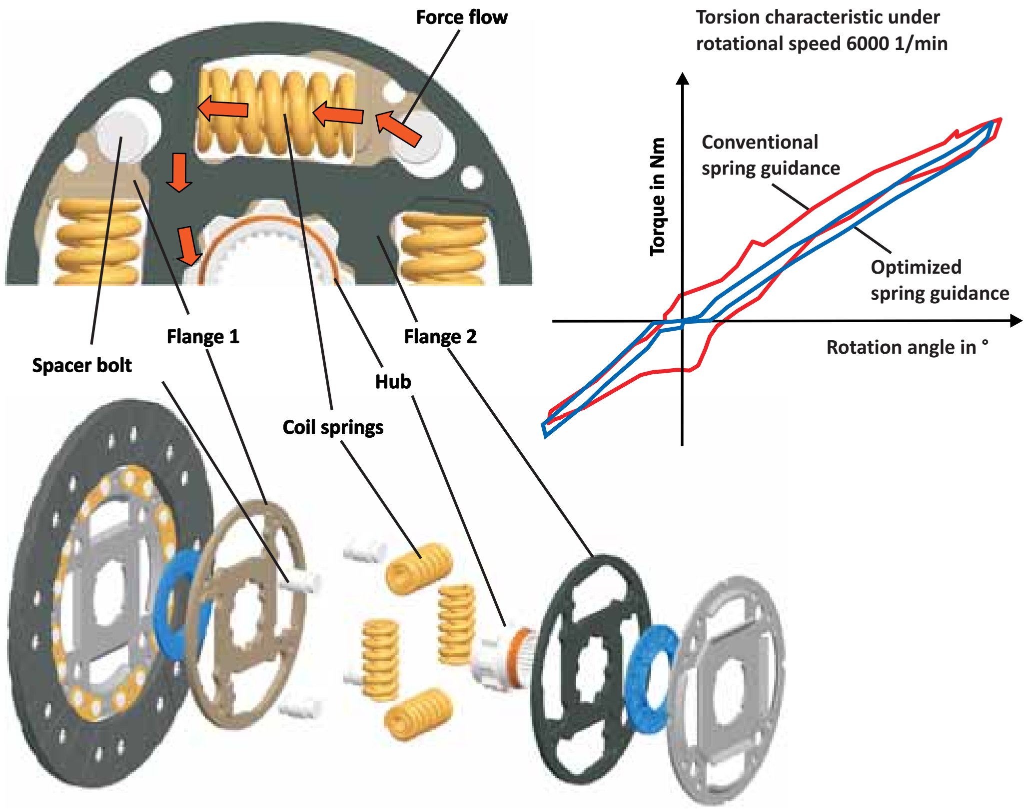

Figure 7 Damper for hybrid application with optimized spring guidance

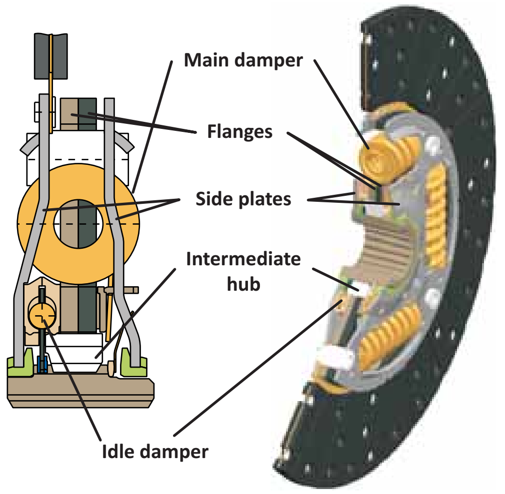

Figure 8 Damper for commercial vehicles with optimized spring guidance

and the wear of the spring guidance are often the limiting factor. With the new spring guidance system developed at LuK, the wear on the coil springs and guides in the damper can be reduced considerably.

With a standard spring guidance system, the position of the coil springs changes between the flange and spring guide plates when transitioning between drive and coast. Geometric deviations in the spring windows of the flange and spring guide plates caused by the production process, as well as displacement in the damper, cause slight radial shifts in the coil springs under centrifugal load with each change in the coil spring support, which causes friction and wear to the springs and guidance. At high engine speeds, the coil spring can even be impeded by the friction at the exact reset point.

In the new concept (Figure 7), the damper has two flanges which remain in constant contact with the respective coil spring ends. The transition between drive and coast torque occurs via the position change from the flange to the spacer bolt or to the external spline of the hub. The circumferential lash between the flanges and the hub also defines the total angle of rotation of the damper.

Due to the elimination of the position change in the spring guidance, less friction and wear occurs there and on the coil springs than in the standard design. This also results in no essential change in the torsion characteristic with increasing engine speed. The comparison of the dynamic torsion characteristics of a standard damper and dampers with optimized spring guidance clearly shows the lower friction of the optimized version (Figure 7).

This system is also realized in a damper for commercial vehicles (Figure 8). In connection with the optimized spring guidance, an additional intermediate hub, which defines the rotation angle of the main damper by means of the external spline and that of the idle damper by means of the internal spline, is necessary to realize an idle stage.

The optimized spring guidance is additionally used for the standard design, depending on the coil spring weight and engine speed.

Development of clutch and facing under one roof

In cooperation with Schaeffler Friction, formerly Raybestos, LuK has access to high system competence with respect to development and manufacturing of facings, which is also revealed in an optimized development process for friction facings (Figure 9), which is characterized in that

1. the facing quality is defined with the friction development in the concept phase of the assembly development
2. the requirements (wear, friction coefficient, gradient of the friction coefficient etc.) of the application are transferred to the requirements of the friction pairing
3. existing test programs are either modified or new programs developed, so that modified requirements can be taken in consideration (e.g., continuous slip in double clutch applications or short slip intervals with high specific compression in hybrid applications)
4. tests are performed first on partial facings, then in the assembly and finally in the vehicle – starting from the respective system loads. In this way, the evaluation of the friction facing material can be made swiftly and without outside influences from other components of the clutch or the vehicle.

One result of this optimized development process is facings with improved burst behavior after thermal damage. Experience shows that it is not

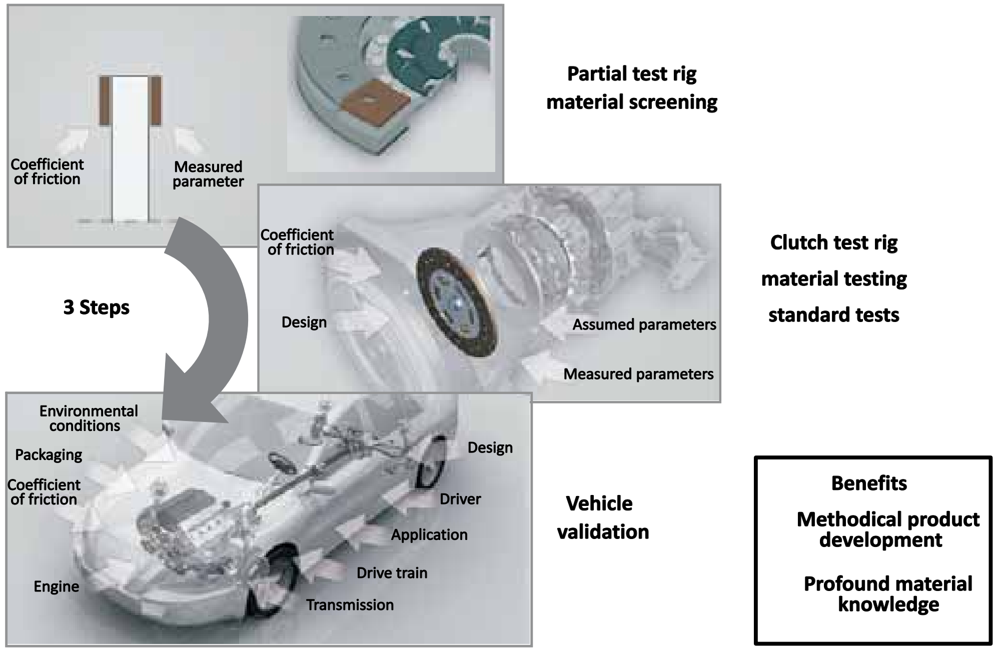

Figure 9 Development process of partial facing, clutch and vehicle

enough just to consider the burst resistance of the new friction facings that have not yet been subjected to thermal load. Rather, the burst resistance of the components must also be tested after longer lasting thermal load – including consideration of thermal abuse. By using high grade facing materials and by optimizing the design relationship of facing and steel plate, clear improvements in the burst resistance can be achieved.

Methods have been developed from test rig loads, targeted thermal damage under laboratory conditions and burst tests, which comparatively describe the mechanical strength of facings after thermal stress and serve as a development tool for the friction facing and clutch developer. Figure 10 shows a comparison of the results from different friction facing materials.

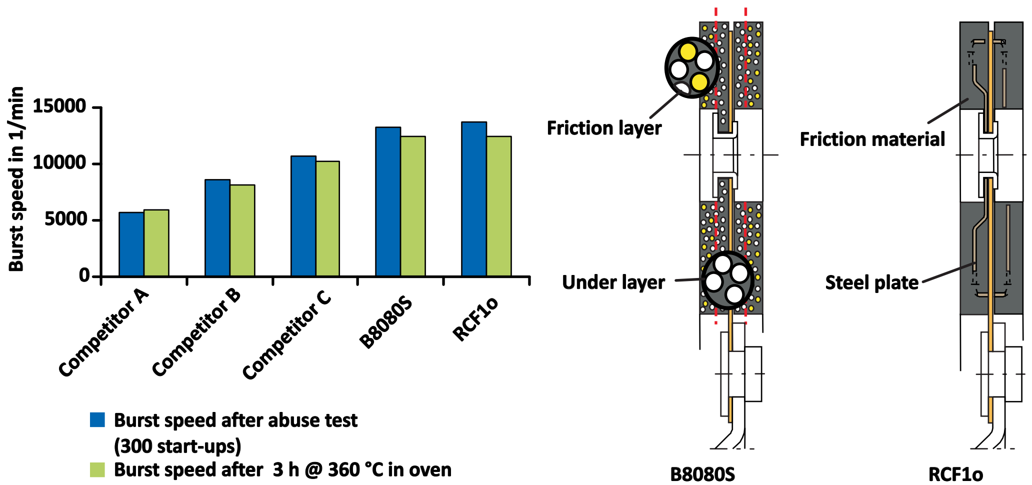

Figure 10 Comparison of burst strength after abuse and thermal damage; configuration of facing and clutch disc

NVH

New ideas for well-known challenges

Noise and vibration phenomena (NVH) are mostly a problem of the entire drive train, which means that in the majority of cases, the cause cannot be traced back to a single component. This can be seen from the fact that a clutch assembly, for example, may cause problems in one vehicle and not in another. Two solution approaches are described below which contribute to reducing the likelihood of problems occurring or compensate for possible faults.

Torsion damper to reduce chatter vibrations

In all drive trains with friction lock-up transfer components, in the slip phase alternating torques are superimposed on the average torque, which can lead to chatter vibrations (Figure 11). However, this is only problematic when it means that vibrations can be felt by the driver. How strong an effect a

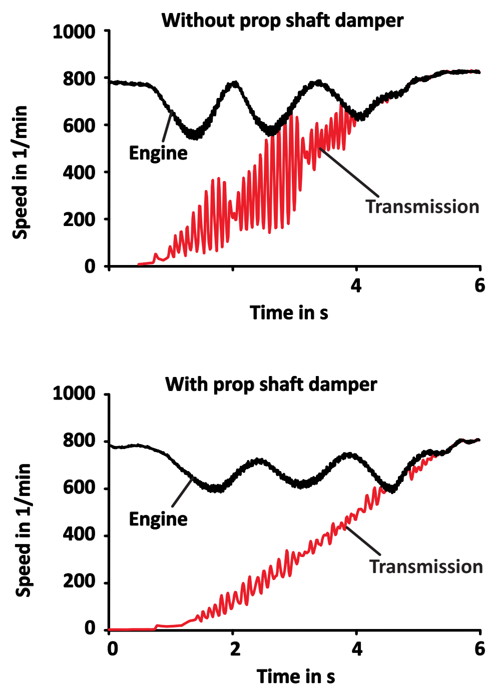

Figure 11 Start-up with chatter vibrations

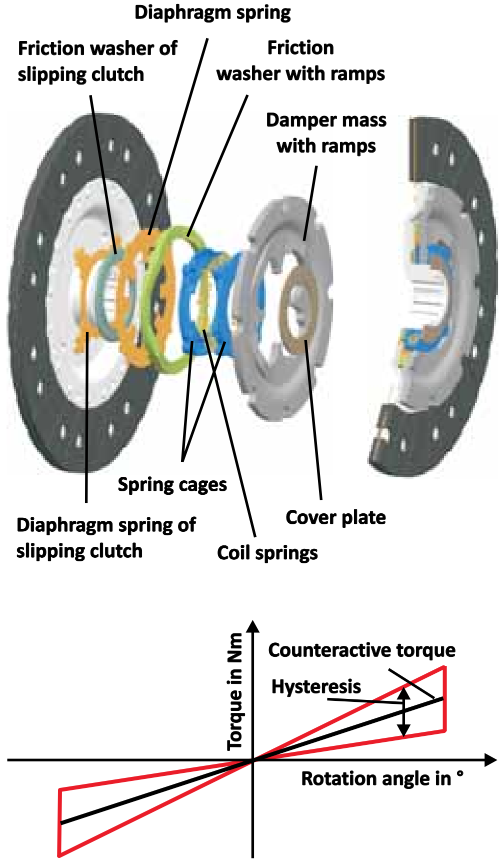

Figure 12 Torsion damper (chatter damper)

given excitation has depends on the engine drive train and vehicle. Vehicles with high sensitivity can, under some circumstances, only be conquered with difficulty at the state of the art.

In principle, a tuned mass damper offers an approach for reducing chatter vibrations that occur by more than 50 %. LuK has already studied such designs many times in the past. The tuned mass damper then consisted of a mass arranged parallel to the clutch disc using springs and a friction control device. The friction had to be tuned to a defined chatter excitation.

As a result, the optimal damper performance was only rarely achieved in real operation, since both excitation and friction can have great variation. If, for example, the friction is greater or the excitation lesser than assumed, the tuned mass damper tends to stick, in the opposite case, the damping is too little for the previous natural frequency shifted by the tuned mass damper and the new natural frequency of the system. A tuned mass damper with speed-proportional damping is supposed to help. Tests, however, showed that the expense for such a module would be too great.

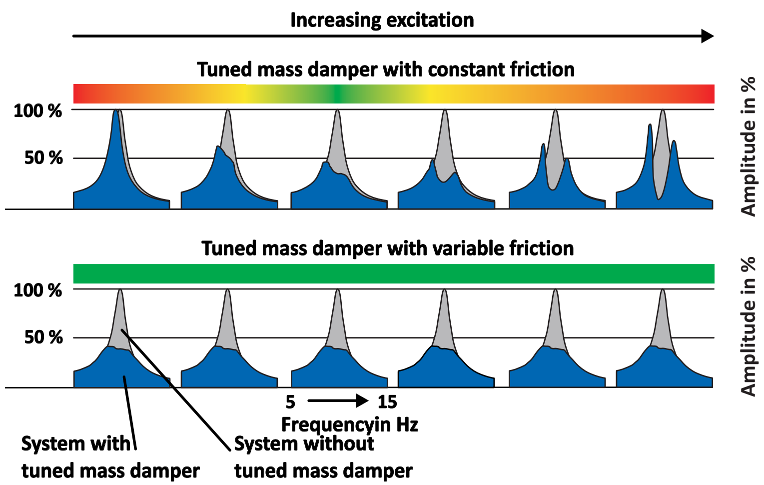

Figure 13 Principle of the tuned mass damper with friction dependent on rotation angle

In the new approach, the friction is made variable such that it increases with increasing relative rotation angle and thus with the moment of excitement. The relationship of friction and rotation angle is determined such that the optimum friction is always set for each excitation amplitude. The friction tolerance is not eliminated in this way; however the damper performance only decreases perceptibly in extreme situations.

The friction control device is provided with ramps that can rotate opposite one another, which act on a diaphragm spring with a linear characteristic curve (Figure 12). The clamp load in the friction control device and thus the friction thus increase in exactly the required measure when the damper mass rotates with respect to the clutch disc (Figure 13). The damper effect is thus independent of the excitation torque.

In order to be able to cover common excitation torques with a design-feasible vibration angle, the damper mass must be around 10 - 20 % of the mass to be dampened. In case of deflections that are nevertheless greater than the maximum vibration angle, the entire damper unit is fastened to the clutch disc with a slipping clutch.

A general advantage of the torsion damper is that chatter vibrations are reduced independent of the excitation mechanism as long as the excitation frequency is close to the damper frequency. In this way, the torsion damper also prevents vibrations from starting up in case of friction-induced excitation (facing chatter).

Clutch disc with decoupling function

Noise problems can also occur in the slip phase of the clutch. A known phenomenon is the “eek noise,” a whistling sound with a constant frequency in the range of 300 - 500 Hz. The noise frequency correlates, in a simplified view, with the natural bending frequency of the transmission input shaft, which is calculated from the mass of the clutch disc and the flexural strength of the input shaft. Theoretically there are two approaches to stabilizing the system with the clutch disc, and thus of either significantly reducing or practically excluding the likelihood of occurrence.

One possibility is to weaken the amplification mechanism. This means that occurring disturbances are transmitted in weaker form to other elements so that a mutual build-up is weakened or entirely suppressed. For this, the tilting stiffness between the facing ring and hub is reduced for the clutch disc. Thus flexural vibrations from the input shaft are transferred to the friction contact between pressure plate and friction facing in weaker form. This can be realized in design by a segment foot configuration with reduced stiffness, for example (Figure 14).

Another option for stabilizing the clutch disc is to detune the noise-determining natural bending frequency of the input shaft considerably. This can be achieved by significantly reducing the mass of the clutch disc dominantly involved in the characteristic form. In design, this means, for example, that the facing mass is radially decoupled from the hub of the clutch disc, for example. Through the now lower mass on the input shaft, the natural bending frequency increases. Through the decoupling, a second natural frequency arises, which is below the original critical frequency. The advantage of the system modified in this way is that the two new characteristic forms are stable within the drivable range, and so do not start up in case of disturbances.

Such a design is already in series production today in misalignment compensation discs, but a radial offset is only possible with low slip torques. For the noise problem, the relevant torque range in which the problem can occur must be covered. For example, the decoupling must work up to about 60 Nm in a currently tested vehicle.

Optimizations to the torsion damper in the clutch disc

In addition to the DMF as the currently most effective system for reducing torsional vibrations, conventional systems with solid flywheel and torsion-damped clutch disc are also still used.

For passenger cars with smaller engines and light commercial vehicles whose requirements for vibration damping in the power train are not so great, such as in medium class cars, the torsion damper in the clutch disc is the best compromise among space requirements, function and cost.

Depending on the application, the torsion characteristic can be designed with one to five stages. In principle, the LuK clutch discs have the flattest possible main damper curve with a high-endurance friction control device for stable friction damping/hysteresis. This is important because a

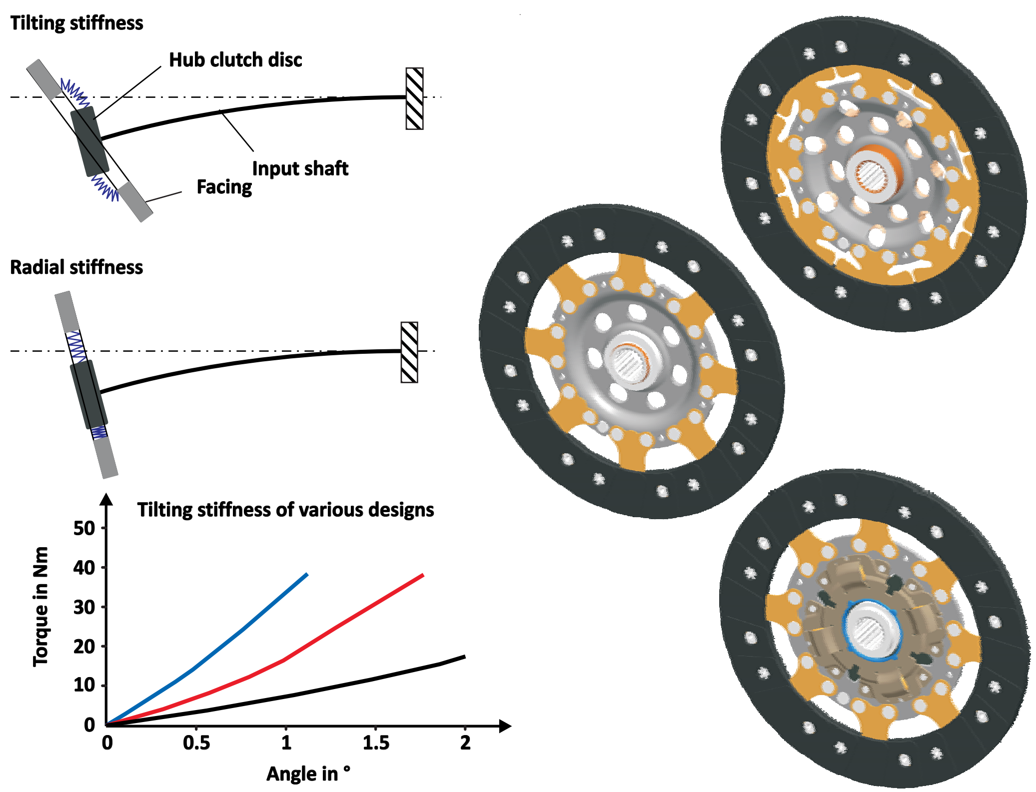

Figure 14 Clutch disks with decoupling function

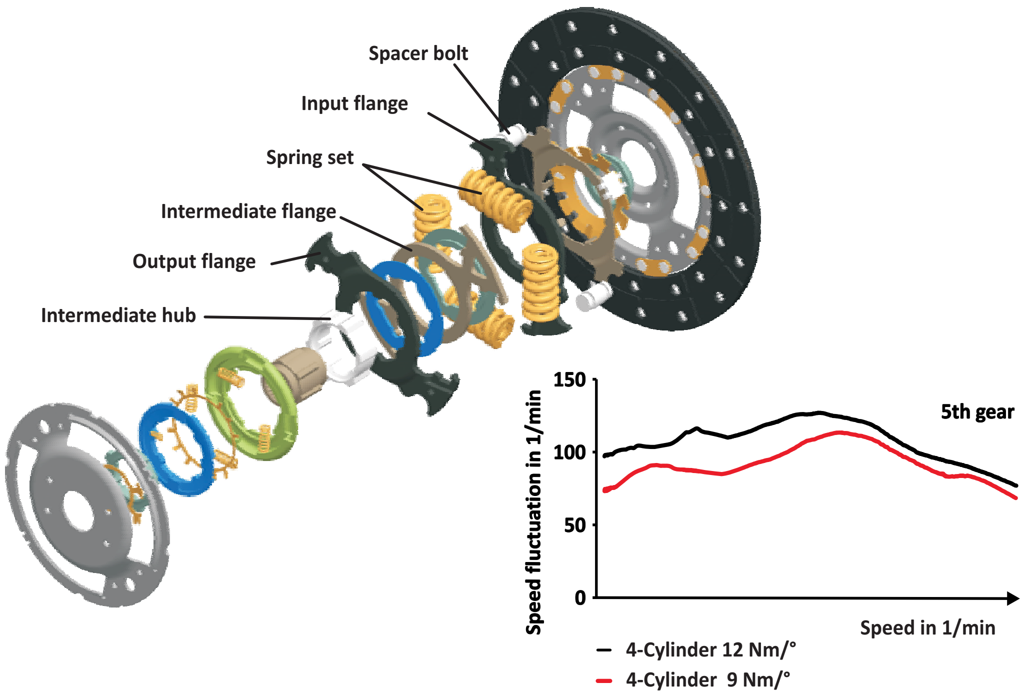

Figure 15 Serial engagement of the coil springs in the damper

noticeable reduction of the damper hysteresis over the service life can in critical applications lead to failures of the synchro ring in the transmission.

One way of reducing the torsional stiffness and thus the torsional irregularity in the drive train is the serial engagement of the coil springs in the damper. This causes a rise in the coil spring weight and results – if appropriate counter-measures are not taken – in correspondingly higher wear on springs and spring guides. The previously mentioned new spring guidance system developed by LuK makes such serial engagements possible even at high torques and heavy coil spring sets.

In addition to the two described flanges, an intermediate flange is also used. The input flange guides the load to two spring sets located opposite one another. These work by means of the intermediate flange on the nearest spring sets, which transfer the load to the output flange (Figure 15). The reciprocal control of input and output flange via spacer bolt or intermediate hub replaces the spring transfer.

The serial engagement of the springs lowers the torsional stiffness by 25 %. When used with a 4-cylinder diesel engine, the speed fluctuations at the transmission input shaft can be reduced 10 - 15 % compared to a standard damper.

The foreseeable replacement of 4-cylinder naturally aspirated diesel engines with supercharged 3-cylinder engines provides new possibilities for the damper in the clutch disc. The relatively narrow axial space in the front transverse drive with 4-cylinder engine, which is available for the clutch, could, if one cylinder is eliminated, be used in part for the clutch. Then clutch disc dampers could be designed with even less main damper pitch.

A double damper, which actuates two partial dampers in sequence, makes it possible to halve the spring stiffness. The mass moment of inertia of such a clutch disc (Figure 16) would normally increase by about 25 %, but could be compensated for in part by measures to the facing, such as thinner segments, optimized rivet recess thickness, etc.

The vibration simulation shows that the torsional irregularity can be reduced by about 25 % by the lower spring stiffness of a double damper in relevant range. In this way, it was possible to achieve a similar vibration behavior using a supercharged 3-cylinder engine in combination with a double damper as with a 4-cylinder naturally aspirated engine and standard damper.

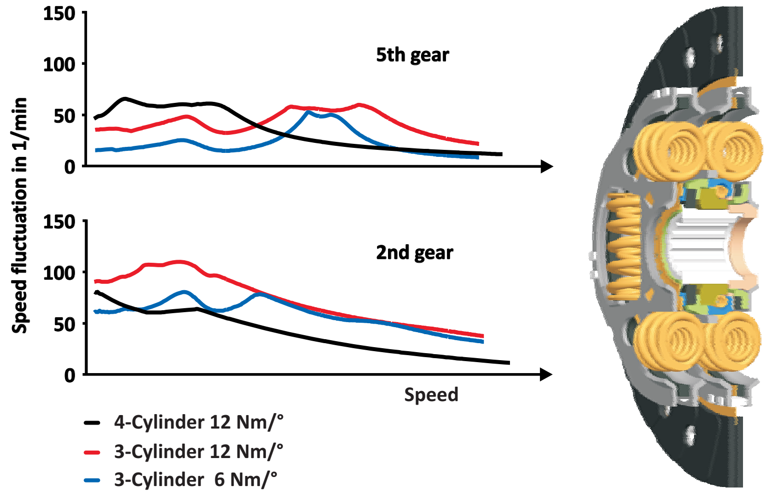

Figure 16 Double damper

Optimizations in the clutch

To reduce the torsional vibrations in the drive train, it is also possible to integrate a centrifugal pendulum-type absorber in the clutch cover (Figure 17), as is already used with the dual mass flywheel [9, 10, 11].

For this purpose, the areas between the strap pockets are used. The large effective radius in combination with large pendulum masses brings about a high system effectiveness. In applications with longitudinal engines, the system can normally be integrated in the available space, while additional space is required for front-transverse applications.

Figure 17 Centrifugal pendulum-type absorber in the clutch

Package

SlimDisc facing system

Especially with double clutch transmissions, due to the thermally relevant masses of the pressure plates and the central plate, which temporarily store the thermal input, there is relatively little space available for the friction facing/cushion deflection system of the clutch. Nevertheless, the mileage (vehicle service life) requirements typical for an automatic transmission of about 250 000 km must be met.

In addition, the partial clutches, which are open for a longer period – unlike use in manual transmissions – experience dynamic loads due to vibrations of the open partial transmission. Burst damage to the clutch disc must be practically eliminated for safety reasons.

These special features result in new specific requirements for the friction facing/cushion deflection system of the clutch discs:

- large wear reserve designed to match the service life
- least possible loaded thickness
- high dynamic connection strength
- increased burst resistance

These requirements are met in the “SlimDisc facing system” (Figure 18) developed by LuK.

In this facing concept, the friction facing is fastened directly to a steel plate without a rivet recess (pressed or glued, depending on the facing material used). This driven plate increases the burst resistance and transfers the torque directly to the retainer plate. The foot area to join with the retainer plate is designed axially elastic so that it does not impede the axial movement of the spring segments in the clutch. Spring segments and shoulder rivets are no longer involved in the torque transfer and are also decoupled from the dynamic circumferential loads occurring when the clutch is open.

The clutch disc with the SlimDisc facing system can be made 1.5 to 2 mm thinner with equal wear reserve than a standard facing concept. This space advantage can be used as needed to enlarge the thermally relevant masses or to reduce the axial space occupied by the clutch.

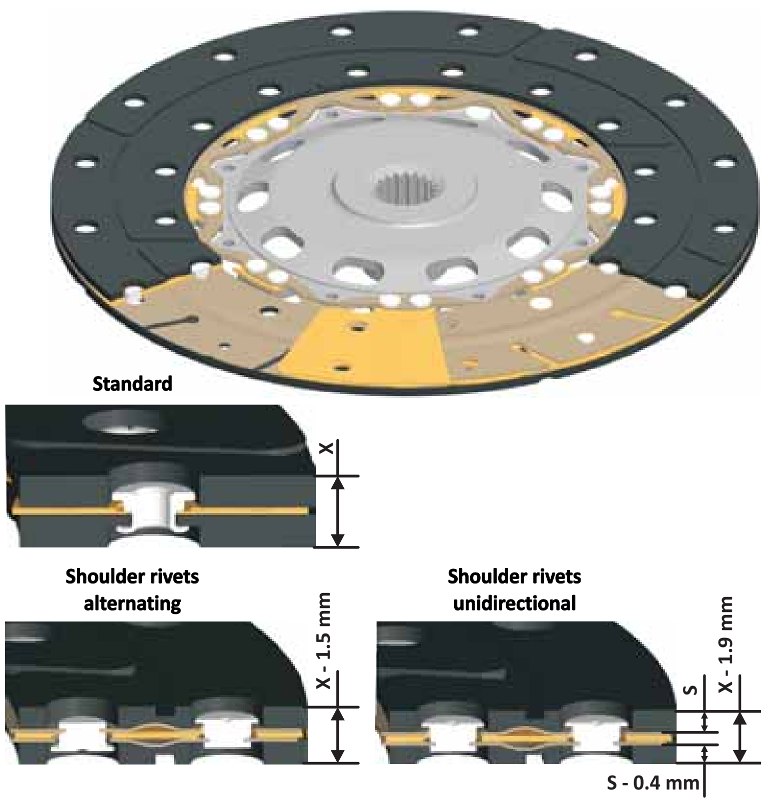

Figure 18 LuK SlimDisc facing system

With this system, whose possible applications are naturally not limited just to double clutches, burst speeds > 13 000 1/min can be realized even after thermal damage.

LuK FlexCompact

For applications of up to 150 Nm engine torque in which weight reduction and/or reducing the axial space requirement is the main focus, the FlexCompact clutch (Figure 19) developed by LuK provides new possibilities.

This light construction clutch was the result of an extensive function analysis. The clutch cover no longer consists of one deep-drawn part, but of several similar components that exhibit a very high axial stiffness after being assembled in the composite.

The function of the well-known diaphragm spring with fingers was divided into the actual diaphragm spring without fingers, which generates the clamp load, and individual actuation levers as a substitute for the fingers that provide the lift-off of the pressure plate by means of a boltless fastening to the cover. The stiff actuation levers ensure an excellent efficiency. In addition, the internal translation of the pressure plate can be variably selected, since there is no direct coupling between the actuation levers and the diaphragm spring load. This is advantageous especially at small engine torques small release loads and thus too small pedal forces would result if with a normal diaphragm spring clutch.

The pressure plate can be made standard as a cast pressure plate or a

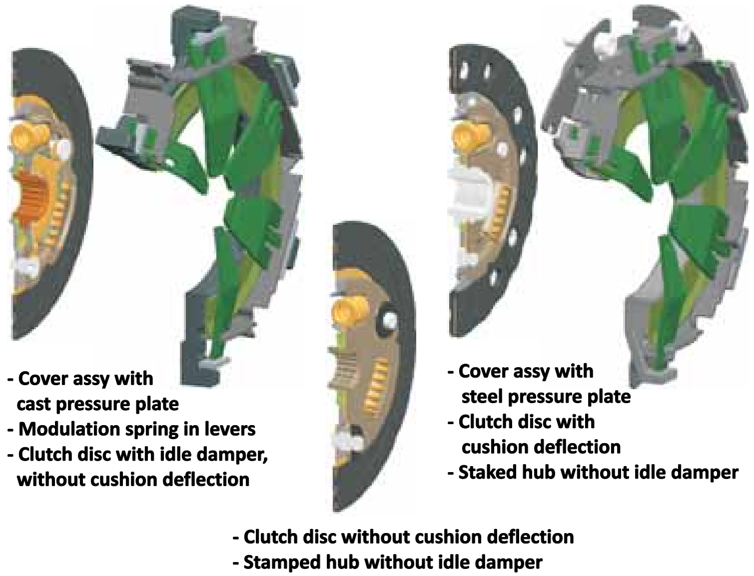

Figure 19 LuK FlexCompact

stamped steel pressure plate with correspondingly high piece counts (Figure 20).

The actuation levers are supported elastically by means of an elastic tab on the outside of the segment cover. The tuning of this tab load can be achieved in two different ways. In one design, the selected tab load is always higher than the maximum occurring release load. The modulation is by means of the cushion deflection in this system. In the other case, the elastic tab is designed such that the elasticity required for start-up is integrated in the actuating levers (modulation spring). In this way, the cushion deflection can be eliminated from the clutch disc. This principle is shown in comparison with cushion deflection in Figure 21. Here the cushion deflection provides immediate movement of the pressure plate with the appropriate actuation. When the effect of this cushion deflection ends, the lift-off of the pressure plate begins.

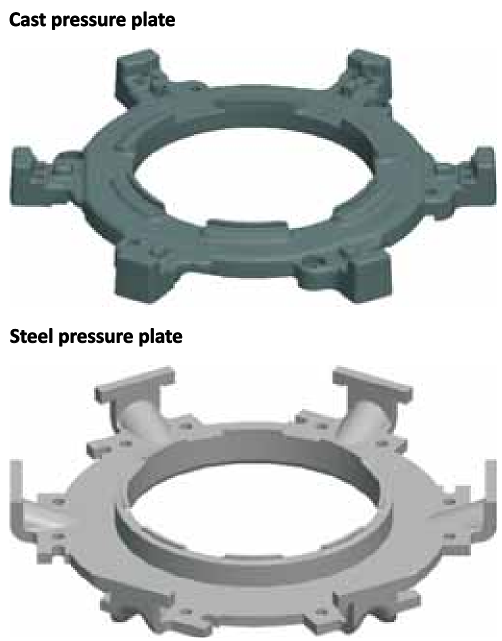

Figure 20 Cast vs. steel pressure plate

With the elimination of the cushion deflection, a retainer plate with a facing pressed onto both sides can be used. This reduces the loaded thickness of the clutch disc by up to 3 mm, which means additional space. The prerequisites for the elimination of the cushion deflection in the clutch disc are a narrow pressure plate and narrow facing rings to keep the thermal distortion low. Otherwise, the drive train should be as uncritical as possible as far as chatter. In this way, it is possible to reduce the mass and mass moment of inertia of the clutch by up to 35 %, depending on the design.

The limitation on applications in the lower torque range and the limited coil spring loads and masses as a result mean that the flange can be eliminated for spring guidance with the torsion damper. The spring guidance is designed so that the load transfer takes place from the retainer plate via the coil springs under shear load to the cover plate, which is directly staked with the hub.

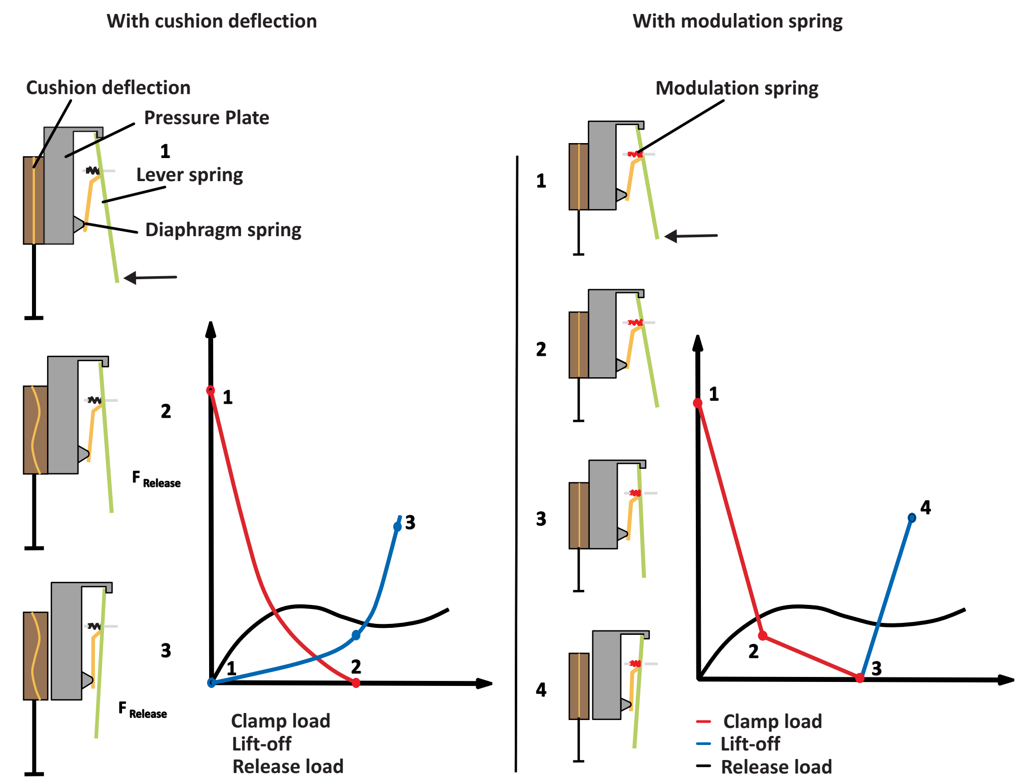

Figure 21 Function of cushion deflection and modulation spring

If the production numbers are high enough, the cover plate and hub can be economically manufactured as a single stamped part (Figure 22). Depending on geometry and costs, a three-part division of the spring window pattern is used instead of the usual four-part division.

A clutch disc with a pre damper can also be realized according to this principle. Through a combination of the possible variants of clutch cover and clutch disc it is possible to configure the LuK FlexCompact clutch according to individual customer specifications.

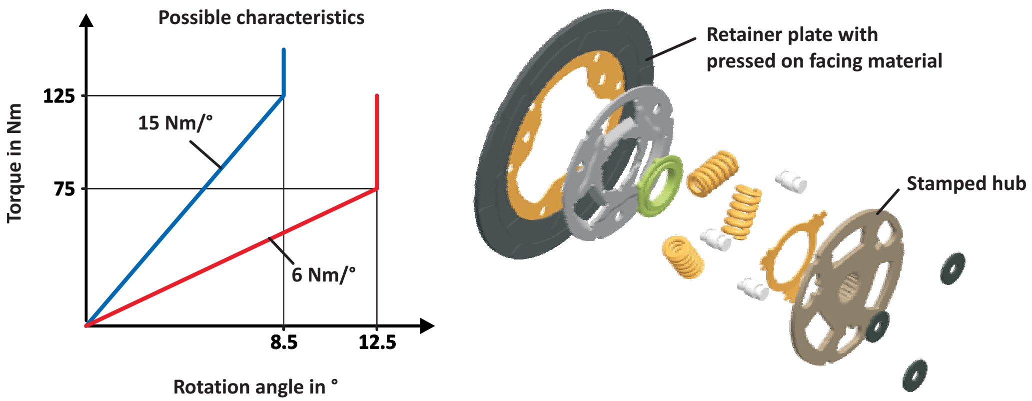

Figure 22 FlexCompact clutch disc

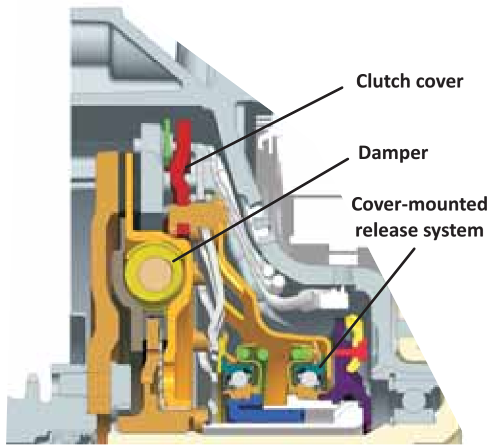

Figure 23 Clutch system for hybrid SUV

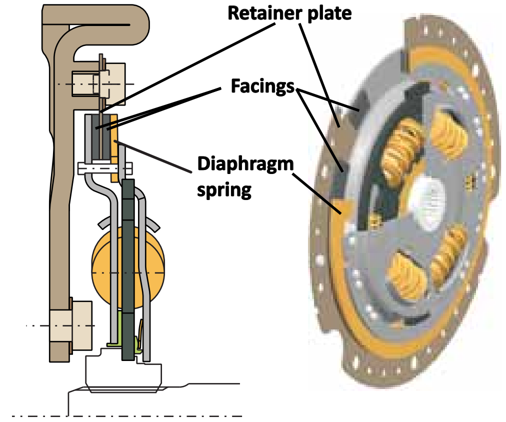

Figure 24 Damper with slipping clutch for safe torque limitation

Hybrid application

Special hybrid applications require a high degree of system integration. The example shown (Figure 23) was developed for a parallel hybrid for the stop-start of the combustion engine by means of the separation coupling. In addition to electrical operation, recuperation and boost are also possible functions. Because of the space available, a clutch design with the diaphragm spring attached on the outside was selected. The clutch disc has an arc spring damper based on the DMF. Cushion deflection can be eliminated due to the drag function of the engine by means of the E-machine (short actuation time with low energy input). The use of a cover-mounted release system makes a compact design in the axial direction possible. In this design, the release system is not supported on the transmission. The result is a reduced load on the crankshaft and a benefit to the vibration behavior of the entire system.

Dampers for hybrid applications range from a damper with clutch to torque limitation by means of a damper with wear-free spring guidance on to an arc spring damper based on the DMF.

Without suitable counter-measures, the mass moment of inertia acting in a hybrid system can lead to excessively high torque peaks, which would quickly cause the destruction of whatever damper is used. For that reason, a clutch is arranged before the damper to limit the torque in some applications.

Unlike other solutions, the concept for this clutch envisioned by LuK (Figure 24) enables easy mounting of the damper on the flywheel by the installer.

For another hybrid system, LuK provides the flywheel, the dampened clutch disc with optimized spring guidance and parts of the release system with a hydraulic line (Figure 25). The examples shown are similar in application, but lead to different designs due to customer requirements.

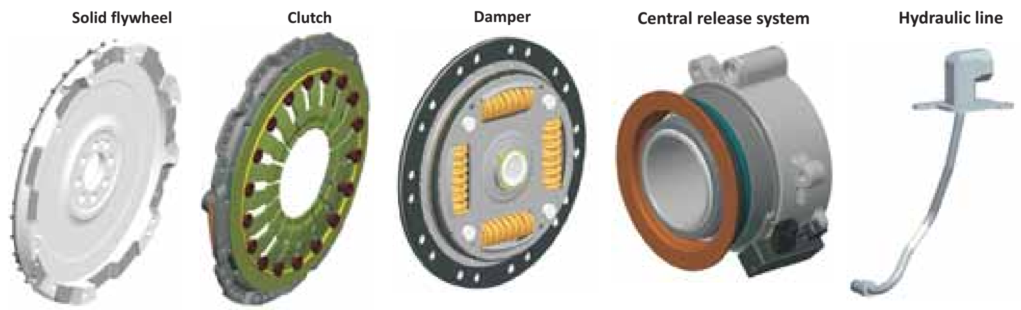

Figure 25 Hybrid system components

Summary

The concepts listed here show that there is still potential for improvement in the clutch system, both in terms of performance and economy. In combination with advanced technologies, especially in the development of new combustion methods and hybrid structures, new challenges are emerging, which LuK is taking on. What is clear even today is that the variety of solutions employed will continue to expand. The right concept, technically and economically, will be selected, depending on the specific customer requirements, and optimized to the benefit of the customer.

Literature

[1] Mikulic, L.: What is the future of conventional combustion engines? Video commentary at http://www.handelsblatt.com, 2009-09-16

[2] Ostmann, B.: E-Motion, auto motor und sport, Issue 21/2009, 63rd volume, p. 3

[3] Alternative Drives – Concept Overview, http://www.auto-motor-und-sport.de/eco/alternative-antriebe-konzept-ueberblick-938005.html, 2009-11-21

[4] Into the Future with Octane, http://www.spiegel.de/auto/aktuell/0,1518,661630,00.html, 2009-11-17

[5] Automakers Losing Faith in Hydrogen Power, http://www.handelsblatt.com/unternehmen/industrie/autohersteller-bmw-verliert-glauben-an-den-wasserstoffantrieb;2495118, 2009-12-07

[6] Reik, W.: The Self-Adjusting Clutch, 5th LuK Symposium, 1994, pp. 43-63

[7] Reik, W.; Kimmig, K.; Elison H.-D.; Meinhard, R.; Raber, C.: New Opportunities for the Clutch?, 7th LuK Symposium, 2002, pp. 191-202

[8] Zink, M.; Hausner, M.; Welter, R.; Shead, R.: Clutch and Release System – Enjoyable Clutch Actuation! 8th LuK Symposium, 2006; pp. 27-45

[9] Fidlin, A. and Seebacher, R.: Simulation Technology with the DMF Example – Finding the Needle in the Haystack, 8th LuK Symposium, 2006, pp. 55-71

[10] Zink, M.; Hausner, M.: The Centrifugal Pendulum-Type Absorber – Application, Performance and Limits of Speed-Adaptive Dampers, ATZ, issue 07-08/2009, pp 546-553

[11] Kroll, J.; Kooy, A.; Seebacher, R.: Land ahoy? – Torsional dampers for engines of the future, 9th LuK Symposium, 2010, pp 28-39