Loading identification on a tire/rim contact for an inflation pressure

R. Gras[1a], F. Hild[1] and D. Melle[2]

[1]LMT-Cachan/ENS Cachan, 61 av Président Wilson, 94235 Cachan cedex, France,
[2]Messier-Bugatti-Dowty, Inovel Parc Sud, 78140 Vélizy-Villacoublay, France
[a]gras@lmt.ens-cachan.fr

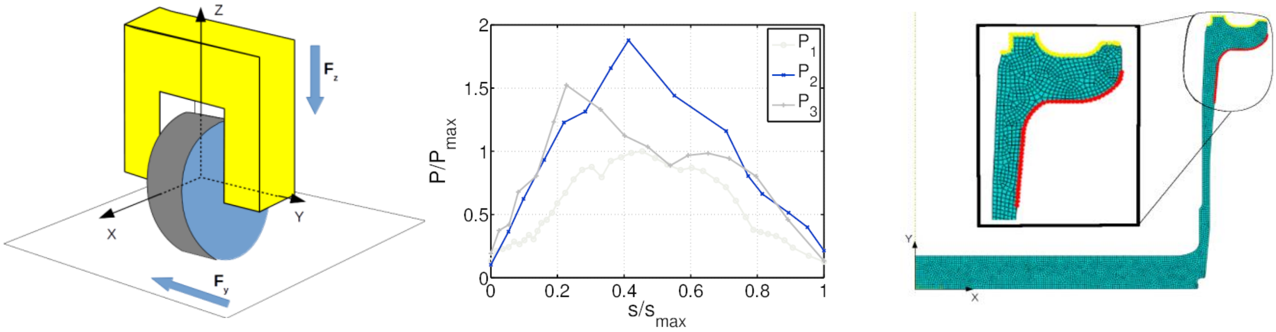
Abstract. This study aims at predicting the loading applied to the rim by a tire for critical structural cases. A full test on a wheel is instrumented via stereo-DIC (Digital Image Correlation). A model of the tire/rim contact is proposed and a sensitivity study is performed to extract the significant parameters to be identified.

Introduction

Defining the correct modeling to predict the behavior of the final chosen design is a key point in industries to reduce the development cost of their products and decrease the number of design iterations. For wheel manufacturers, the loading applied to the rim plays an important role in the accuracy of the predictive model. The value known to be applied to the wheel is the assumed point-wise loading between the ground and the tire. Knowing only the input load from the tire behavior and the resulting pressure distribution on the rim for a few loading cases, the challenge is to determine the correct applied load between the tire and the rim for load cases that are critical for structural design. This study aims at defining a better understanding and modeling of the loading between the tire and the rim knowing the applied load from the ground to the tire.

Test set-up and modelling

The test consists of applying several quasi-static compression and transverse loadings to the assembly made of a rim and a tire (Fig. 1a). This test is instrumented with stereo-DIC [1], which gives access to rich kinematic data (i.e., fields) and strain gauges. However, the test conditions are challenging the DIC technique due to the complexity and large size of the structure to observe, and the poor accessibility. The contact between the tire and the rim takes place in the inaccessible inner part of the rim. Consequently it is chosen to observe its outer part (i.e., opposite of the tire contact). The symmetric behavior along the YZ plan is assumed. However it is not symmetric along the XZ plan due to geometric effects. Ten cameras where placed around the wheel to observe half of the rim on both sides simultaneously during the loading. The second half of the rim was instrumented with strain gauges. In order to reduce the relative rigid body motion between the rim and the cameras, it was chosen to fix the cameras to the crossbeam of the testing machine. A specific frame has been manufactured which is mounted on the testing machine without modifying its actual structure.



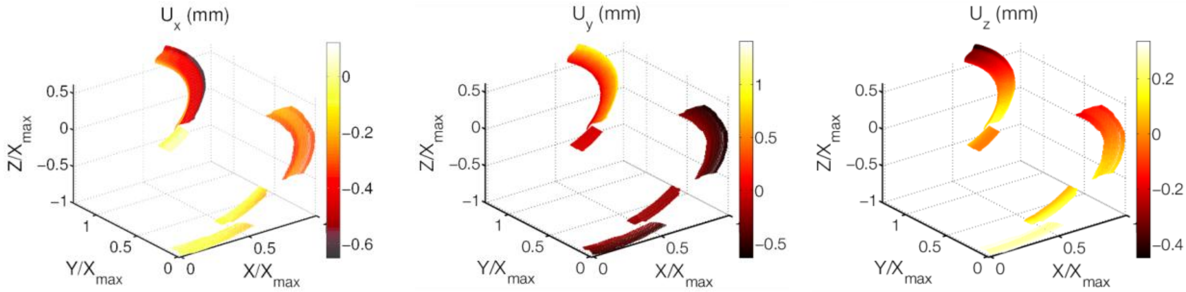
(a) (b) (c)

Figure 1: (a) Schematic view of the testing machine. (b) Pressure distributions along the curvilinear abscissa of the rim section profile *s*. (c) 2D axisymmetric model where the surface in red, resp. in yellow, is where the pressure distribution is applied, resp. the displacements are measured

In this study, the modeling is 2D axisymmetric and the considered loading is an inflation pressure of the tire (Fig. 1b and 1c). Data are provided as a pressure distribution along a section profile of the rim corresponding to an applied load from the ground to the tire. This information is available for different tires and profiles and is given by the manufacturer (Fig.1b). It is worth noting that the pressure distribution for the simple inflation of the tire takes various shapes.

Stereo-DIC measurement

Combining images from two points of view, it is possible to reconstruct the shared 3D observed area. Then, the displacement field is obtained by performing DIC analyses on the series of images taken by each camera. A first step is the calibration of the different cameras, performed by imaging a known object to determine the distortion and the relationship between the 3D and the 2D camera space. The 3D surface is then reconstructed and the displacement field is obtained for the different pairs of cameras [2]. The local reference attached to the reconstructed surface is fitted on the global reference to be able to compare the measured and simulated displacements for the identification process (Fig. 2).



(a) (b) (c)

Figure 2: Displacement field expressed in mm in the global reference along the *x*-axis (a), *y*-axis (b) and *z*-axis (c). The characteristic length of the rim is dimensionless

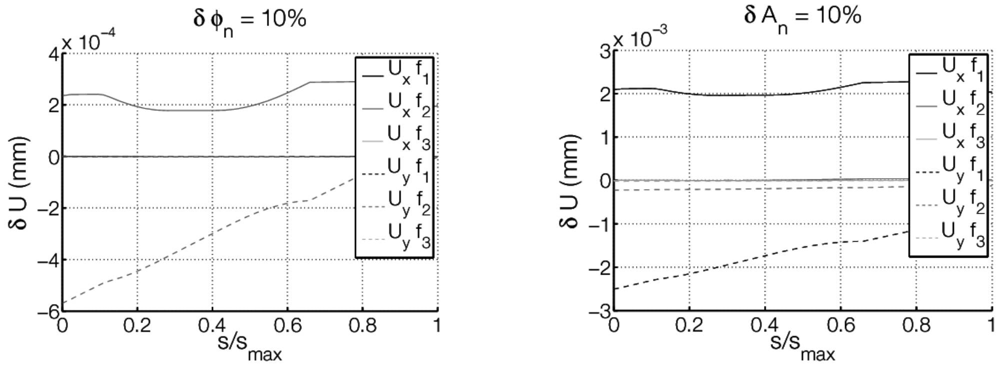
Load modeling and sensitivity study

The pressure distributions are decomposed as a series of cosine functions characterized by their amplitude, A_n, their spatial frequency, f_n, and by their phase, ϕ_n

$$P(s) = \Sigma A_n \cos(2\pi f_n s + \phi_n) \quad (1)$$

where *s* is the curvilinear abscissa. A sensitivity study on the 2D axisymmetric model is performed with the commercial code Abaqus™, in order to determine the significant parameters of the cosine decomposition. It is chosen to fix the rim section profile and dimension and to apply different pressure distributions to this geometry. The distributions are rescaled on the actual profile so that the spatial frequencies are fixed and the considered parameters are the amplitudes and phases for the different frequencies. The effect of a parameter variation is observed on the area where full-field measurements are obtained.

It is shown that after the third frequency, the change in displacement is less than the measurement resolution, whose standard deviation is estimated from two sets of reference images. It is equal to 5.7 µm. Consequently, the parameters for the first three frequencies are studied. Each parameter, A_n and ϕ_n ($n \in [1\ 3]$) is independently modified by 10% and the corresponding difference on the displacement field is shown in Fig. 3. It is shown that the most sensitive parameters are the first amplitude, A_1, corresponding to the mean value of the pressure distribution and the phase of the second frequency, ϕ_2. These two parameters will be identified for different pressures and for different tires in order to obtain their evolution and to validate the modeling of the load between the tire and the rim.



(a) (b)

Figure 3: Sensitivity on the simulated displacement field for a variation of 10% of each parameter, the amplitude, A_n (a) and the phase, ϕ_n (b) corresponding to the frequency f_n

References

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