ENGINSOFT

WHITE PAPER

Aerodynamic optimization of the Volvo Polestar Olsberg Green Racing C30 using modeFRONTIER

The Rationale

Motorsport is a highly competitive environment where performances, time and budget represent conflicting objectives. Polestar, racing in the Swedish Touring Car Championship with two Volvo C30 OGR, has to cope with them. To this extent, a challenging task of primary importance is to establish a tool that may help race engineers in finding the car aerodynamic optimal configuration directly on the track in real time, using a limited budget and a clever experimental campaign to tune it.

Figure 2: Polestar C30 OGR in the moving-ground Volvo wind tunnel

modeFRONTIER has played a crucial role in meeting these objectives.

First, it allowed to achieve significant experimental campaign cost reduction by selecting a small but highly meaningful set of experiments to be performed in the Volvo moving ground wind tunnel facility. Then, modeFRONTIER's sophisticated interpolation models have been trained and fitted to such wind tunnel data. Now, they are powerful real-time tools in the hands of the Polestar race engineers, supporting them to forecast the behavior of their C30 OGRs with different set-ups and in any track condition. All this helps the Polestar team to compete at the maximum level in their championship: so far, the results are thrilling, with a first and second position for the two team cars, both in qualifying and at the finish line, in the 2009 season-opening race at Mantorp Park.

The Challenge

Getting a detailed knowledge of the aerodynamic behavior of a race car is complex and expensive. Complex, since there is a large number of sensitive parameters to be taken into account: managing efficiently multiple parameters requires adequate methodological tools. Expensive, since accurate wind tunnel tests are costly and normally facilities have limited availability in terms of time and sessions: a wind tunnel similar to the one considered here costs more than 2500€/hour just for the facility rental.

In fact, to measure accurately drag and down-forces and hence train a reliable prediction model, a full-size wind tunnel facility is required. Moreover, the moving ground allows to capture the "close to ground" effects, which are essential in racing cars. In such facilities, the test car wheels are placed on a steel belt that simulates the road under the moving car, while a fan is blowing the air with the

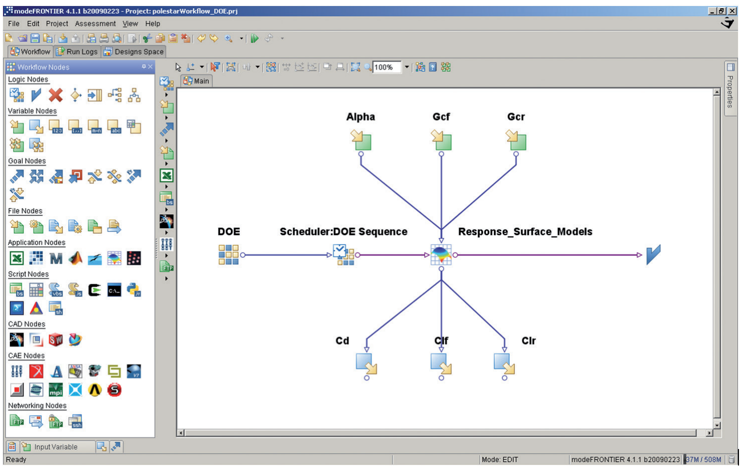

Figure 3: modeFRONTIER software Graphical User Interface

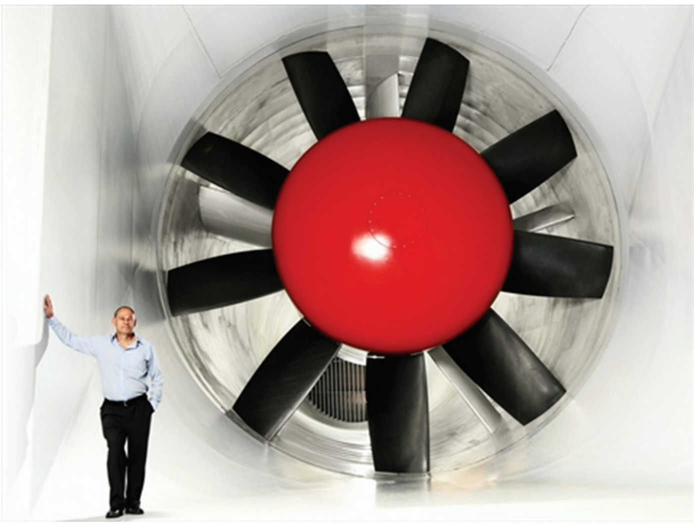

Figure 3: Tim Walker, responsible for Vehicle Aerodynamics at Volvo Car Corporation, and the wind tunnel fan

requested speed and direction. This allows to load up the wheels and tires exactly as they are when driving on the open road. The Volvo Wind Tunnel with "moving ground" has been exploited to carry out a test campaign: this facility provides 5.3m-long and 1m-wide steel belts, and a 5 MW fan capable to generate wind velocities corresponding to road speeds of up to 250 km/h. Transferring the gained knowledge to the race track could be even more challenging: reliable but lean predictive models should be able to forecast aerodynamic car behavior (outputs) at any given car setup (inputs), with the minimum number of wind tunnel experiments required to tune them.

Typical outputs are car drag (Cd) and down-forces on the front (Clf) and on the rear (Clr) axles, while input parameters defining a race car aerodynamic set-up are the ground clearance of the front (Gcf) and rear axles (Gcr), angle of attack of the rear wing (α), and so on.

The Solution

All these challenges have been tackled by Polestar Racing thanks to the modeFRONTIER software: complete and fast aerodynamic prediction models of the C30 OGR have been produced, based on few well-selected wind tunnel tests, to be used on-the-field by race engineers.

First, some meaningful experimental data are needed to "train" such predictive models. Having only a wind tunnel test session available, modeFRONTIER has been used to define a reduced but meaningful set of experiments out of the high number of possible car aerodynamic configurations to be tested. This can be achieved by varying simultaneously all the considered parameters, in the most diverse and uncorrelated way. This technique is known as "Design Of Experiments", and here a "Factorial" sampling mechanism has been used: it allows to detect, for each output, the influence of each variable separately (main effects), and also their interactions.

Therefore, only very few car aerodynamic set-up configurations have been tested in the wind tunnel, with a considerable budget and time-saving while achieving the requested quality of extracted information. For each car aerodynamic set-up configuration, the drag and down-force outputs have been measured, and data have been transferred back to modeFRONTIER to complete the data analysis. A model that describes each one of the outputs

Figure 4: Aerodynamic set-up parameters (inputs) and aerodynamic forces (outputs) on the C30

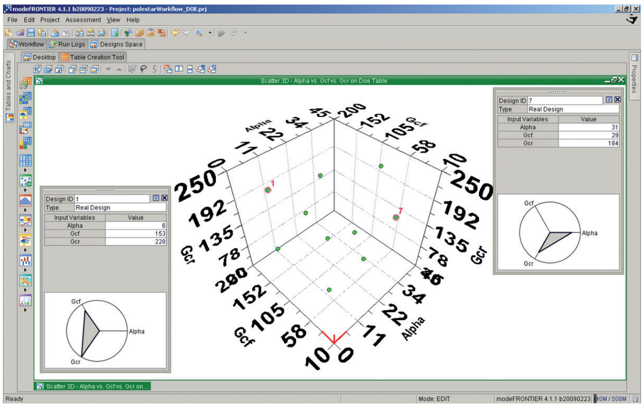

Figure 5: Sketch of a Design Of Experiments in the space of the input variables: each bubble represents a particular combination of parameters to be tested

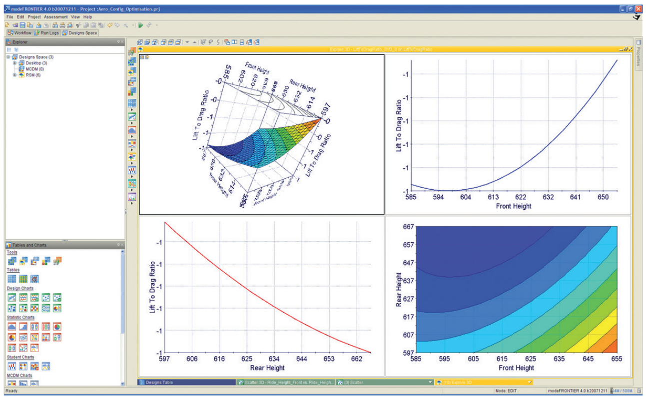

Figure 6: The predictive Response Surface Models of the lift/drag force ratio, trained over a set of available experimental data, plotted as a function of two of the considered input parameters (front and rear car height).

(drag and axle down-forces) as a function of the input parameters (ground clearance of the front and rear axles, angle of attack of the rear wing, etc.) at a given condition (car speed and direction, etc.), has been built by interpolating the available data. To do so, a set of state-of-the-art reliable interpolating techniques, known as "Response Surface Models", are available in modeFRONTIER together with easy tools to judge their quality in terms of relative errors when used for forecasting. A reliable set of such models have been produced and then exported into MS Excel worksheets, thanks to the dedicated modeFRONTIER interface. They are now being used by the race engineers, to support them in finding the optimal set-up of their C30 OGR in real time at the track side.

Conclusions

Polestar appreciated the modeFRONTIER capability to handle multi-variable challenges. It allowed to select a reduced but meaningful set of wind tunnel experiments, to characterize the aerodynamic behavior of their C30 OGR. This has led to considerable savings in testing budgets while keeping constant the quality and completeness of the extracted information.

Moreover, modeFRONTIER's sophisticated Response Surface Models have been crucial to generate accurate and fast aerodynamic forces predictive models, based on the wind tunnel experiments, to be used directly at the track side through a simple MS Excel interface. This accomplishes the technical goals of the collaboration between Polestar and Esteco (EnginSoft) Nordic.