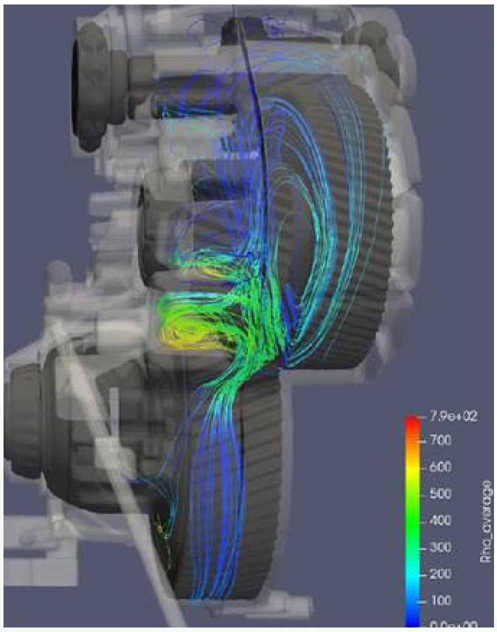
Transmission Design:

SPH MODELLING IMPROVES EFFICIENCY, INCREASING EV RANGE WITHOUT ADDING COST



SPH model, illustrating simulated particle path

Reducing global CO2 emissions will remain the most powerful driving force behind the development of new powertrains for the foreseeable future. The preferred solution appears to be electrification but consumer acceptance of EVs is still held back by purchase price and range anxiety. Extending range without pushing up vehicle cost means improving efficiency, so where should we look first?

The common view is that aerodynamic drag is the main source of energy loss in a vehicle, but this is only true at higher speeds. Steady state test results from a typical EV show that the drivetrain is the largest energy draw on the system up to approximately 80km/h (50mph). Future body shapes, with even lower drag, are likely to be push this higher still.

The most effective way to maximise real world operating range without adding cost is by improving EV drivetrain efficiency. Though bearing and gear losses are well understood, the interactions between rotating components and the transmission lubricant, such as churning and windage, have historically been difficult to simulate. Practical tests using casings with observation windows are limited in value and the hardware lead times can be prolonged. Finite Volume CFD modelling involves extensive run times, with each test point requiring several weeks' computing just to generate a couple of seconds of real time data.

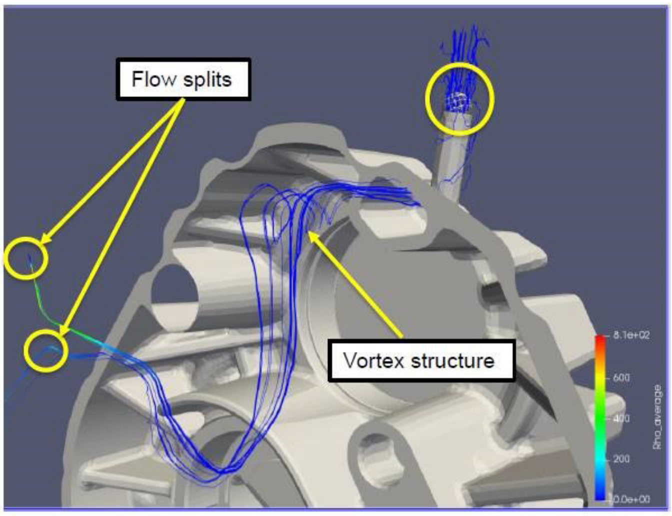
At DSD, we have been applying Smoothed Particle Hydrodynamics (SPH), using both nanoFluidX and Particleworks software, to extend robust analytical design methods into this previously empirical area of transmission design. The new modelling approach reduces the time from weeks to just a few days.

The SPH method is a mesh-free alternative to the more common finite-volume CFD codes. A model of a typical single-speed EV transmission would contain approximately 10 million such particles, enabling the analysis of a couple of seconds of data in less than two days with modest computational expense; an order of magnitude faster than previous techniques. The method typically solves on cost-effective graphics processors, such as those developed to solve artificial intelligence problems.

Our first application of SPH was a planetary transmission design for an EV application. Planetary gear trains present several lubrication challenges; supply to the sun-planet mesh at the centre of the system is often obstructed, while the planet gear bearings often run at high speeds and therefore require a robust supply of lubricant.

Our aim was to manage the lubrication more efficiently; by accurately visualising and analysing the behaviour of the lubricant and its interaction with the rotating assemblies, we were able to develop a highly optimised, passive lubrication system with low losses.

For better thermal management without high churning and windage losses, we increased the oil volume by creating a remote sump in a segregated chamber within the transmission casing. This was charged by a vaned impeller, designed as a low-cost moulding clipped to the planet carrier, which scavenges the cavity containing the rotating components and supplies it to the sump under pressure, avoiding the cost and packaging penalty of an electric pump. Residual pressure in the sump forces oil from the exit via a series of baffles and guides to the centre of the planet pins, where it is most needed.



SPH model, illustrating complex phenomena in oil flow using simulated particle paths

Unlike testing on physical components with limited visual access, the model allowed key sections throughout the assembly to be examined, to confirm the satisfactory penetration of oil into those areas. It also enabled the confirmation of satisfactory, and rapid, pump priming and the correct functioning of the various guides.

A level of correlation was achieved by simulating a simplified system against physical tests for fluid movement and drag losses. Results from a single helical gear on a spin rig with a torque cell and high-speed video recording provided enough confidence to proceed with the SPH method for analysing the more complex planetary system.

The improved understanding of lubricant behaviour provided by SPH modelling enabled us to introduce design improvements with confidence. The pump was actually more effective than necessary, so a revised impeller with fewer vanes and different geometry was introduced, reducing drag without compromising lubrication. We then cut the oil capacity by 100ml, reducing drag further. All told, we cut drag losses by almost 30 percent by the final iteration while maintaining satisfactory lubrication of all the transmission elements.

Over recent years we have used SPH to design thermal and fluid systems concurrently, with further development and correlation of our SPH toolsets planned. We continue to utilise SPH as a credible alternative to existing, more established, methods of predicting fluid flow around a transmission and an important addition to the designer's toolkit. It offers a level of interaction with, and analysis of, the results that is not available with conventional testing, and those results can be achieved in a much shorter time frame than is possible with either testing or fixed volume CFD approaches.

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In-house R&D allows DSD to identify and develop new ways of maximising driveline efficiency, new tools for accelerating product development, and new areas of value for automotive, commercial, off-highway, defence and aerospace applications. Our specialists attend many of the major conferences and look forward to meeting you.

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