Driving Flanders to Electric Powertrain Innovation

Voxdale BVBA and Flanders' DRIVE delivering on the demand for innovation in the Automotive Industry.

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Figure 1. Range Rover Evoque at Flanders' DRIVE media day with proposed driveline, April 2013

The not-for-profit organisation, Flanders' DRIVE, was set up in 1996 as an automotive industry initiative by an assortment of companies in Belgium to cope with the increasing demand for innovation in the sector. Activities started in 2001 with the support of the local Flemish Government and by 2004 the building and infrastructure of Flanders' DRIVE in Lommel, Belgium, came into operation.

At first, Flanders' DRIVE focused solely on product innovation. Since 2005 however, it expanded its focus to include process innovation for production and assembly companies as well. Over the past few years, Flanders' DRIVE has developed into a research center for the Belgian vehicle industry, which supports the sector with a hands-on approach and a permanent and flexible focus on the actual needs of the sector. For this, Flanders' DRIVE has a team of 45 employees and state-of-the-art infrastructure available for innovation support and application-oriented research together with and for the Belgium automotive industry. It now has over 170 Partners including Volvo, Tyco, Toyota, Bombardier, Alcatel-Lucent, Continental, DAT Trucks, Ford, IVECO, Johnson Controls, Siemens, NXP, and TI Group to name a few.

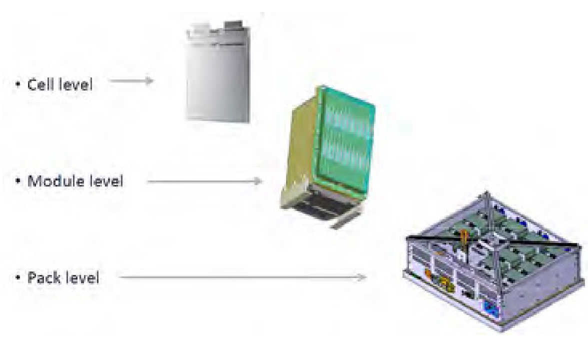

Figure 2. EV Battery Pack component levels

Flanders' DRIVE has in its aims targets for technological solutions in the fields of Advanced Manufacturing Processes, Clean & Energy Efficient Vehicles, Lightweight Solutions, Intelligent Driver and Traffic Systems and Intelligent Development Tools. In the years ahead, Flanders' DRIVE wants to play a leading part in the transformation of the vehicle industry towards a green and smart mobility industry. This will be done through focused development of strategic competences and knowledge diffusion, creation of an increase in scale through strategic and application-driven cooperation with other research centers, and further integration in European clusters and participation in international projects. Recently, Flanders' DRIVE through an "Electric Powertrain" project (with 12 partners*) wanted to prove an innovative conceptual EV drive train on a typical Range Rover Evoque car.

The project involved:

1. Developing further knowledge on state of the art battery systems (Lithium titanate oxide anode)
2. Designing, developing and integrating a full functional innovative battery pack
3. Special attention for energy management, the battery housing and thermal management so that the:
   a) Power pack would cover regenerative braking
   b) Development of an electrical ABS, leading to significantly shorter braking distances.

Originally the project targeted an 800V Battery Pack but eventually it opted for a 400V pack due to space reasons in the Evoque. We were aiming for Maximum Power in = Maximum Power Out which would be good for regenerative braking. Each Pack would have 12 cells per module and 15 modules per pack and the 180 cells would take up 235 liters of space in the car with a total mass of 225 kg. Each elementary cell would be made up from six layers repeated n/6 times. Heat transfer in the battery would be predominantly by conduction. Voxdale chose the FloEFD 3D CFD package that's embedded in PTC Creo as the simulation tool for designing thermal aspects of the Battery Modules because of its ease of use and easy meshing methodology for complex repeated geometries like in this example.

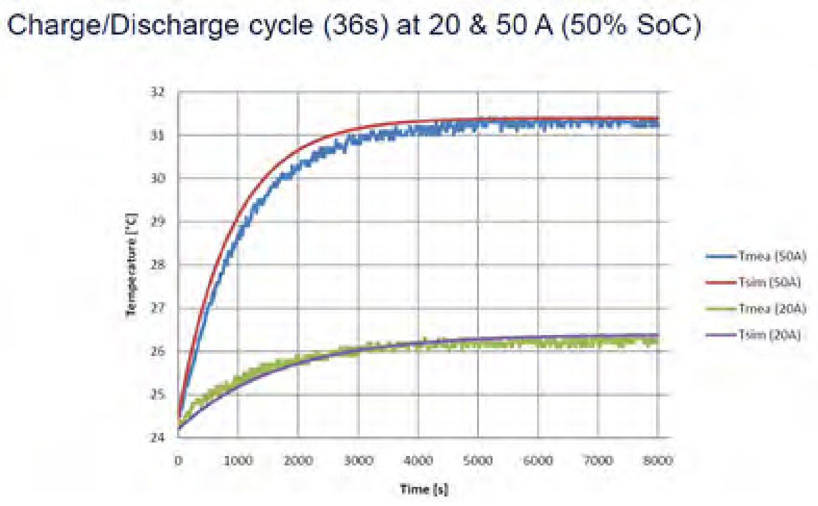

Figure 3. CFD thermal simulation versus experimental measurements.

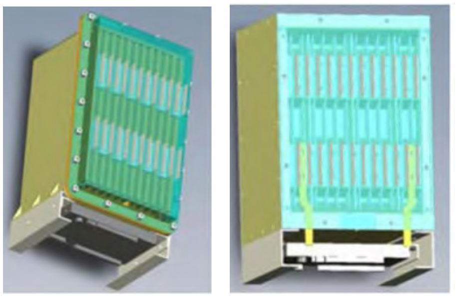

Figure 4. Battery Pack "Wet Module" (left) and "Dry Module" (right)

We initially validated our CFD thermal simulation approach versus experimental measurements in the laboratory and we got good agreement. (Figure 3).

The two Battery Pack Module concepts were investigated in the study are illustrated in Figure 4.

1. Wet Battery Module
   a) Cells submerged in cooling liquid
   b) Inlet and outlet for forced liquid cooling/heating
2. Dry Battery Module
   a) Aluminium cooling ribs between cells
   b) Cooling ribs connected to the base plate
   c) Base plate cooled/heated by Peltier elements.

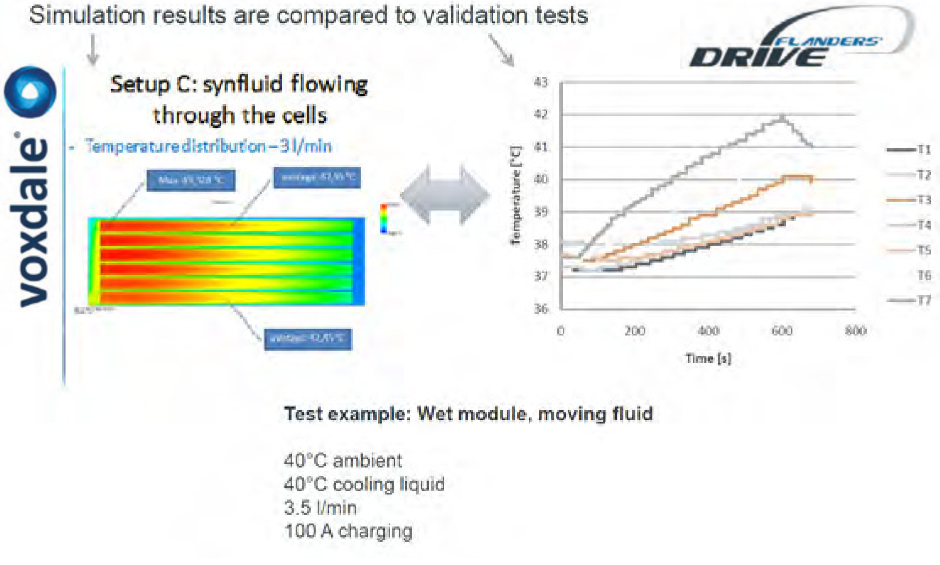

Figure 5. FloEFD simulation results versus experimental measurements for Wet Module

The fluid flow and heat transfer predictions revealed complex flow fields in the Wet Battery Module channels which we were able to rapidly assess with FloEFD. (Figure 5)

Parametric FloEFD predictions for the Dry Battery Module channels also showed that a set of Peltier elements were able to cool the module adequately whereas the Wet Module created considerable packaging challenges. In addition, unknown longer

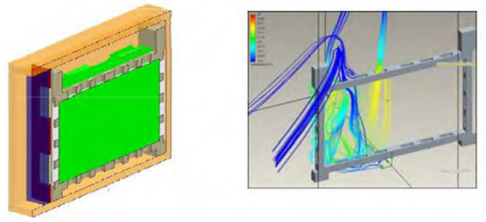

Figure 6. Geometry and detailed FloEFD thermal predictions for parts of the Dry Module

Figure 7. Voxdale concept electric vehicle chassis

term effects on the cell packaging due to the cooling liquid meant that the Dry Module was our recommendation for the EV Battery being designed. (Figure 6)

Based on our work and that of the other consortia partners, Flanders' DRIVE set up a press and media day in April 2013 showing the new EV Powertrain design inside a two-wheel drive Land Rover Evoque's powertrain (Figure 1). It included four switched reluctance motors, one powering each wheel separately, thus eliminating the need for a differential between wheels. Powering each wheel with an independent motor should also lead to enhanced safety, speed and handling of the electric vehicle. Cornering would also be improved because the car's outer wheels would spin faster than the inner wheels as the car turns. This in turn improves the car's overall torque because the power generated by the batteries would be sent to where it is needed most. The Flanders' DRIVE motors also did not use magnets – thus potentially reducing the price and helping to generate additional power for the engine through a regenerative braking system. The next step for Flanders' DRIVE researchers will be to optimize the powertrain technology in conjunction with its European Partners which include Jaguar Land Rover and Skoda so that they can be applied to all hybrid and electric vehicle combinations.

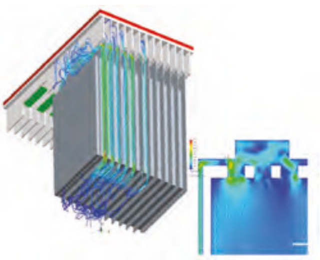

Figure 8. Aquilo concept car battery pack cooling simulation in FloEFD

Finally, my colleague at Voxdale, Wouter Remmerie, and I decided to see if we could think through what we had learnt from the initiative to facilitate some "blue sky" thinking related to electric vehicles with novel battery locations, a patented 3D printed chassis monocoque concept, and thermal management (via FloEFD), all inside PTC Creo. We called our Project "Aquilo" and decided to look at a fundamental new conceptual aerodynamic design process with CFD simulation prototyping related to cooling and heating of battery packs, cooling of powertrain (Figure 8), cooling of electronics, and simulation of battery cooling media, plus lightweight casings for a generic two door EV sports car chassis design (Figure 9). The battery casings were designed with FloEFD and fabricated in the laboratory to validate them.

Our final sports car design with novel monocoque, FloEFD aerodynamic styling and battery driveline was visualized in PTC Creo (Figure 9). A very interesting exercise and something that illustrates the power of tools we have available to us inside PTC Creo.

For more information visit:

http://bit.ly/1kWdC9M

* The Flanders' DRIVE Electric Powertrain project was a consortium of 12 companies including Arteco, CTS, DANA, EIA Electronics, Imec, Inverto, LMS, NXP, Punch Powertrain, Triphase, Umicore and Voxdale: flandersdrive.be/en
voxdale.be/en

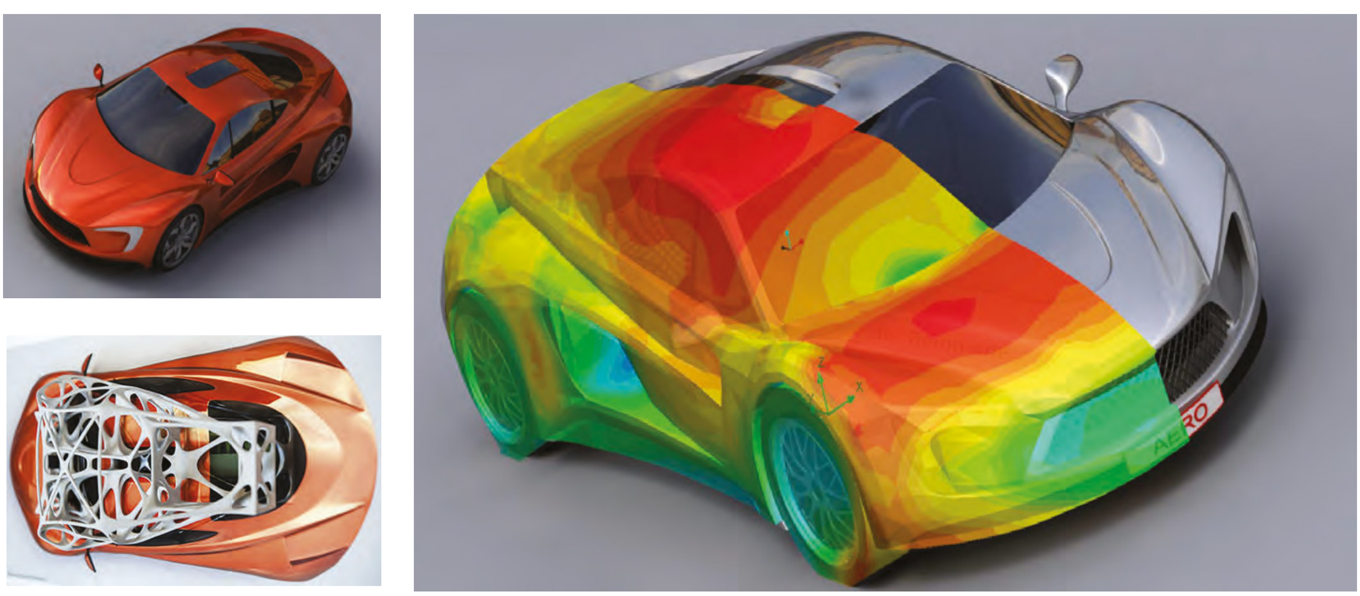

Figure 9. Aquilo concept car design in PTC Creo with external aerodynamics pressure predictions from FloEFD Simulations