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All-wheel drive disconnect clutch system

Brian Lee

Introduction

All Wheel Drive vehicles continue to be popular around the world for their advantages in safety and capability. Therefore, the fuel economy of AWD must be improved like their conventional vehicle cousins. The additional rotating components offer new opportunities to eliminate losses. By disconnecting the secondary driven axle and propshaft, the rotating losses in the bearings and seals are eliminated. Such a system is capable of achieving greater than 5 % fuel economy improvement in a typical passenger car. The system can be packaged in a conventional AWD powertrain or, where space is a constraint. The space and weight savings created by inclusion of the Schaeffler lightweight differential in a transaxle allows introduction of a disconnect clutch system.

The basic configuration of the system can be seen in Figure 1. AWD vehicles generally consist of permanently engaged front and rear drive axles connected via 90° ring and pinion gearsets located in the front power transfer unit (PTU) and the rear differential assembly. During normal driving, i. e. non-slipping road conditions, the secondary axle, typically the rear, is spinning but contributing no power to the vehicle propulsion or control, therefore significant energy is lost due to friction in these drivelines.

System description

The Schaeffler AWD disconnect clutch system is incorporated into the input shaft of the front PTU, thus allowing disconnection of the power flow where the secondary axle driveline branches from the primary axle. When used in conjunction with rear axle disconnects, perhaps simple dog clutches, the secondary driveline rotation can be stopped thus eliminating the parasitic power losses. Reconnection of the power flow is initiated by an electronic control module based on pre-emptive monitoring of multiple driving conditions. Lock-up of the system can be completed within 500 ms.

The disconnect system (Figure 2) is comprised of a high-torque, triple cone synchronizer pack energized via an electromotoric actuator. The electric motor is coupled with a force multiplying roller ramp system capable of producing the several thousand newtons of shift force required for synchronizing driveline velocities. The shifting mechanism is packaged radially around the driveshafts thus eliminating the need for a secondary shift-rail axis. This unique arrangement produces an extremely efficient package volume capable of high-energy synchronizing events.

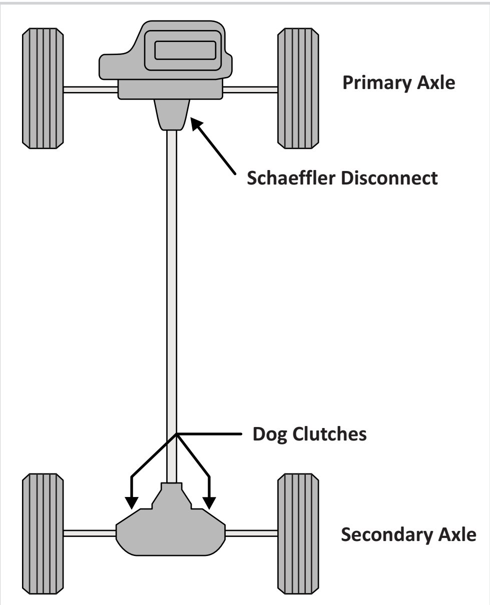

Figure 1 Typical layout of an AWD powertrain

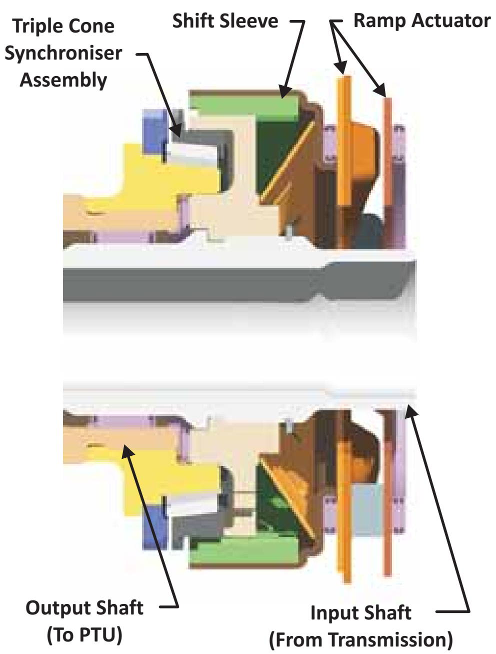

Figure 2 Cross section of actuator and synchronizer

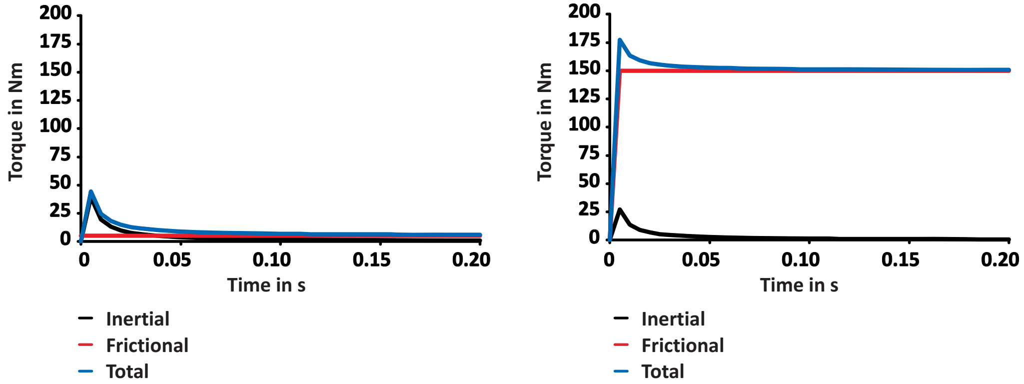

Figure 3 Synchronization torques and times for manual transmission (left) and AWD (right)

While drawing on proven systems and materials, designing for the dynamics of the AWD requires a restudy of the synchonization equations. Synchronizer design is governed by the power limits of the chosen materials. Synchronization power can be defined by the following equation, where I is driveline rotational inertia, ω is differential velocity, t_{synch} is time to synchronize and T_{drag} is the frictional torque to rotate the driveline:

$$P = \frac{I \cdot \omega^2}{t_{synch}} + (T_{drag} \cdot \omega)$$

The power equation can be easily separated into two components, one influenced by inertial loads and the other by frictional loads. In a typical manual transmission shift event, the power contribution from the inertial loads is on the order of ten times greater than the frictional loads. High differential velocities synchronized in very short times produce high inertial loads, while well lubricated transmission bearings maintain frictional torque at low levels.

Looking at the components of the power equation in the AWD application, we see a reversal of the contribution of each component, particularly at cold temperatures where driveline frictional drag becomes extremely high. In a cold temperature AWD shift, the frictional component becomes significantly greater than the inertial component.

Removing the velocity parameter from power yields the equation for synchronization torque:

$$t_{synch} = \frac{I \cdot \omega}{t_{synch}} + T_{drag}$$

Figure 3 shows the influence of each torque component in a manual transmission versus an AWD synchronization event, where the green line is total synchronization torque, red is the inertial component and blue is the friction component. While it can be clearly seen that torque is higher in the AWD disconnect system, the power limits of a manual transmission synchronizer are not exceeded.

AWD synchronization requires significantly higher torque than a manual transmission shift, and it must be maintained throughout the shift. These requirements dictate a unique design for the shift actuation system. The traditional shift system design, using a shift rail, shift fork, and pads becomes unacceptable under these conditions. High loads transmitted through the shift fork to the secondary shift rail axis produce excessive bending moments and can cause binding, fatigue and wear problems in the components.

The Schaeffler disconnect clutch system eliminates the secondary axis of the shift rail and fork and replaces it with a coaxial roller ramp actuator module. This unit consists of an input plate with ramps, an output plate with ramps and a caged roller assembly between the two plates.

The input plate is coupled to the electric actuator motor via a gear train and is able to rotate around the main PTU input shaft axis. The output plate is rotationally fixed to the PTU aluminum case via tabs on the outer diameter, but is able to move coaxial along the main shaft axis. When the input plate rotates, the rollers ride up the ramps thus forcing the output plate to move axially. The output plate is coupled with the synchronizer shift sleeve, therefore the function of the ramp actuator is to apply force to the synchronizer assembly through the shift sleeve. In this manner, the relatively low torque of the emotor is magnified to create adequate force for synchronizing AWD torques. In a first step the velocity of the parts is synchronized. Once the parts are synchronized the parts are coupled by a spline (Figure 4).

In addition, the coaxial positioning of the actuator allows a high system stiffness and thus less likelihood of a shift system failure. Finally, the coaxial package produces a very compact shift system, which produces minimal underhood packaging complications.

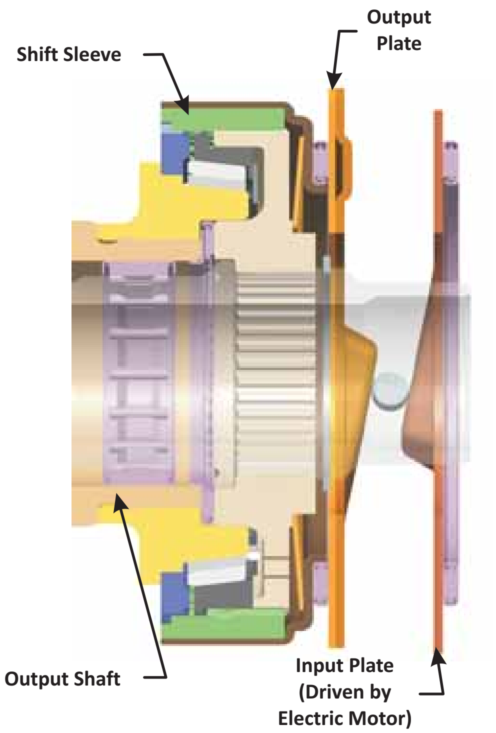

Figure 4 Actuated AWD disconnect clutch system

Conclusion

The AWD disconnect clutch system consists of known, reliable parts and is packaged radially around the shaft of the PTU. It is operated by a coaxial, electromotoric actuator. The engangement mechanism is especially designed to the high operation forces. By disconnecting the second axis of a drivetrain a significant reduction of friction losses and thus a much better fuel economy is achieved. In extreme cases the second axis is actuated within 500 ms. The system offers fuel savings potential of about 5 %, bringing an AWD vehicle to a similar fuel economy as the FWD base vehicle with no sacrifice in driveability.

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