High-performance Friction Elements for Automatic Transmissions

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High-performance Friction Elements for Automatic Transmissions

Modern drivetrains and new trends in transmission design require compact clutches that provide smooth shifting capability and high fuel-efficiency. Such clutches need to be equipped with suitable friction enablers that can handle high temperatures, and facilitate stable friction characteristics as well as higher coefficients of friction. By optimising wet friction elements and offering design solutions, BorgWarner provides improvements in various aspects of clutch operation.

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Trends and Challenges

Current global transmission design trends are towards reduced package size or increased torque density, improved transmission efficiency, improved shift quality, and increased durability. In addition, recent developments of eight-speed to ten-speed automatic transmissions have created a need for friction materials that can handle the increased power density and increased energy levels. Along with the requirement of minimal dimensional changes in the lining, smoother clutch engagement necessitates the friction torque curve to maintain a positive controllability (u-v relationship) throughout the lifetime of the transmission under various operational conditions, including higher pressure applications.

The chemical and physical interactions of various fluids with friction materials play a key role in affecting the key friction performance of a wet clutch system. Wet friction elements are used in shifting or starting clutches inside conventional stepped automatic transmissions, dual clutch transmissions (DCT) and continuously variable transmissions (CVT) as well as in torque converter lock-up clutches, transfer case clutches and disconnecting clutches in hybrid applications.

Various clutch designs make high demands on applied wet friction elements, which not only need to provide stable friction characteristics and high temperature resistance but must also be able to handle higher torque and/or limited oil flow. Higher torque can be generated either by the use of high friction coefficient materials or by the use of higher unit loads by applying higher pressure. The use of simulation tools can help to optimise the friction plate design to reduce drag torque. New ideas for the core plate design reduce axial length, weight and cost. [1]

Development Steps in Friction Plate Design

According to the specific requirements for each application, the friction plate design is unique for every single application. The design process is started by the Statement of Requirements (SOR) from the customer. The first step in this process is the verification of the geometrical layout by calculation of net pressure on the basis of the required torque capacity. The second step is the thermal calculation of the interface and oil outlet temperature. The input here is the shift cycle by the customer.

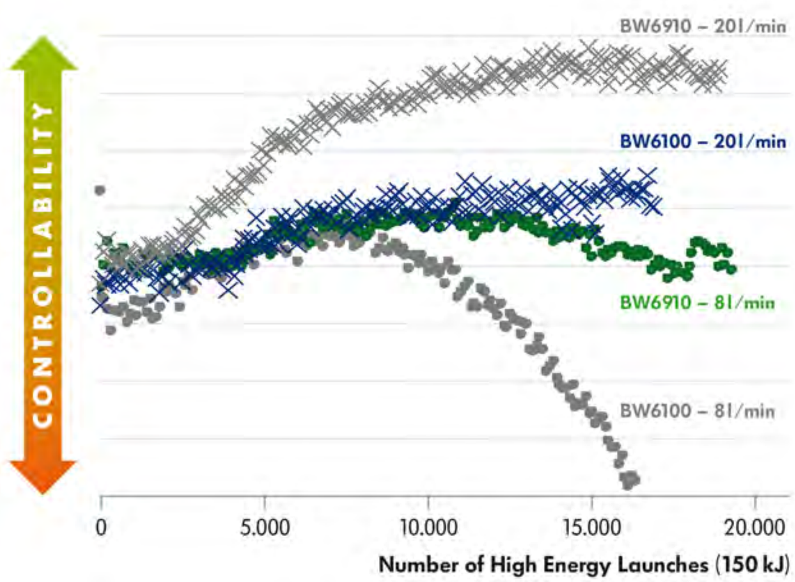
The third step is the drag torque calculation, using analytical, CFD and neural network simulation tools. The fourth step is the lifetime prediction using the duty cycle of the customer as input data.

Based on durability testing on different energy levels, it is possible to predict the lifetime of the friction system. The result of the whole process is the definition of the friction plate design in terms of the lining/friction material, groove geometry and core plate geometry as well as the definition of manufacturing in terms of segmenting and post processing.

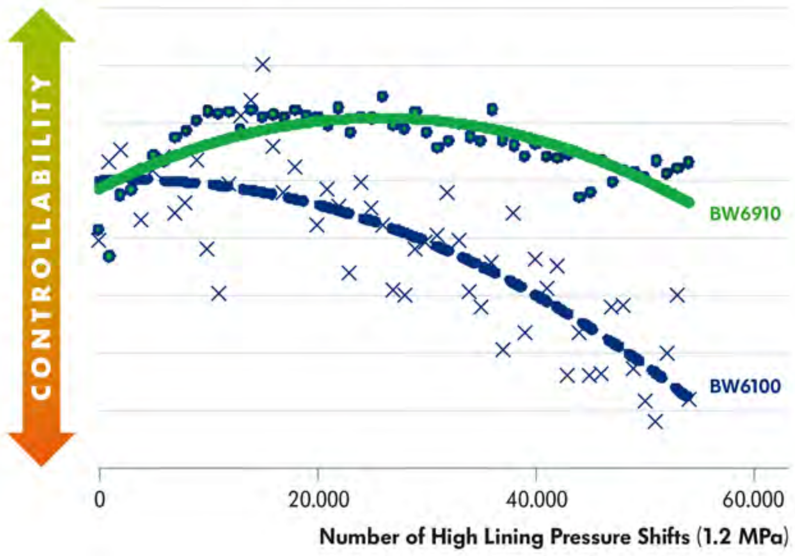
High Surface Adsorption Capacity

Modern friction materials feature improved heat resistance, thus enabling safer operation over the entire lifetime, even at lower cooling flows. However, the increased demands of new transmission designs require further and continuous advancements, such as friction elements with high surface adsorption capacity which readily adsorb the oil friction modifiers in the automatic transmission fluid (ATF) strongly on the surface while not being affected by degraded ATF.

To fulfil these requirements, BorgWarner has



Results of the durability test of the friction material during high energy launches



Results of the durability test of the friction material during high lining pressure shifts

developed a new friction material family. One friction material from this family is called BW 6910, which is especially designed for wet starting clutches, torque converter lock-up clutches, torque transfer clutches and hybrid disconnecting clutches. The material provides resistance to oil degradation and glazing, even with the use of modern low-viscosity oil. The material's ability to withstand high interface temperatures and to maintain a stable and positive µ-v characteristic (shudder resistance) is an enabler for the Low Lube concept.

In this case, the reduction of the cooling oil flow allows the use of more efficient pump systems and the optimisation of the efficiency of the transmission. In addition, the material makes it possible to handle a higher surface pressure. This provides the opportunity to reduce the number of surfaces or to reduce the friction diameter. Vehicle measurements of shudder at acceleration with micro slip conditions verified the advantage of this material type compared to standard launch friction material.

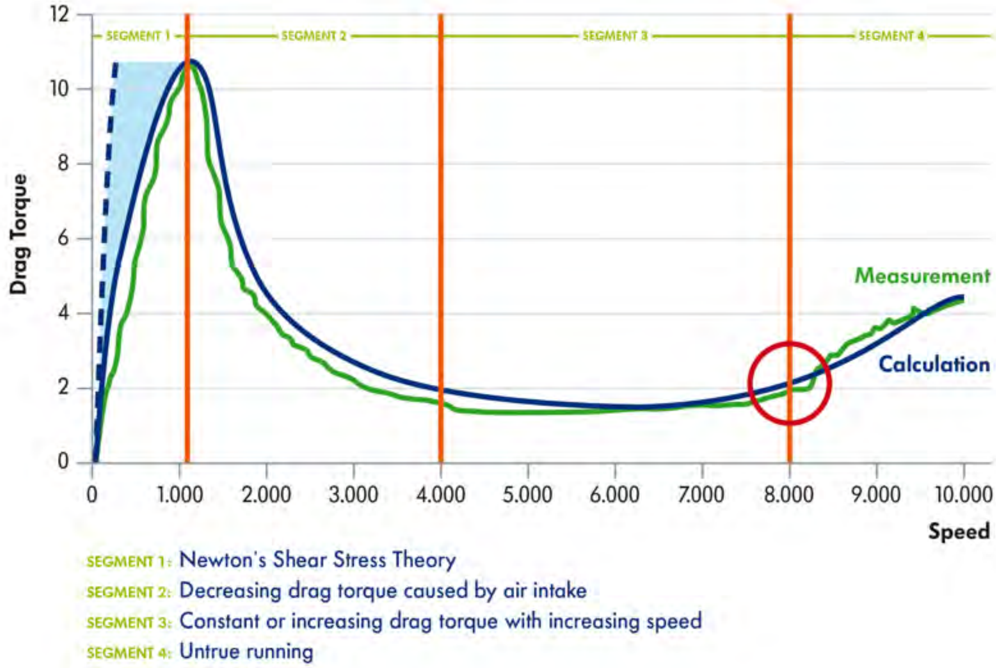
Hot Spot Resistance

New automatic transmission architectures require a higher differential speed on the shifting clutch elements. The emerging extreme shifting conditions at 70 m/s in conjunction with very low oil flow cause severe accumulation of hot spots on separators.

The new BW 5000 material family has especially been developed for those applications. This material is extremely elastic, has a uniform oil retention surface and a high-temperature fibrous surface. Target applications are shifting clutches in new state-of-the art automatic transmissions.

Drag Torque Reduction

Reducing drag losses plays an important role with wet clutch systems. There are various parameters that can cause drag losses inside a wet clutch. For example, in a dual clutch transmission, drag losses can be classified into three main categories: during pre-selection, id-



Analytical calculation of drag torque reduction

le-D losses and drag losses to the seal rings or bearings.

The cooling oil temperature plays an important role, too. However, most of these negative effects can be reduced or avoided by the use of software optimisations in the transmission control unit (TCU) or by implementation of an engine start-stop system [2]. Nevertheless, clutch design optimisation and improvements of the applied friction material are further possibilities for reducing drag torque.

For this purpose, there are different calculation tools that can be used for reliable drag torque prediction. Analytical modelling uses a calculation program with adjustment by actual measurements. The neural network method uses artificial intelligence for drag torque prediction on the basis of previously collected measurement data. A third method is the use of CFD software to perform exact calculations of fluid behaviour inside the clutch. Recent calculations finally resulted in the following different friction material design solutions – depending on the respective application – to effectively reduce drag torque:

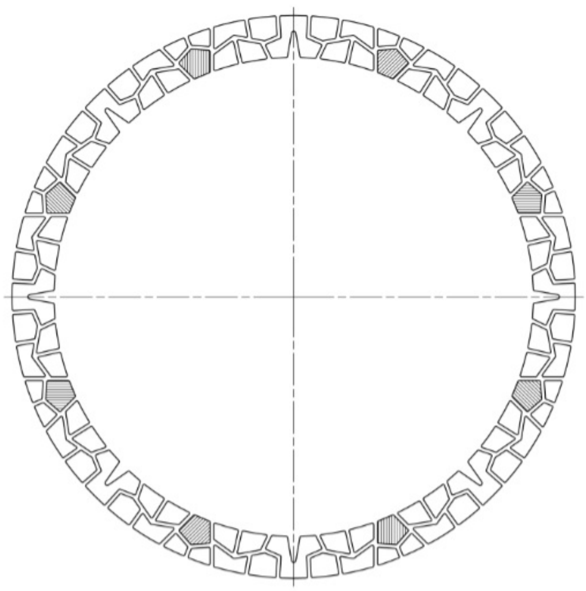


Illustration of the two-step lining design

- waved friction plates
- waved separator plates

Illustration of the Hemmed Spline design

• optimised groove pattern
• active separation
• two-step lining.

The two-step lining is a new concept that uses two different friction materials on the friction surface. A basic friction material appropriate to the specific application complemented by additional areas with a second very elastic material with increased thickness. When the clutch is open, the elastic lining element with an additional height causes an active separation process and prevents the friction surface from experiencing any suction to the separator surface. This concept leads to perceptible drag torque improvements compared to a waved plate design. It also improves controllability at low temperature and low pressure and results in less tumbling at high engine speeds.

Core Plate Modifications

Apart from the friction plate design, there is further potential for optimisation by modifying the core plate design. One new concept is the Hemmed Spline design. Here, the core plate steel in the spline area is folded double to increase the spline contact area. This can be used to reduce the length of the clutch pack without reducing the contact area of splines.

In an existing clutch, it is possible to increase the contact area without increasing the length of the clutch pack, or to avoid expensive heat treatment like nitriding when hammering problems occur. In summary, the Hemmed Spline design helps reduce weight, axial space and material cost while providing the same spline contact area.

A further modification method is the segmentation of the core plates. This new technology allows a much better utilisation of the core plate steel material, which is a reasonable contribution to cost reduction efforts. BorgWarner has developed a series production process and started series production with an OEM customer in 2012.

Conclusion

Recent trends in automatic transmission design also require improvements to the friction materials used. The choice of the appropriate friction product depends on the respective application and must be predicted using simulation tools in close cooperation with transmission and vehicle manufacturers to guarantee an optimum result. These simulations help to reliably predict the drag torque and allow optimisations of the friction plate layers during the design phase. The new BorgWarner BW 6910 friction material enables clutch systems with a high torque density and a low lube strategy, improved durability and improved NVH robustness to be produced. A reduced cooling oil flow (low lube strategy) additionally helps to optimise the efficiency of the transmission. What is more, optimised friction materials such as the BW 5000 family allow shifts to be performed at high differential speeds without a severe accumula-

Illustration of the segmented core plate

tion of hot spots on the separators. Further possibilities to improve drag torque, packaging and costs are new design concepts such as the Two Step Lining, a Hemmed Spline design and Segmented Core Plates.

References

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[2] Moser, A.; Saxena, V.; Schäfer, M.; Rischel, M.: Insight on wet clutch efficiency, 10th CTI Symposium, Berlin 2011

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