Organic Drivetrain Friction Elements

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Demanding requirements and emerging trends for modern transmissions mean that new developments in wet friction elements are much needed

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Introduction

The recent global automotive market trends for modern drivetrains require compact, smooth-shifting and highly fuel-efficient designs for transmission technologies. High-performance friction solutions need to withstand high temperatures and feature stable friction characteristics in combination with higher coefficients of friction, while further preventing hot-spotting.

Automatic transmissions with eight to ten gears triggered the development of friction materials that can handle the increased power density and energy levels. In addition, smoother clutch engagement necessitates a consistent positive μ-v relationship of the friction torque curve under various operational conditions over the transmission's entire lifespan. Wet friction elements are used in dual-clutch transmissions (DCT), continuously variable transmissions (CVT) and multistep automatic transmissions, as well as in torque converter lock-up clutches, transfer case clutches, and disconnecting clutches in hybrid applications. These different clutch designs, one of which can be seen in Figure 1, place high demands on applied wet friction elements, which have to provide stable friction characteristics as well as high temperature resistance, while handling higher torque and/or limited oil flow.

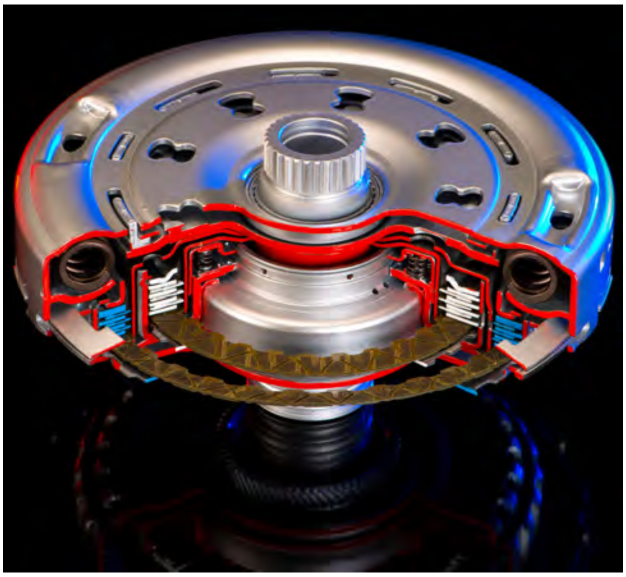

Figure 1. BorgWarner's optimized friction elements provide high torque density, low lube strategy and improved durability as well as NVH robustness

Friction Component Design

The friction plate design is unique to each individual application and is modeled according to its specific requirements. The design process then starts with the statement of requirements from the customer, followed by the verification of the geometrical layout by calculating the net pressure on the basis of the required torque capacity. Subsequently, the thermal calculation of the interface and oil outlet temperature based on the input of the shift cycle, as well as drag torque calculation, are carried out using simulation tools.

The last step is to make a lifetime prediction on the basis of durability testing on different energy levels. The whole process provides the definition of the friction plate design in terms of the lining/friction material, groove geometry and core plate geometry, as well as further providing definition of manufacturing with regard to segmenting and post-processing.

Friction Material Development

BorgWarner has developed a friction material family with a high surface adsorption capacity

Figure 2. BorgWarner developed innovative groove designs and uses advanced friction materials for a stable friction coefficient and improved temperature resistance

to fulfill the requirements of current transmission designs. The material BW 6910 is used for wet starting clutches, torque converter lock-up clutches, and hybrid disconnecting clutches. It provides resistance to oil degradation and glazing, as well as a higher-pressure capability.

Additionally, it features high interface temperature resistance and is able to maintain a positive µ-v characteristic. These abilities qualify the material, which is illustrated in Figure 2, as an enabler for shudder resistance over the whole lifetime. The extremely elastic BW 5000 friction material features a uniform oil retention and high-temperature fibrous surface. It was developed for applications with a high shifting energy and extreme shifting conditions at differential speeds of up to 100m/s. It can also handle low cooling oil flow, which causes severe accumulations of hot spots on separators. Since the new transmission architectures require a higher differential speed of the shifting clutch elements, the BW 5000 is used for shifting clutches in state-of-the-art automatic transmissions.

Drag Torque Reduction

Most negative effects causing drag losses in a wet clutch can be reduced or avoided by using a stop/start system or by using software optimizations in the transmission control unit (TCU). Nevertheless, improvements to the clutch design are needed to further reduce drag losses. Various calculation tools such as analytical modeling, the neural network method and CFD software are used for reliable drag torque prediction. The calculations resulted in five different friction material design solutions to effectively reduce drag torque depending on the application in hand.

One solution is the two-step lining, a concept which makes use of two different friction mater-

Figure 3. Illustration of the segmented core plate

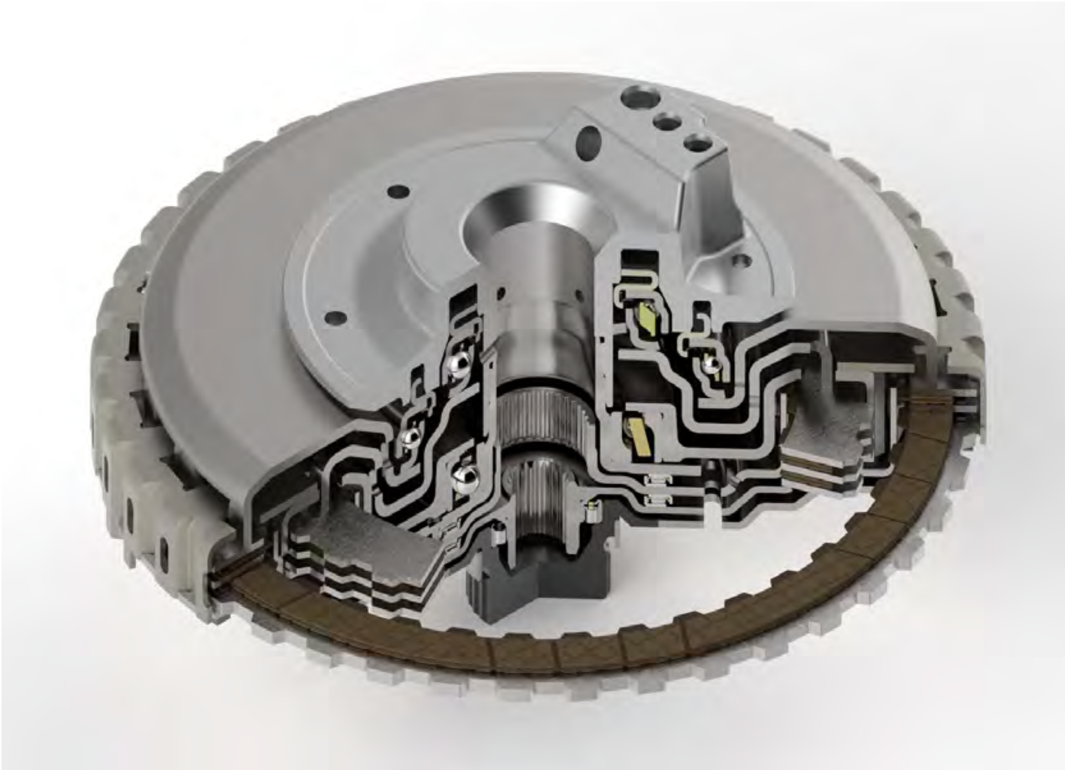

Figure 4. High-efficient dual clutch design

ials on the friction surface, including one basic friction material appropriate to the specific application and one very elastic material for increased thickness. This elastic material causes an active separation process and prevents the friction surface from experiencing any suction to the separator surface when the clutch is open. The result is improved controllability at low temperature and low pressure, which enables less tumbling at high engine speeds and offers significant torque improvements compared with a wave plate design.

New Design Solutions

Modifications of the core plate design, such as the hemmed spline or the segmented core plate design, allow further improvements to be made. The hemmed spline design features a double-folded core plate steel in the spline area, which can be used to decrease the length of the clutch pack without reducing the contact area of the splines. In addition, it offers the possibility of increasing the spline contact area of existing clutches without added clutch pack length, and it helps to avoid expensive heat treatment such as nitriding when hammering problems occur. The segmented core plate design, which is illustrated in Figure 3, allows for a better utilization of the core plate steel material to reduce costs.

Because of recent industry trends, BorgWarner has improved its friction materials and friction element designs, as can be seen in Figure 4, working in close cooperation with the transmission and vehicle manufacturers using simulation tools to optimize the performance for the applications involved. For this reason, BorgWarner has developed the friction materials BW 6910 and BW 5000 for improved durability and NVH robustness. The hemmed spline design helps to reduce axial space and weight. The segmented core plate design enables lower material costs, while maintaining the same functionality. In addition, the two-step lining concept is a further possibility for improving drag torque, packaging and costs.

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