

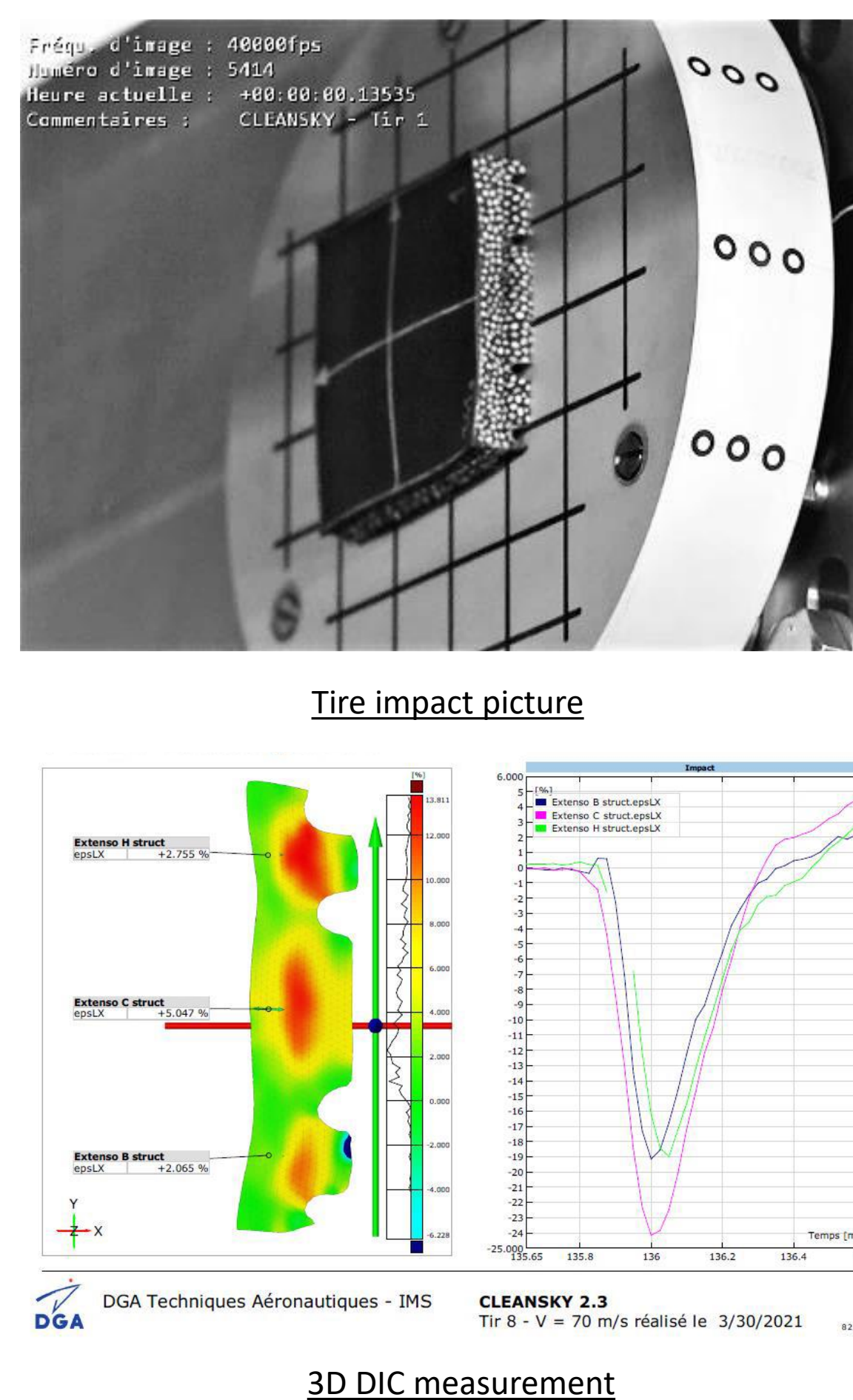
# Development of a numerical model of tire fragments for high-speed impact

The study carried out with Dassault Aviation, SONACA, CENAERO and DGA TA has three objectives :

- Create a composite wing to contribute to reduction in aircraft weight.
- Analyse the effect of a tires debris impact on a composite panel.
- Optimize the design and test phases by improving our numerical simulation expertise.

## Test measurements

Twelve tire impact tests performed on a rigid frame equipped with load sensors and accelerometers, according to arrangement of the TIOC WING Cleansky 2 project. The aim of these dynamic tests campaign is to analyze the behavior of a small tire fragment for its characterization, in order to develop a numerical model. A 3D DIC stereo correlation measurement was carried out on the edge of the tire to measure its strain and the strain rate.



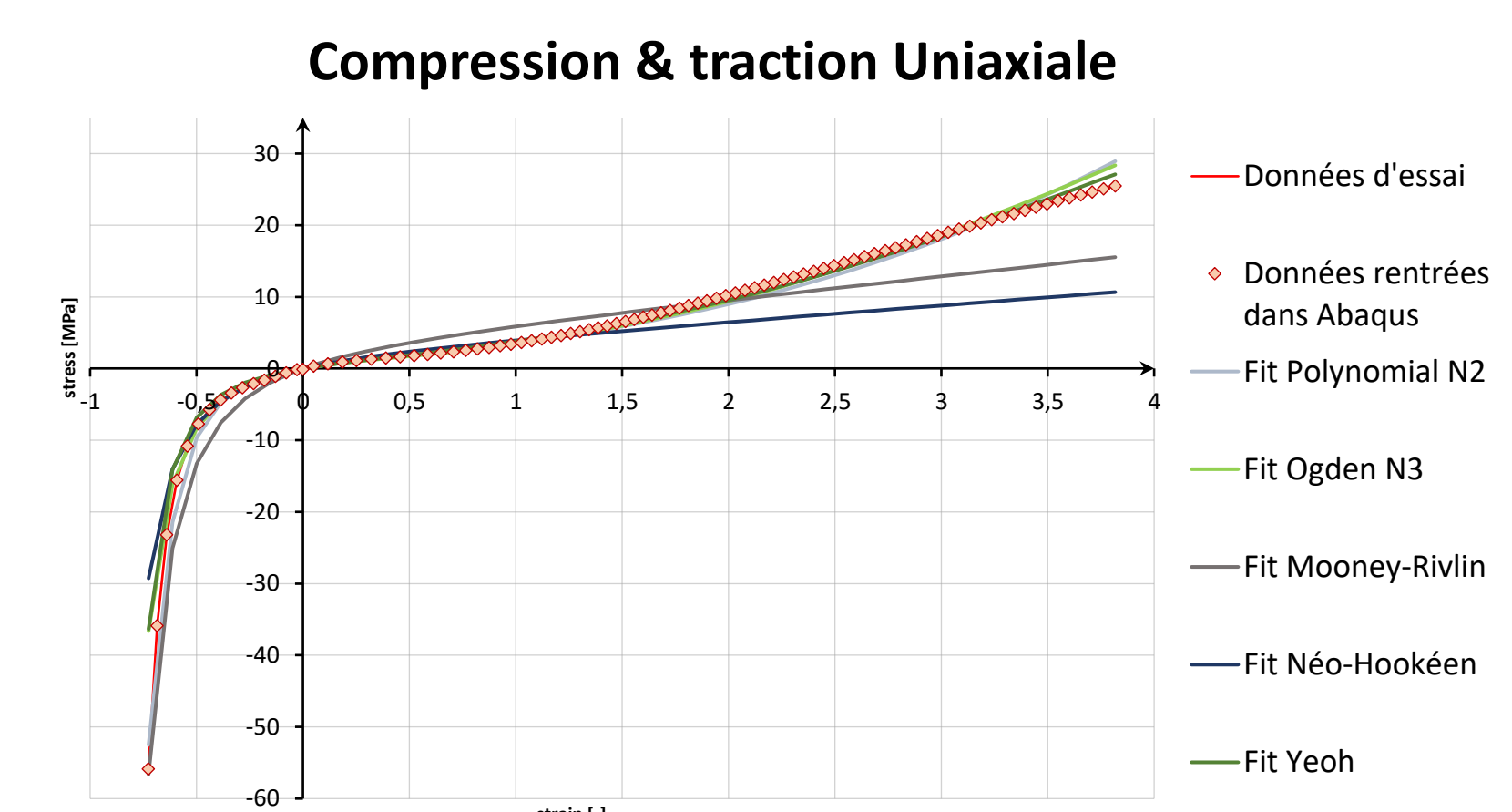
## Tire behaviour model:

There are many hyper elastic model to model the behaviour of rubber. The simplest is the Neo Hook model (elastic behaviour, 1 parameter) and the most complex used for this study is the second order Ogden model (6 parameters).

Ogden law :

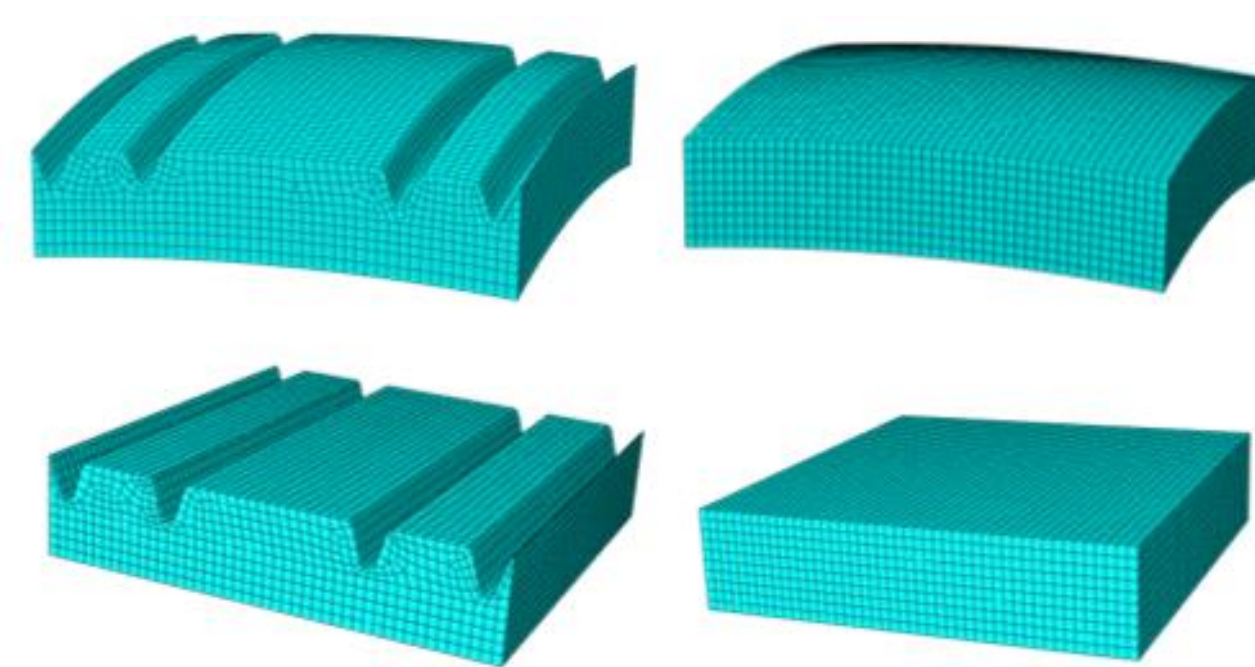
$$W = \sum_{i=1}^N \frac{2\mu_i}{\alpha_i^2} \times (\bar{\lambda}_1^{\alpha_i} + \bar{\lambda}_2^{\alpha_i} + \bar{\lambda}_3^{\alpha_i} - 3) + \sum_{i=1}^N \frac{1}{D_i} (J^{el} - 1)^{2i}$$

with  $\mu_i, \alpha_i, D_i$  material parameters and N the order of the model



## Numerical geometrical analysis :

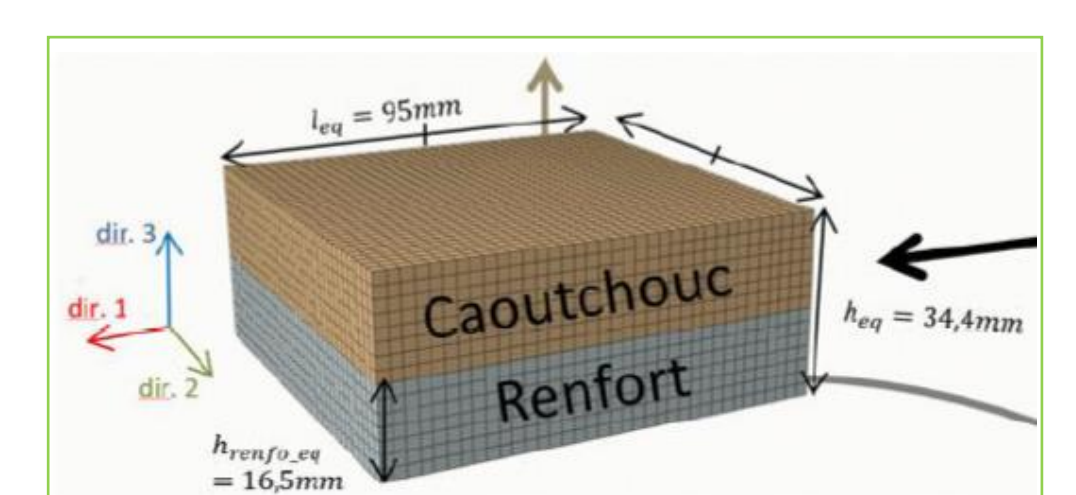
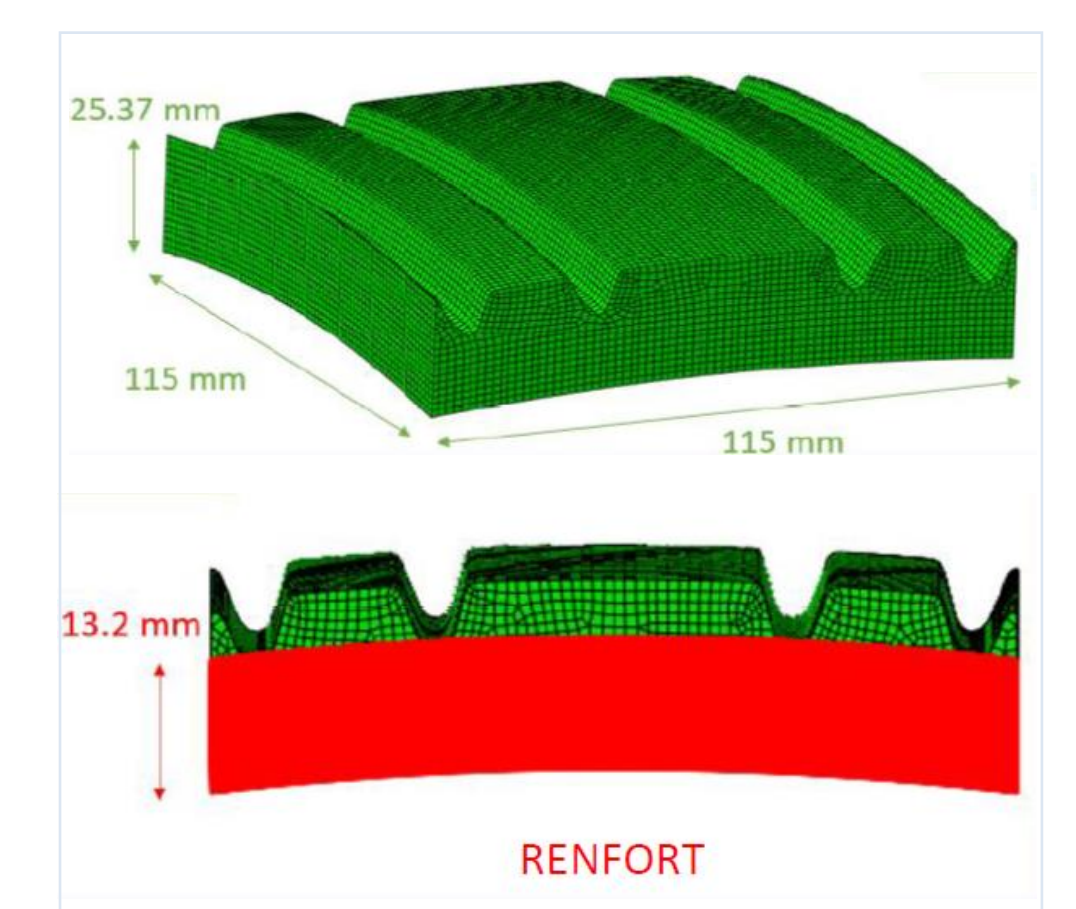
The development of a complex model being time-consuming and expensive, a study has been set up to study the feasibility of simplifying the geometry of the numerical fragment.



The parameters studied are the influence of the presence of the reinforcement, the curvatures of the fragment and the presence of grooves. The conclusions of this study are:

- modelling of the reinforcement is necessary,
- impact surface is dimensioning and therefore the simulation must take into account the grooves,
- small influence of curvatures.

The bibliography has shown that the OGDEN model was mainly used in the tire fragment impact study. To compare the different models obtained, the maximum load obtained during the impact tests on the rigid frame was used. The reference for the comparisons is the most complex model obtained called the "optimal model". The results make it possible to conclude that for the case study the Neo-Hook model makes it possible to obtain reliable results. This result can only be applied for cases of flat impacts.



## Conclusion :

Throughout the project, an in-depth analysis was made of the behaviour of a pneumatic fragment on impact. The complex model made it possible to establish and conclude on the important parameters to be taken into account for the modelling of a tire impact on a composite panel :

- Not taking into account the Mullins effect is conservative if only new tires are used,
- up to 100 m/s the viscoelasticity has no influence, for higher speeds it could have a strong impact.
- a hyperelastic model of the Neo Hook type allows a good representativeness of the tests,
- bends have no influence on the results.
- Impact surface (grooves) have strong influence on the results. Construction of an equivalent surface makes it possible to eliminate the grooves.

All these results were obtained for a flat tire impact for a small debris, configurations considered to be the most significant. Particular attention must be paid to the conditions of use of the tire during the test to best adapt the model.