Improved synchronization in vehicle transmissions

S^3 construction saves material and weight

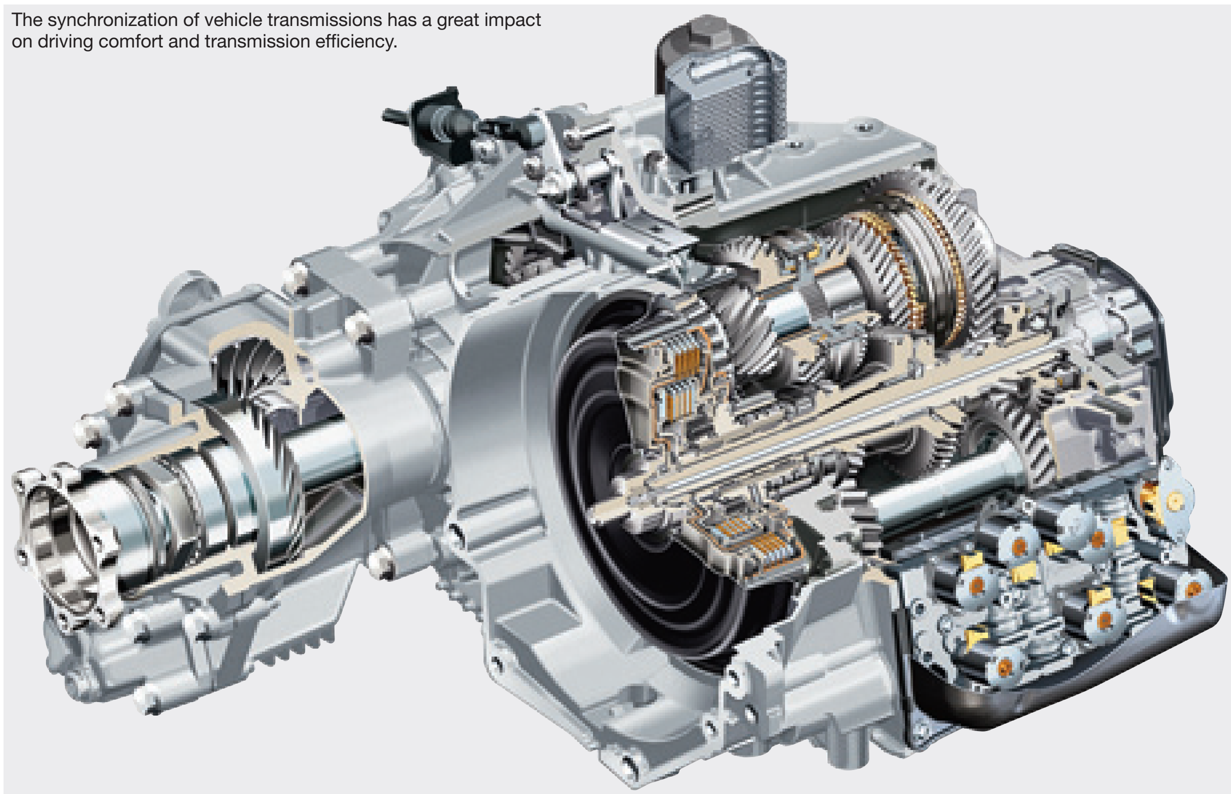
Metco has left the Sulzer Group and is now part of the Oerlikon Group.

oerlikon metco

High-performance transmission components generally lead to greater material use and complexity. This not only increases manufacturing costs but also affects the environment in a negative way. The engineers at Sulzer Friction Systems show that there is another way. They have developed the innovative S^3 (Segmented Synchronizer System) transmission synchronization, which guarantees high performance capabilities with reduced material consumption and weight.

Energy efficiency and fuel consumption are important issues in the automobile industry. The exhaust emission guidelines are being tightened in increasingly shorter intervals. The Euro 6 guidelines for passenger vehicles with drastically reduced upper limits will be introduced in 2015. Based on these stricter legal regulations and growing public awareness for ecological products, the manufacturers are focusing more on environmental aspects when developing new vehicles. A material- and resource-conserving design is already a core consideration during the development phase. One approach taken by the automobile producers is to optimize energy use

The synchronization of vehicle transmissions has a great impact on driving comfort and transmission efficiency.



1 Synchronizers today are primarily constructed according to BorgWarner principles. Increased performance is achieved through multiple-cone synchronizations, which have a greater weight.

along the entire power train. Efficiency is improved through measures such as:

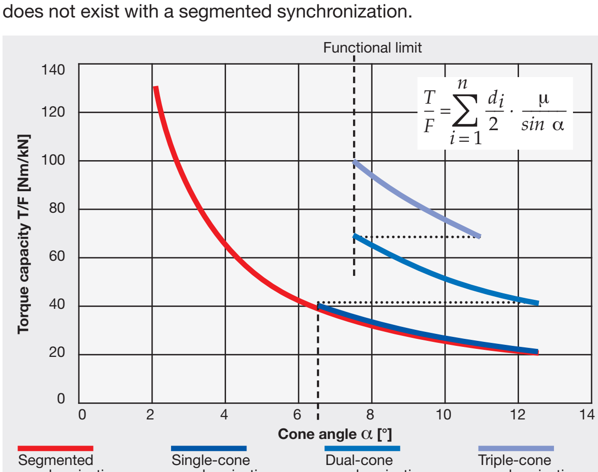
- Downsizing (for example, smaller engine displacement with the same performance)
- Forced induction engines / turbocharger (improved fuel combustion through forced air intake)
- Innovative high-efficiency transmissions

Synchronization for high-efficiency transmissions

The world's first seven-speed manual transmission has been available since 2011. Eight-speed, double-clutch transmissions and new hybrid transmissions, which make it possible for the brakes to regenerate energy, are currently under development. An essential component of these transmissions is the synchronization.

The synchronization reduces the differential speed to zero between the gear shaft and the gear wheel with a cone-shaped friction contact before the gear is engaged through a positive locking. The BorgWarner principle 1 has been the dominant synchronization design for decades. The shift force initiated by the driver through the gear lever is directed to the synchronization through an external and internal shift mechanism and exerts an axial force onto the outer ring of the synchronizer. The cone-shaped friction contact, as a reaction to the axial force, produces corresponding synchronizer torque, which reduces the differential speed between the friction contact surfaces.

2 Desired synchronizer torque capacities using a standard BorgWarner design are achieved through an alteration of the cone angle and through the use of multiple-cone synchronizations. However, the achievable torque capacities are limited by the construction. This limitation does not exist with a segmented synchronization.



The limits of existing optimization approaches

The most important criterion for synchronization is synchronizer torque capacity, i.e., the frictional torque generated, related to the axial actuation force. Depending on the position of the gear and the comfort requirements of the customer, different specifications result for the synchronizer torque capacity. This can only be varied through the angle of the cone when a radial case space is given 2. Theoretically, greater torque capacities could also be realized with very small cone angles. However, in practice, a reduction of the cone angle is only possible to a specific functional limit. Once the angle falls below this limit, a self-locking effect occurs, so that the friction plates cannot release themselves without an external force because of the friction conditions. This condition reduces shifting comfort or, in extreme cases, can lead to a gear locking so that it is impossible to shift into a gear. Furthermore, an increase in the torque capacity can only be achieved through a greater number of friction surfaces (multiple-cone synchronization). Due to the growing demands on the performance capabilities of synchronization, in particular, in the lower gears, double- and triple-cone synchronizers have established themselves.

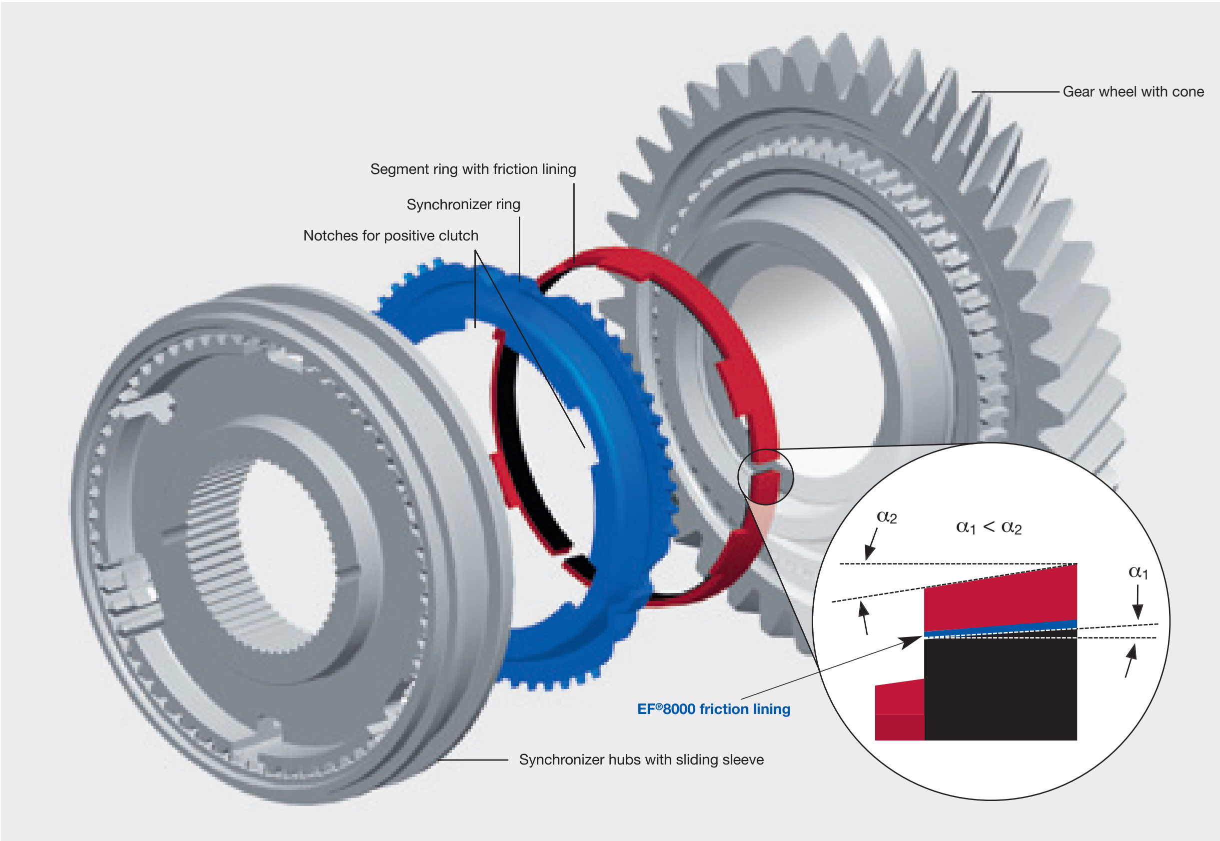
Sulzer has completely eliminated the constructive limitations of conventional synchronizations.

These multiple synchronizations are, indeed, more efficient, but they require more friction material and are heavier and more complex. This is not only bad for costs but also leads to increases in fuel consumption and emissions.

Over time, it has been possible to reduce this disadvantage of the BorgWarner design through continuous improvement and the use of innovative materials and assembly methods, but it has not been possible to entirely overcome it. The EF®5010 two-layer carbon friction lining developed and established on the market by Sulzer has, for example, an advantageous friction coefficient characteristic that shifts the functional limit to smaller cone angles. Using steel-plate forming technology, engineers have been able to realize considerable weight savings over earlier standard steel or brass forging technologies.

Innovation step through the new S³ construction

Through an innovative design approach, Sulzer Friction Systems has now succeeded in completely eliminating the con-



3 The new S³ construction approach for segmented synchronization (blue and red components) sets itself apart in that the synchronous torque production and the release of the frictional contact are improved by being spatially separated and completely independent of each other (detail drawing).

structive limitation of the self-locking effect of the BorgWarner synchronization. The fundamental idea consists of spatially separating and splitting among different surfaces the different functions, namely the task of synchronization—i.e., the generation of synchronizer torque—and the task of releasing the frictional contact. By doing this, the geometric layout can be optimized through the consistent and independent separation of the functions:

- High-torque capacity through small cone angles on the surfaces generating torque
- Excellent shifting through larger angles on the surfaces responsible for disengaging

Further, the inner circumferential loads in the ring have to be eliminated by segmenting the ring. The construction of this segmented synchronizing has the following advantages:

- Meets current requirements for synchronization performance and shifting comfort in manual and double-clutch transmissions
- Can be adapted to the existing construction space of conventional synchronizations without altering the surrounding components (drop-in design)
- Reduced weight through steel-plate forming technology instead of standard techniques
- Harmonizes with Sulzer coating technologies and equipment
- Lower manufacturing costs compared with multiple-cone synchronization

The system harmonizes with standard components and fulfills the requirements for a drop-in concept.

Optimum constructive execution

Figure 3 shows the favored construction for segmented synchronization. The segment ring is characterized by a large cone angle on the outer circumference (release function surface) and a smaller angle on the inner circumference (synchronization function surface). The inner circumference has a friction lining. This friction contact produces the necessary synchronizer torque in connection with the corresponding cone on the gear wheel. The outer circumference is in contact with a corresponding surface on the synchronizer ring. In addition, a positive coupling between the segmented ring and the synchronizer ring is necessary so that relative movement only occurs at the foreseen friction contact on the inner friction surface. The system is completed with standard components—synchronizer hubs with sliding sleeve and gear wheel—from conventional synchronizations. The requirements for a drop-in concept are thereby fulfilled.

Sulzer Friction Systems

Sulzer Friction Systems, as part of Sulzer Metco for over 50 years, has been a leading supplier of coatings and synchronization components with proved thermal-sprayed molybdic coatings and innovative carbon friction linings.

In 2009, Sulzer took over the automobile synchronization division of BorgWarner Inc., Auburn Hills, Michigan, USA. Through the development of new synchronization concepts, such as the S³ design, Sulzer offers customers high-performance and cost-effective solutions, which protect the environment through material and weight savings.

For more information on Sulzer's automotive components, please visit **www.sulzer.com/automotive**

Adapting to customer requirements through modular construction

The Sulzer solution with an inner cone angle of 3° has the same performance capacity as a conventional triple synchronization with a cone angle of 9°. Yet it has a greatly reduced weight and smaller friction plates with a corresponding lower need for friction material. The modular construction makes it possible to adjust the torque curve characteristics of the synchronization to the application requirements by just exchanging the segmented rings with another inner cone angle. The costs of making this exchange are low compared with the expense of changing three components in a multiple-synchronization design. This adaptation makes it possible to adjust the synchronization to the needs of the customers at a minimum cost.

High-performance carbon friction surfaces required

Because of the much smaller friction surface at the same performance level, the surface load on the friction material increases. The loads on the friction material in the form of surface pressure, specific energy, and performance are greater than for triple-cone synchronizers by a factor between 2.5 and 3. Such applications require high-performance friction plates. The latest carbon friction material technology makes this synchronization possible. Besides the proved EF®5010 friction surface, the latest Sulzer innovation, the two-layer material EF®8000 is particularly suited for this application. These two-layer materials stand out through very high durability and excellent friction coefficient characteristics even under extreme conditions.

Cost reductions and functional capabilities confirmed

The first analyses have confirmed that segmented synchronization can be manufactured for about 30% less than an equivalent triple-cone synchronizer 4. The principle concept of segmented synchronization has been proved in practice through function tests on a component test bed. It was possible to verify the theoretically calculated torque capacities through measurements. Continuous shifting tests have shown that the EF®8000 friction material used can stand up to the higher loads. The next step is the validation of the concept in transmissions and vehicles both in-house and at customers' sites.

Segmented synchronization is an innovative step for synchronization, which has been dominated by the traditional BorgWarner principle for decades. Sulzer has presented this concept to customers and the general public during seminars and direct discussions. The feedback was exceptionally positive and promising. Sulzer customers benefit from synchronization with greatly reduced weight and with the same performance capacity at a lower price. Sulzer's objective is to get segmented synchronization ready for series production. By doing so, the company will contribute to the fulfillment of the strict environmental standards of the automobile industry.

The segmented synchronization can be manufactured for about 30% less than a triple-cone synchronizer.

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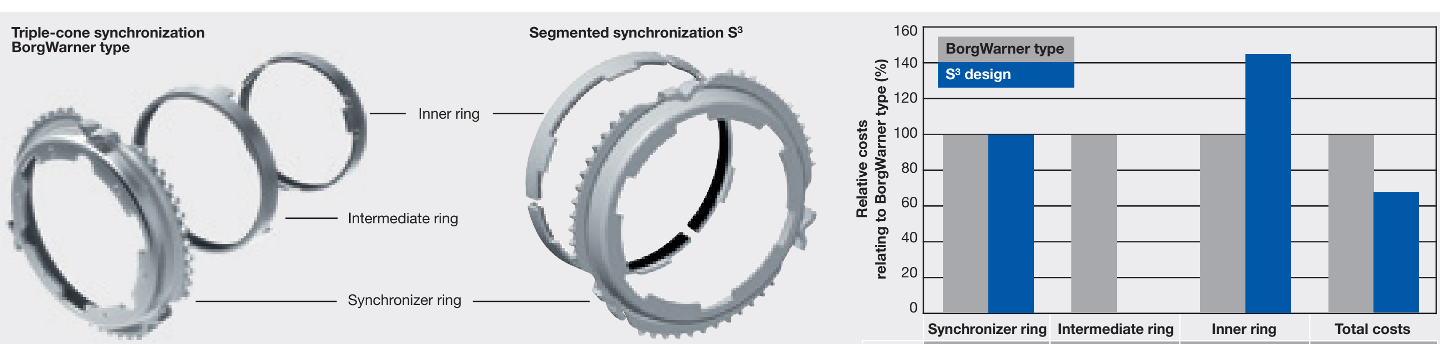

	Synchronizer ring	Intermediate ring	Inner ring	Total costs
Costs (BorgWarner type)	100%	100%	100%	**100%**
Costs (S³ design)	100%	0%	143%	**68%**

4 A comparison between segmented S³ synchronization and triple-cone synchronization with the same performance reveals material and cost savings of 32% with the triple-cone synchronization.