EV transmissions: lessons learnt from a decade of EV projects

Drive System Design has been at the forefront of EV transmission technology for over a decade and in that time has worked on more than 70 EV transmission projects. In 2011, DSD commenced development of its own powertrain with an integrated multi-speed transmission called MSYS. The concept was ahead of its time with a revolutionary alternative approach to powershifting at the heart of the system.

We've often been asked why an electric powertrain needs a transmission at all, since traction motors can deliver high torque from low speed. In practice, motor efficiency is poor at low speed, which reduces range, and torque drops rapidly as revs increase, limiting the vehicle performance. This makes a design without a transmission, such as one with wheel-mounted motors, better suited to low-speed, short-range vehicles where maximum cabin space is a priority. Typical examples are the autonomous pods or 'skateboards'.

Even a single-speed transmission can improve an EV powertrain. Firstly, it increases packaging flexibility because the motor, or motors, no longer need to be on the axle centre line. Secondly, a large reduction ratio (up to 15:1 with a two-stage reduction) can be achieved, enabling the motor to operate at speeds and torques where efficiency is optimised for the vehicle's most frequent operating region. And finally, for a given vehicle performance, the motor can be smaller, lighter and lower in cost when combined with a transmission.

Multi-speed EV transmissions become preferable for applications that demand the highest performance or efficiency. In performance terms this could be: improved launch, top speed, off-road capability, or various special vehicle modes. Efficiency increases come from downsizing the motor and power electronics, in turn increasing the vehicle's range or reducing the battery capacity requirement.

The appropriate number of speeds is not only determined by engineering requirements; as few as two speeds could potentially optimise both launch and top speed. However, such a system would typically have a ratio step of around 2.5:1 which is too great for adequate shift comfort. Customer expectations for smoothness are likely to only be met if the ratio step is limited to around 1.6:1.

This requirement for smooth (power-) shifting also dictates the preferred transmission type. Multi-speed EV powertrains for passenger cars generally require powershifting to eliminate torque interruption, which limits the choice to an automatic, DCT or a system like the DSD's MSYS. But there is more to shifting than just refinement; drag losses must be reduced to a minimum, no energy should be consumed when in gear and development risk and costs should be minimised by using proven technology.

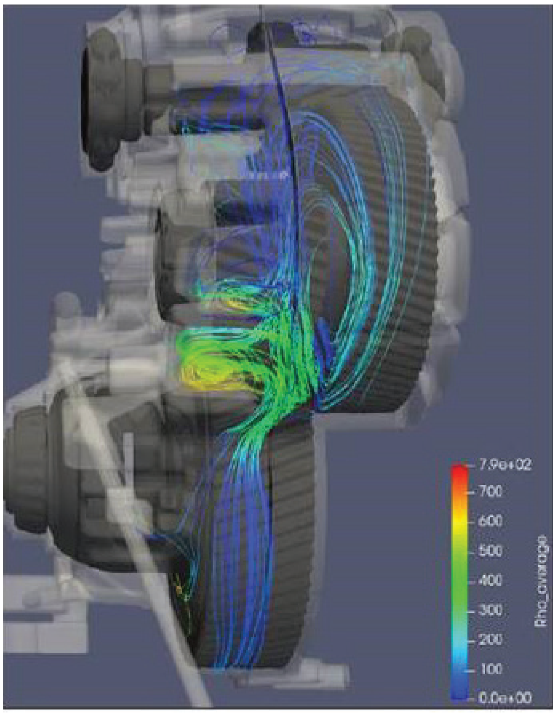
In the case of our MSYS system, these requirements were met by using a cone clutch to transfer torque as a friction device during the shift, and a dog clutch to lock the gear in place. By separating the functions in this way, the cone clutch provides the seamless shifting required while the dog clutch latches the system to ensure that no energy is consumed between shift events.

Any EV transmission must meet exacting NVH standards because there is no IC engine to mask unwanted noise. Designing for improved refinement often conflicts directly with the need for maximum efficiency. At DSD, we developed a method for the optimisation of gear geometry; ensuring a design

DSD's multi-speed electric powertrain MSYS that provides low TE (transmission error), low sensitivity to manufacturing tolerances, and the best possible durability and efficiency. This method is now proven and used to solve many EV transmission noise issues.

Low noise in EV transmissions is not only a function of low excitation; controlling the level of response is also important. Sensible design of the housings enables the separation of the various system modes and the distribution of strain energy. Through the redesign of one such housing, we reduced the vibration level to less than 50% of the original. In another example, the vibration measured on an EV transmission housing, peaked at 481m/s2. After just six weeks' work, the optimised system with new gears and a modified housing was tested at only 10.6m/s2, a 98% reduction.

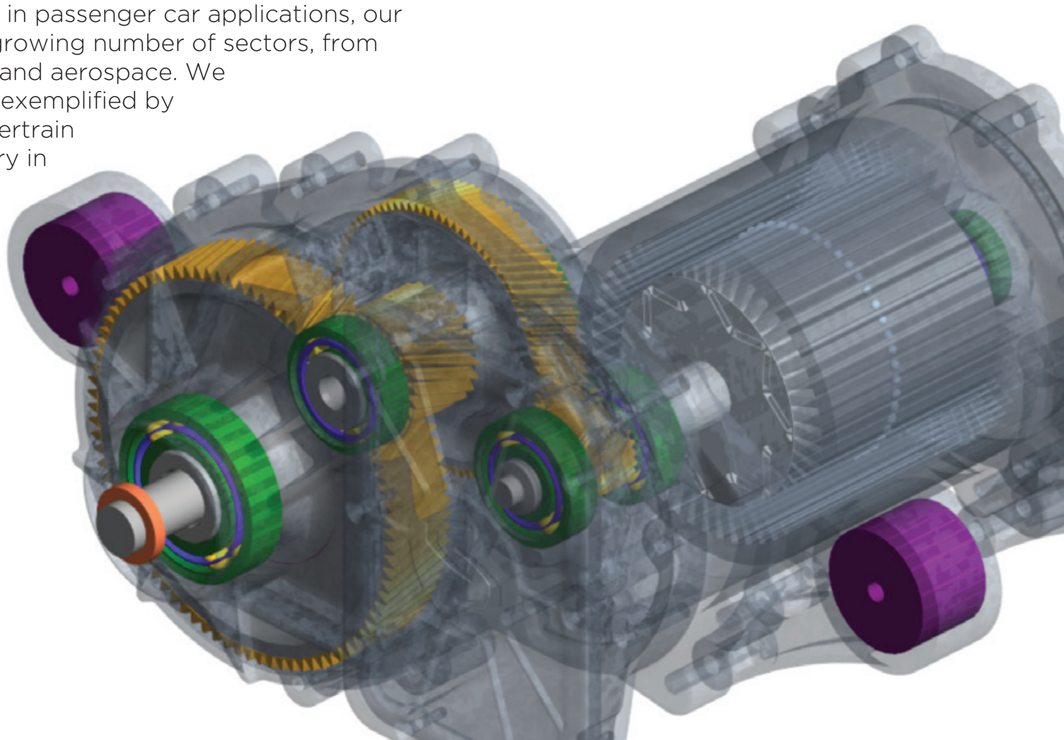
The mounting strategy can also be used to alter the noise behaviour of the system; wide mounts provide good transient and load reversal response, and are compatible with conventional powertrain mounting positions. However, they require a very stiff, large structure to hold them in place, which risks a vibration response in the critical 1-3 kHz region, as well as an airborne noise risk. In contrast, narrow mounts avoid the large structure but are less able to meet transient and load reversals, and may produce structure borne noise. There is no universal solution and, in general, the mounting strategy employed is largely dictated by package space.



Optimising lubrication flow to improve efficiency

Any transmission design must also deliver the expected durability. In the case of EV transmissions, a common concern arises with spline fretting. At DSD, we have generated spline fretting models that examine the effects of constraint conditions and misalignment for different loads. The key learning is that a location diameter near to the spline helps considerably in the reduction of fretting damage. To avoid interface and durability issues, the best designs integrate the motor and transmission into a single electric drive unit.

Over this last decade, we have developed a track record of determining the optimised EV drive solution, achieving the best compromise in often conflicting attribute requirements. From an initial focus in passenger car applications, our experience has been applied to a growing number of sectors, from commercial vehicle to motorsport and aerospace. We know that an holistic approach, as exemplified by our 'ePOP' toolset (electrified Powertrain Optimisation Process), is mandatory in this optimisation process. We also know that all sub-systems of a full EV drive system are equally important, and in this last decade, our skills in electric motors, power electronics, controls, test and development, have reached the same world-class level of capability as our core EV transmission skills.


Electric Drive Units (EDUs) have become increasingly more integrated

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