

4SED: THE COMPACT SEAMLESS-SHIFT CLUTCH-LESS TRANSMISSION FOR ELECTRIC VEHICLES

“The 4SED is a patented design concept for electric vehicles that takes inspiration from DCT (Dual Clutch Transmission) technology, from which the 4SED takes all the benefits but not the problems in terms of weight, size, efficiency and cost.”

DESIGN CONCEPT

The selection of two drive motors instead of one for electric vehicles is not new, but mating those drive motors to a gearbox with independent input shafts, which then drive a common output through multiple ratios is a new and novel concept. This is the patented design for the 4SED, where the motors are permanently bound to the transmission input shafts (one for odd and one for even gears). It has the advantages of requiring no clutches and no synchronisers and, thanks to the control strategy possibilities, the ability to control torque and speed in order to use only one motor or both motors at the same time.

The aim for the 4SED was improving performance and efficiency, being able to shift seamlessly and avoiding the complexity and cost of a conventional powershifting transmission. The solution is an ingenious mechanical design that is controlled by a reduced set of transmission control software, when compared to alternative automated transmission technology.

The demand for more speeds comes from the efficiency variability at different speeds; electric motors operate at a peak efficiency of around 90% but this can fall to 60-70%, particularly at low speed. Figure 1a shows the theoretical Force-Speed envelope for the 7 possible operating states, covering each possible gear combination. Each state has its own sweet spot for efficiency, resulting in a wide range of operating conditions that run close to maximum possible efficiency: The 4-speed dual motor concept has a predicted 15% improvement in efficiency over the combined European cycle compared to a single speed gearbox [1]. Figure 1b illustrates the wide range of sweet spot conditions by combining the areas of high efficiencies (approximately >90%) in all gears and combinations of gears.

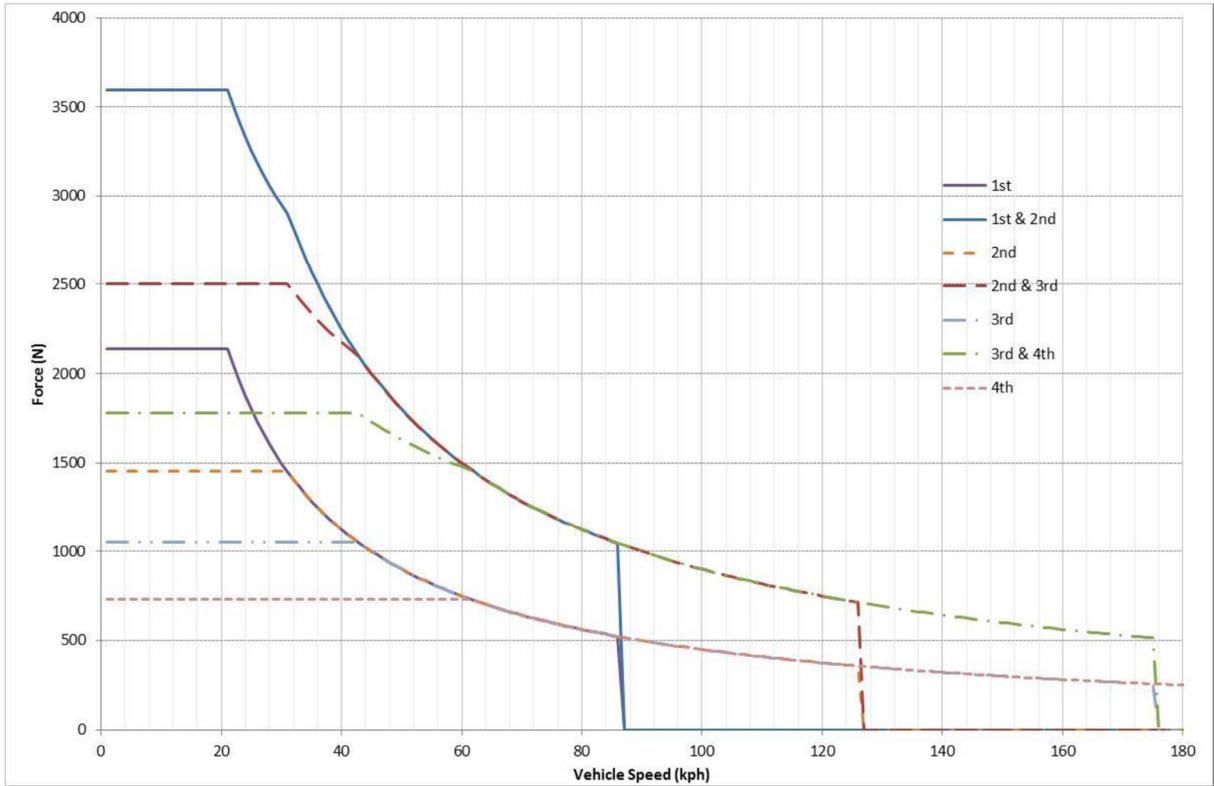


Figure 1a: An example of the traction force as a function of vehicle velocity for the different transmission states

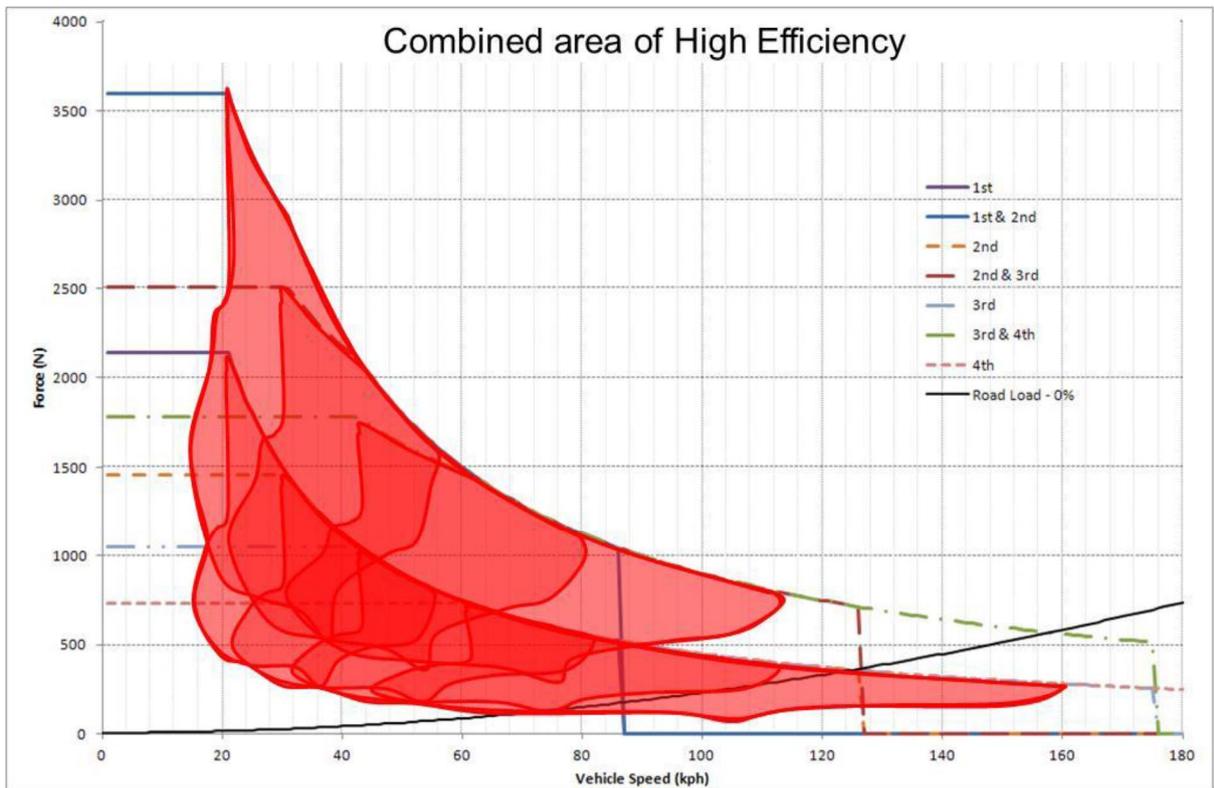


Figure 1b: An illustration of the wide range of operating conditions that can be typified as >90% operating efficiency of the motors in all gear combinations

Simplicity and Modularity

The elegance of the patented 4SED mechanical design is in its simplicity and modularity. This gives rise to a cost effective solution for the automotive market and makes it attractive for the full spectrum of automotive applications from low cost city cars to high performance GT cars and commercial vehicles.

The simplicity of the 4SED is achieved because of the omission of clutches and synchronisers because the motors can be used for launch manoeuvres and gear-shifts in the 4SED configuration.

The modularity is achieved through scalability of the design, and also from the ability to have the motors located at opposite ends of the gearbox, the layout shown in Figure 2, or parallel to each other, Figure 3, giving ultimate flexibility for vehicle installation.

Figure 2 is an example of the generation 1 design, which is the transmission used in a high performance GT vehicle, and Figure 3 is an example of the generation 2 design for use in more mainstream automotive applications.



Figure 2: The first assembled prototype unit, with both motors mounted at the same ends of the transmission



Figure 3: The second generation prototype which has each motor mounted at opposing end of the transmission

DEVELOPMENT ACTIVITIES

Activities are currently underway to produce a demonstrator vehicle for the 2nd generation design of the 4SED. The philosophy for this design was to exploit the benefits of the 4SED for an electric minibus, where the use of multiple ratios gives good benefits in gradeability and high load carrying. The project is being part-funded by the Niche Vehicle Network and is a collaboration led by Vocis Ltd. with 2 partners, Zytec and Surrey University; Zytec offer complete driveline solutions to some of the most challenging OEM EV programmes and Surrey University have a Faculty of Engineering with the capability to develop detailed models to simulate and optimise the benefits in economy and performance.

The versatility of the 4SED was also demonstrated by being able to have a design with opposing motors or adjacent (parallel) motors, with a high degree of commonality of parts, as shown in Figure 4.

		<p>Common Input Shafts</p>
		<p>Common components on Intermediate Shafts</p>
		<p>Common gear-select actuation system</p>
		<p>Common Differential</p>

Figure 4: The Generation 2 design showing the assembly for opposing motor design on the left and the adjacent design on the right, highlighting the commonality of parts between the two designs

For this second generation design the gears are selected by an electrically actuated barrel cam. This solution has the advantage over the electro-hydraulic solution because it removes the complexity and cost of the electro-hydraulic pack, The motor and gearbox specification for the second generation design are found in Table 1.

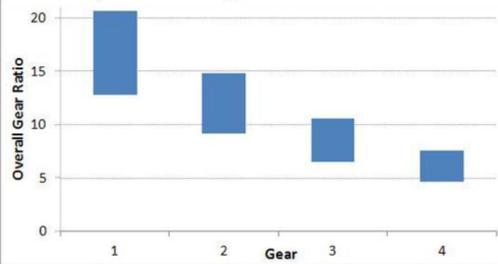
Motor	Motor Continuous Peak Power	25kW ea. 50kW total	35kW ea. 70kW total										
	Maximum Torque	64Nm ea. 128Nm total	75Nm ea. 150Nm total										
	Maximum Input Speed	15,000rpm	15,000rpm										
Gearbox	 <table border="1"> <caption>Overall Gear Ratio Data</caption> <thead> <tr> <th>Gear</th> <th>Overall Gear Ratio</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>18</td> </tr> <tr> <td>2</td> <td>14</td> </tr> <tr> <td>3</td> <td>10</td> </tr> <tr> <td>4</td> <td>7</td> </tr> </tbody> </table>			Gear	Overall Gear Ratio	1	18	2	14	3	10	4	7
	Gear	Overall Gear Ratio											
	1	18											
2	14												
3	10												
4	7												
Open Differential													
Electric Motor via Barrel Cam for Gear Actuation													

Table 1: Powertrain Specification figures for the Generation 2 Design 4SED (25kW and 35kW)

SUMMARY

Future electric vehicle growth is a certainty and the patented 4SED exploits the benefits of electric machines in a new and novel way. The mechanical design and transmission control software gives a complete transmission solution for electric vehicles that gives improved economy and performance over more conventional systems. The ingenuity of the concept is in the simplicity of the design, deleting the requirement for clutches and synchronisation elements whilst maintaining the features of a powershifting transmission. The efficiency benefit of two smaller motors in relation to one larger motor, coupled with the low cost of the 4SED make this transmission configuration very appealing for many different market segments, and for more information please contact us by email using enquiries@vocis.co.uk.

For more contact information, please follow the link to the Contact page.

REFERENCE

[1] Rinderknecht, S., Meier, T., Fietzek, R., 'Electric Two-Drive-Transmission for EVehicles', VDI-Berichte, No.2130, 2011.