Flexible Multibody Simulations to Assess the Impact of Body-in-White Construction in the Handling and Ride of Road Vehicles

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June 3, 2024

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Abstract

With the increasing demand for lighter vehicles, to reduce the CO2 emissions and extend the autonomy of electric cars, it is particularly relevant to understand the effect of lighter and softer materials on the dynamic behaviour of road vehicles. The use of alternative structural joints to bolting and spot-welding techniques is fundamental to join dissimilar materials and composites. Suitable numerical methods are essential to better understand how materials and structural joints employed in the construction of the body-in-white (BiW), which is the main structural component of a road vehicle, affect ride, handling and active safety. The finite element method allows to study the static structural deformation, the vibration of vehicle structures, and to simulate crash scenarios, however, the simulations tend to oversimplify the excitations and the suspension elements that are fundamental to assess ride and handling. Flexible multibody simulations, on the other hand, allow to consider the tire-road interaction, the suspension characteristics, and the flexibility of the BiW. Therefore, flexible multibody simulations are suitable to study how the materials and structural joints affect the dynamic behaviour of road vehicles. Ambrosio [1] and Tamarozzi [2] used flexible multibody simulations to assess the effect of considering the BiW flexibility in road vehicle dynamics, hinting that the flexibility of the body-in-white may affect ride and handling. Sampò considered an analytical model to evaluate the effect of the roll stiffness in the handling of a racing car [5]. Nevertheless, it is not clear how realistic changes in the materials and structural joints of the BiW of a car, to reduce weight and increase life cycle, may affect the ride, handling, and active safety. The present work discusses the development of flexible multibody models of road vehicles and examines the effects of changing the materials and structural joints of the BiW in the dynamic behaviour of road vehicles.

The multibody simulation of road vehicles with flexible components requires the use of a flexible multibody formulation and a suitable tire-road contact model. The flexible multibody formulation implemented in the in-house code MUBODyn is described in previous works by the authors [4]. In the present application, the component mode synthesis is used to reduce the number of state variables of the equations of motion, thus increasing the efficiency of the simulation. Consequently, the mass matrix, the mode shapes and the natural frequencies of the flexible bodies are required, which may be extracted from a modal analysis carried in any general-purpose finite element code. In what concerns the tire-road contact model, an adapted version of the UA tire model is considered in MUBODyn. The “enhanced” UA tire model, which is a physical tire model, consists of an adaption of the original model to improve its numerical efficiency and stability by smoothing functions that lead to force discontinuities [3].

Preliminary analyses consider a flexible multibody model of a Lancia Stratos, developed in MUBODyn, consisting of 16 rigid bodies and the flexible BiW, which are connected by kinematic joints and force elements to model the suspension mechanisms. To better understand the effect of BiW stiffness and material selection on the vehicle performance, three BiW models are considered, including a rigid BiW, a BiW made from Steel and a BiW made from Aluminium. To understand the effect of these BiW constructions in the vehicle dynamics, comprehensive quantities and indicators that are defined in the standards and used by the industry for characterising vehicle handling are analysed. Obtaining these quantities requires the simulation of steady state and transient manoeuvres, and to draw and analyse the vehicle handling diagrams. The results suggest that for the understeering vehicle, the tendency to oversteer decreases with material stiffness. Additionally, interesting results relate to the “sine with

dwell" manoeuvre, shown in Figure 1, in which some significant differences between rigid and flexible models are observed. Both flexible models fail to pass the test, as the vehicle loses control after the last steering input (~2.9s). Figure 1 (b) shows the vertical load transfer at the front and rear axles of the vehicle, highlighting clear differences between the three models, which, ultimately, affect the performance of the vehicle during the manoeuvre. In particular, the torsion mode of the vehicle affects the wheel-load transfer at the axles.

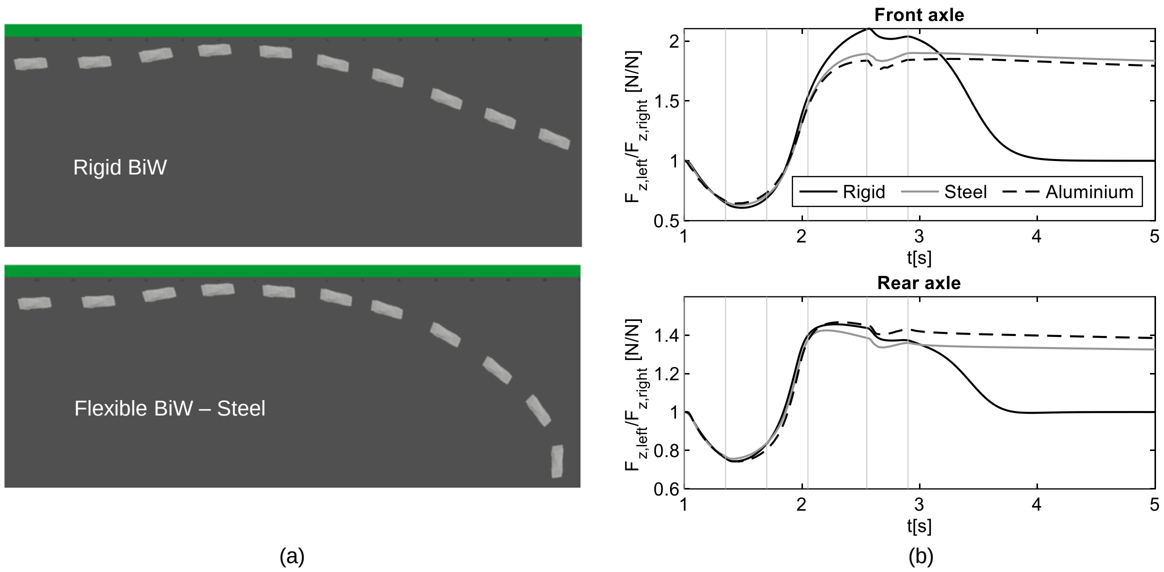

Figure 1: Sine with dwell: (a) top view of the trajectory of the Lancia Stratos for the rigid (up) and flexible (down) BiWs; (b) vertical wheel load transfer at the front and rear wheels.

The preliminary results suggest that the materials employed in the construction of the BiW can affect vehicle handling and active safety. By looking at vertical wheel load transfer, side-slip angles at the wheels, and the deformation of the BiW, one may understand what explains different handling characteristics between cars with different BiW constructions. Flexible multibody simulations are an important tool to comprehend the effect of BiW in the vehicle dynamic behaviour and may help to achieve better designs, that fulfil weight requirements and ecological targets without compromising vehicle performance, safety, and comfort. Further work is devised and planned to be carried, not only to characterize vehicle ride, but also to consider a vehicle with a more up-to-date construction and to propose more complex material combinations and diverse structural joints to understand its effect in vehicle dynamics.

Acknowledgements

This work has been supported by the Portuguese Foundation for Science and Technology (FCT) through the PhD grant UI/BD/151204/2021. Also, this work was supported by the Portuguese Foundation for Science and Technology through IDMEC, under LAETA, project UIDB/50022/2020.

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