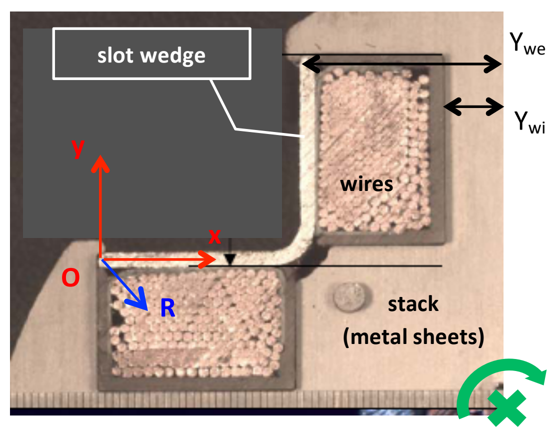
Renault uses Maple to develop new motor for full electric vehicle

In order to successfully enter the growing electric vehicle market, Renault wanted to create a new motor design. Rather than restricting themselves to existing designs and processes that are often inadequate in handling both driving pleasure and mass production requirements, teams were given the opportunity to start with blank canvases, while respecting standard constraints of deadlines, budgets and quality.

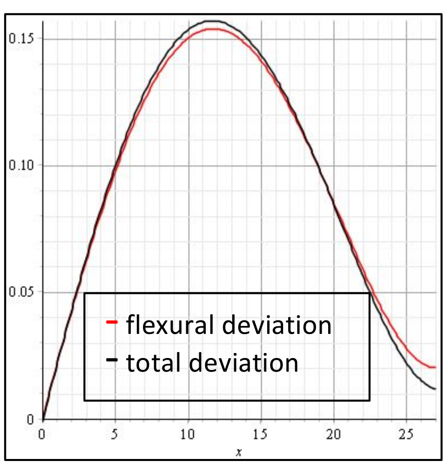
In particular, a group led by Mr. Patrick Orval was in charge of structural analysis for the wound rotor of the motor. In the earlier phases, they turned to Maple and started quickly with first-order approximations of the rotor. They got a sense of how the components would behave with different parameters and operating conditions, allowing accurate choices to be made for the main dimensions.

After analyzing this first set of results, they also understood which topics would demand higher fidelity. From there, they further developed the corresponding mathematical models in Maple based on the physical equations. "*As a beginner, I found Maple to be very user friendly and intuitive,*" remarks Mr. Orval. "*We began by building mathematically-simple models, and were able to get results in line with project goals. Using the wealth of in-product and online support and resources, we were able to gain confidence and develop more sophisticated models in a short amount of time.*"

One particular issue of growing complexity that was solved with Maple was that of the slot wedge, which holds the rotor wire in place to ensure reliability over both maximum loads and long-term operation.



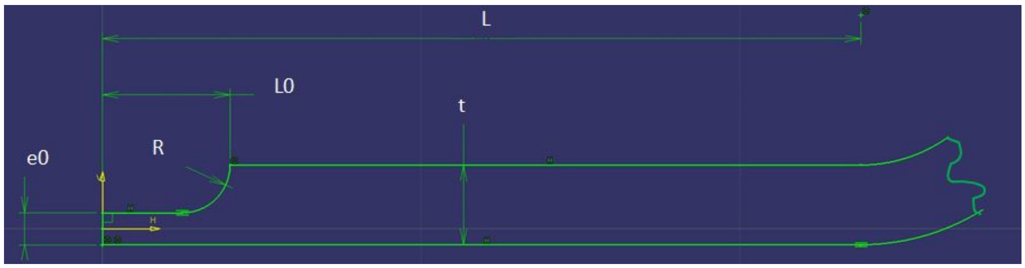
By modelling wedge deviation under centrifugal and thermal loads, they determined a first simple rule based on flexural stiffness. By taking into account competitors' data, they selected the appropriate thickness and material for the wedge.



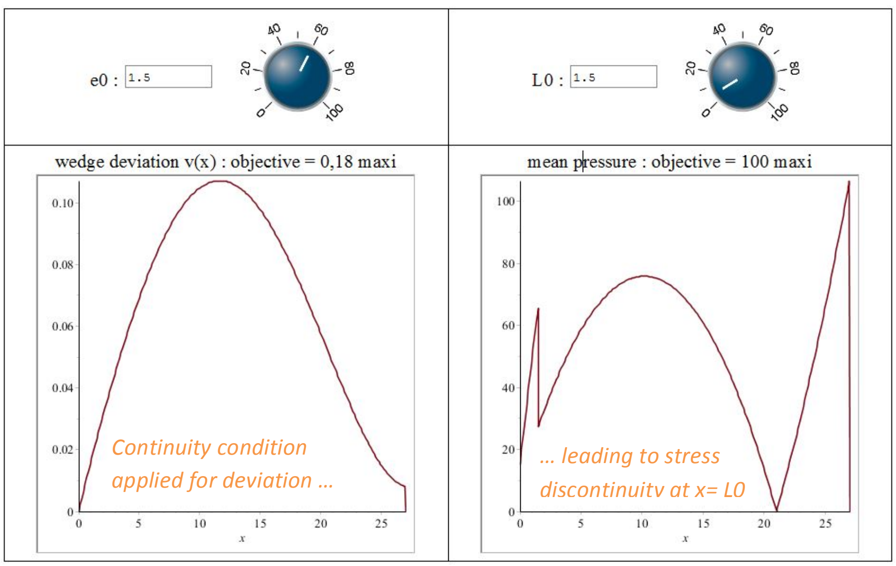
➔ rule #1 : $\frac{\rho[T/mm^3] \cdot N[rpm]^2}{E[MPa] \cdot t[mm]^3} \approx cste$

Figure 1: Modeling the slot wedge at 1st order approximation

Thanks to this simple model, an opportunity for reducing the mass of the rotor was detected (the lighter the better, as the car can go further on the same battery charge). They imagined a solution depicted as two thicknesses that were 'mathematically connected' in Maple to create a first-order approximation of a new slot wedge. This was done in a parameterized analytical manner, so that they could easily determine a viable set of dimensions for this 'new shape' of the wedge. They then investigated the concentration factors library to limit stresses at the point where the wedge thickness changes, and performed finite element analysis (FEA) to validate the complete design.



(a) Cross-section of the 'new-shape' for the slot wedge



(b) Dynamic optimization in Maple for two parameters (e0, L0)

Figure 2: 5% reduction in mass of the rotor

This work not only enabled the team to reduce the rotor mass, but also led to the successful filing of a design patent. Describing this achievement, Mr. Orval says "*Maple was instrumental in helping to define the third-generation e-powertrain rotor. Its breadth enabled us to create models that are perfectly suited to our needs and achieve outstanding results early on in the design process. Additionally, the work carried out with Maple significantly contributed to reducing our engineering costs, by enabling us to incorporate third-party technology such as FEA*."

Having developed the slot wedge, the team then went on to examine the resulting internal stresses on the wires in the system. Among other factors, internal stresses are determined by wire stiffness and the friction between the slot wedge and the stack of metal sheets – both of which were completely unknown and difficult to determine. Previously, they would have used a finite element model. However, that approach would have required a tedious amount of trial and error, and the team would have encountered difficulties with numerical convergence. Using Maple instead, the team was able to model non-linear features such as friction between the wedge and the stack, and local loss of contact between wires and the wedge at high revolution speeds. They expect it to yield good physical results, because the set of ODEs and the conditions governing the wedge deviation were fully coupled.

ODEs for wedge deviation v(x) are:

$$\begin{cases} \frac{d^4}{dx^4} v(x) - \frac{12}{5} \frac{(1+\nu)\, k_{wi} \left(\frac{d^2}{dx^2} v(x)\right)}{t E} + \frac{12\, k_{wi}\, v(x)}{E t^3} = \frac{12\, Y_{we}\, \rho_{we}\, \omega^2}{E t^2} + \frac{6\, \rho_{wi} \left(Y_{we}^2 - Y_{wi}^2\right) \omega^2}{E t^3} & k_{wi}\, v(x) < \frac{1}{2} \rho_{wi} \left(Y_{we}^2 - Y_{wi}^2\right) \omega^2 \\ \frac{d^2}{dx^2} v(x) = \frac{6\, Y_{we}\, \rho_{we}\, \omega^2 x^2}{E t^2} + \frac{12\, R_y\, x}{E t^3} - \frac{12}{5} \frac{(1+\nu)\, Y_{we}\, \rho_{we}\, \omega^2}{E} & \textit{otherwise} \end{cases}$$

With boundary conditions: $\{v(0) = 0 \ \textbf{and}\ v(L) = -u(L)\}$

While hyperstatism { R_y , u(0) } and Coulomb's friction law can be solved by:

$$\begin{cases} u(0) = 0 \ \textbf{and}\ \frac{d}{dR_x} W(R_x) = 0 & |R_x| < \mu\, |R_y| \\ R_x = -\mu\, R_y \ \textbf{and}\ u(0) = \frac{d}{dR_x} W(R_x) & \textit{otherwise} \end{cases}$$

The two unknowns (wire stiffness and friction coefficient) were determined by comparison with strain measurements, and finally used as first realistic data in a FEA of the rotor.

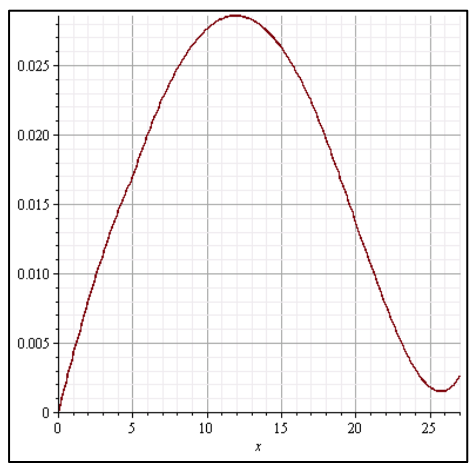


Figure 3 – Realistic deviation v(x) obtained with Maple

Summing up this phase of the project, Mr. Orval concluded "*Maple greatly reduced the need for experimental learning. Both the development timescales and rotor reliability are in line with project expectations – a combination that would not have been achieved without the use of Maple*". As Mr. Orval and his colleagues work on subsequent phases of the project, they plan to continue using Maple to analyze and validate their design options, enabling them to improve the final product.