Safety Analysis of Children Transported by Bicycles in Urban Accident Situations

Johannes Wilhelm, Mariusz Ptak, Marek Sawicki, Ricardo J. Alves de Sousa, Fábio A. O. Fernandes

I. INTRODUCTION

The focus of this study is to perform a safety analysis of children travelling in dedicated bicycle baby-seats and trailers. The crashworthiness of a popular rear-frame-mounted baby-carrier was investigated. While kinematics and biomechanics are broadly studied for pedestrians and cyclists, there is no clear understanding of the injury risk of child passengers in commonly used bicycle baby-carriers. We believe that this study can contribute to the improvement of crashworthiness of these devices and of child safety while being transported on bicycles.

II. METHODS

The authors simulated a variety of possible real-world frontal and side-impact scenarios via a hybrid finite element (FE) multibody (MB) framework achieved by coupling LS-DYNA and MADYMO software. The geometrical models of vehicle, baby-seat and trailer were created using a 3-D scanner and an advanced photogrammetry method to obtain a realistic cloud of points, which was subsequently transformed into FE models. The implementation of an original bicycle model and biofidelic multibody dummy models allowed the authors to evaluate the influence of the transport modes on the resulting kinematics. The constitutive material models, both for the vehicle, the bike and the baby transportation devices, were also investigated through destructive and non-destructive tests. Finally, some parts of the numerical models were validated during experimental research. This two-step approach is illustrated in Fig. 1. The results are compared to full-scale tests presented in the literature, as well as to the authors' preliminary verification test with a bicycle and seated Hybrid III child dummy.

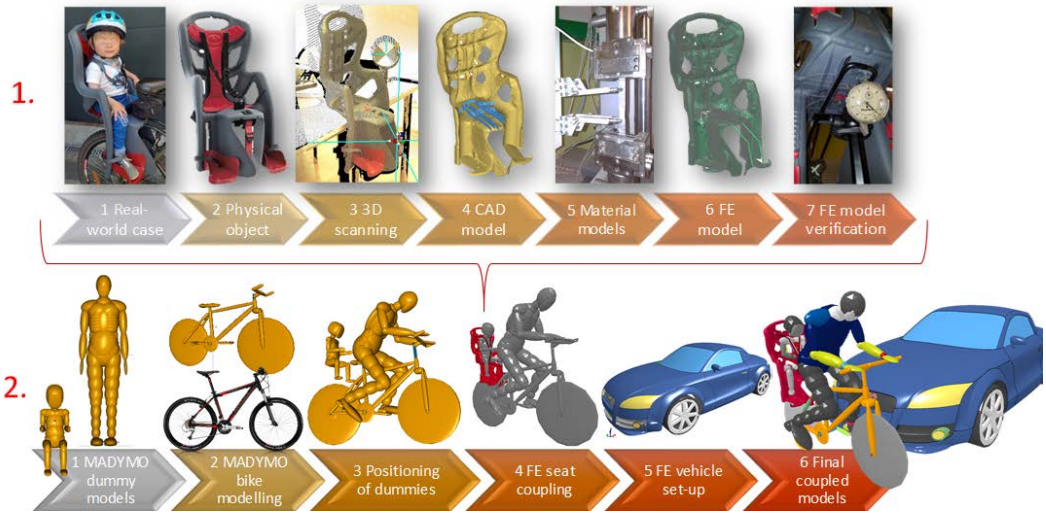

Fig. 1. The two-step approach to create the bike-dummy-vehicle coupling: 1. (top row): child seat modelling and verification. 2. (bottom row): bike modelling, dummy and child seat adjustment, vehicle setup, adopted from [1].

J. Wilhelm (e-mail: johannes.wilhelm@pwr.edu.plphone: tel: +48-71-320-38-60) is Mechanical Engineer and PhD Student, M. Ptak is Associate Professor and M. Sawicki is Mechanical Engineer and PhD Student, all at Wrocław University of Science and Technology, Poland. R. J. Alves de Sousa is Professor in the Department of Mechanical Engineering and F. A. O. Fernandes is Mechanical Engineer, Invited Assistant Professor and post-doctoral researcher, both at University of Aveiro in Portugal.

III. INITIAL FINDINGS

The main goal was to assess the safety measures and injury risk for children transported in commonly used types of baby carrier. The structure of the bicycle-mounted baby-carrier was found to be a very important factor in terms of changed moment of inertia. In addition, we observed a strong likelihood of direct cranial impact for trailer transport. Generally, the resulting child kinematics differs significantly from the kinematics observed for the cyclist. Besides the very high possibility of second impact of the seated child to the ground, it was obvious that seat-belt performance must be improved to enhance the baby carriers' crashworthiness. The flexibility of the baby carrier and of the FE three-point seat-belt means that the infant's harness can loosen in a crash scenario. This is particularly the case when a child is not properly belted or when the seat-belt is affected by the child's clothing, for example when wearing a thick jacket in wintertime [2]. Figure 2 shows:

(a) 50th percentile male and 1.5-year-old child MB models coupled with a FE vehicle: child on bicycle-mounted seat – compact car impacts at 40 km/h. The child slips out from seat-belt and impacts the bonnet. The child's seat crashworthiness is assessed – the head bonnet contact is magnified.

(b) The impact scenarios for a bicycle with an attached child trailer. In this case, the combination of bicycle and trailer is hit by the vehicle, with an initial velocity of 40 km/h, at approximately the seating position of the transported child. A direct cranial impact to the front of the vehicle was observed at 55 ms after the initial collision with the side of the trailer.

(a) (b)

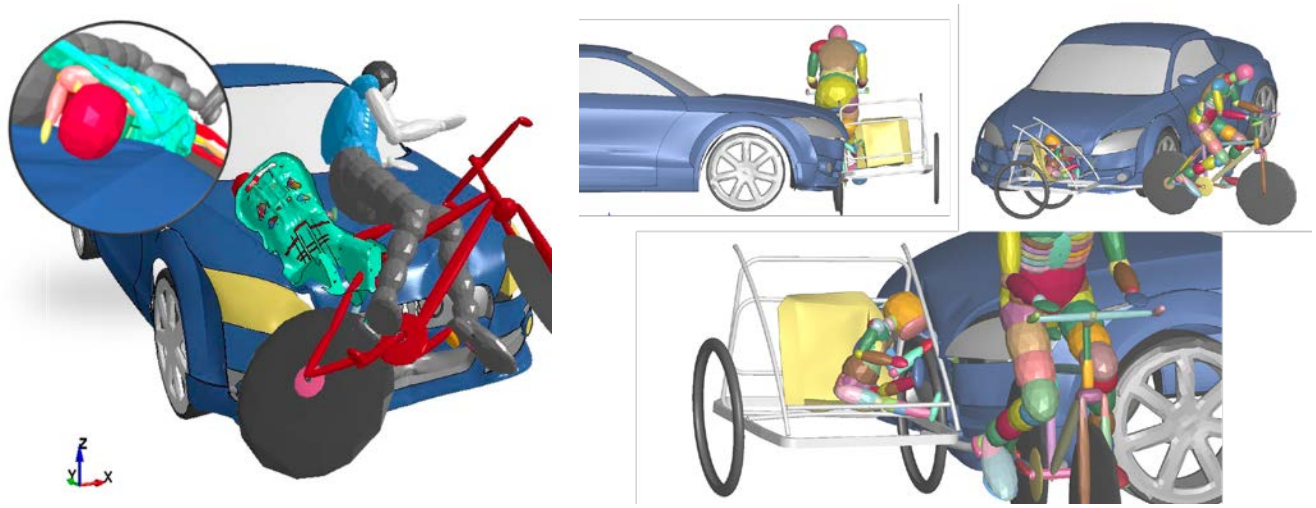

Fig. 2. Impact situations for the bicycle with an attached child: (a) seat; and (b) trailer.

IV. DISCUSSION

The aim of this paper was to analyse the vulnerability of children travelling in bicycle-mounted child seats and in bicycle-attached trailers. To date, there are very limited findings with regard to the crashworthiness of child-related bike transportation, despite the fact they are used frequently on modern roadways. The study found that the crashworthiness of the baby-carrier is inadequate, with accidents often including head side-impact and face-first contact to the bonnet, as well as a high likelihood of secondary impacts. Cycling is promoted as a healthy and safe type of transport in urban environments, by governments among others, and while this is relatively true, our study also shows it to be true that crashworthiness must be improved by additional active and passive safety devices for bicyclists and their passengers – as set out in, for example, [3]. This research represents one of the first attempts of advanced numerical simulation of a real-world bicycle-to-car impact scenario featuring the vulnerability of a child being transported on the bicycle.

V. REFERENCES

[1] Ptak, M., *et al*., *Int J Crashworthiness* 2019.
[2] European Committee for Standardization, 2004.
[3] Ptak, M., *Appl Sci*, 2019.