Analysis of Bonnet Deflection due to Body Loading in Full-Scale Pedestrian Impacts

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I. INTRODUCTION

Deployable pedestrian protection systems (DPPS) to improve the passive pedestrian safety of passenger cars have been in use for several years. When there is impact involving a pedestrian, those systems provide additional clearance between the bonnet and underlying structure, ideally with the bonnet fully deployed before head impact, so that impact energy can be reduced and possible head injuries can be mitigated. However, due to the loadings induced by the pedestrian while wrapping around the vehicle front-end, the generated clearance is expected to be significantly compromised prior to head impact. This phenomenon is not reflected by component tests with pedestrian head impactors either in legislation or in consumer testing. Indeed, Euro NCAP has established two theoretical criteria that must be fulfilled such that impactor tests may be performed against the deploying or fully deployed bonnet [1]. The first criterion requires a certain remaining percentage of additional clearance during selected human body model (HBM) simulations. The second criterion prescribes a positive, unquantified deformation space subsequent to loadings induced by the HBM. However, these criteria do not follow earlier studies suggesting a fixed minimum clearance for avoiding bottoming-out of the headform during component tests [2]. Furthermore, while the preamble of Amendment 3 to UN Global Technical Regulation No. 9 (GTR9) is examining possible development and implementation of such procedures in the future [3], so far no requirements have been imposed in legislation. This short communication investigates the actual influence of pedestrian body loading on the bonnet clearance at the time and location of the head impact.

II. METHODS

The actual bonnet deformation of passenger cars during pedestrian accidents was investigated in two full-scale vehicle crash tests with the ‘Primus Unbreakable’ dummy with its focus on impact kinematics and contact biofidelity [4].

Experimental Crash tests with sedan and small SUV Representative

Bonnet deflection was measured during the lateral impact of a sedan-shaped passenger car against the Primus dummy, crossing the road from the right to the left, at an impact speed of 40 km/h. A second crash test was carried out with a small SUV impacting the dummy at 50 km/h when crossing the road from the left to the right. The point of first contact between the vehicles and the lower extremities of the dummy was located on the foremost vehicle point on the longitudinal vertical vehicle centreplane. The stationary dummy was in walking posture, with its right leg in front but with hanging arms. The release of the dummy was initiated by an electromagnetic hanging mechanism, directly before the vehicle impact, in order to maintain its upright position until the time of first contact.

Data Acquisition

For determination of the bonnet deflection close to the head impact location, both vehicles were equipped with a string potentiometer and the change of string length was measured in vertical direction over the time. Due to the length and geometry of the tested bonnets, the string length acquisition was realised at the intersection of the longitudinal vertical vehicle centreplane and Wrap Around Distance (WAD) 1500.

INITIAL FINDINGS

Figure 1 depicts the bonnet displacement vs. time in both tests. Approximately 62 ms after first contact of the dummy with the sedan (black curve), a first elastic bonnet deformation of 10 mm occurred at WAD 1500. After deforming back, the bonnet was loaded a second time with a maximum deformation of 28 mm after 111 ms. The deformation remained elastic, with the potentiometer returning to almost its initial position after the test.

As illustrated in Fig. 1, the head contact on the sedan occurred shortly after the time of maximum bonnet deformation at WAD 1500. However, its impact was approx. 500 mm rearward of the maximum deflection, on the windscreen (WAD 2010). Altogether, the influence of bonnet deflection on the head injury risk may be negligible, but an effect on the chest deflection can be assumed, compare Fig. 2.

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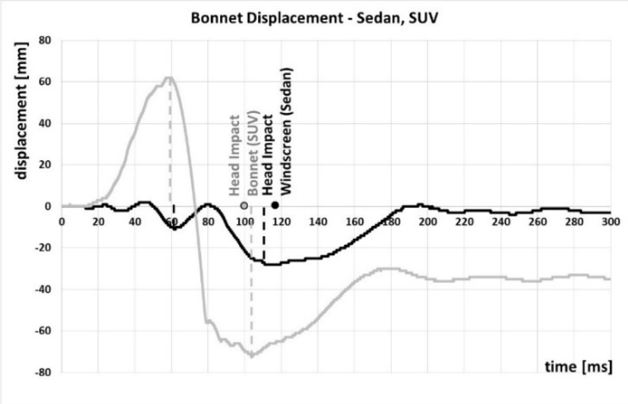

Fig. 1. Bonnet deflection during pedestrian impact – sedan (black), small SUV (grey).

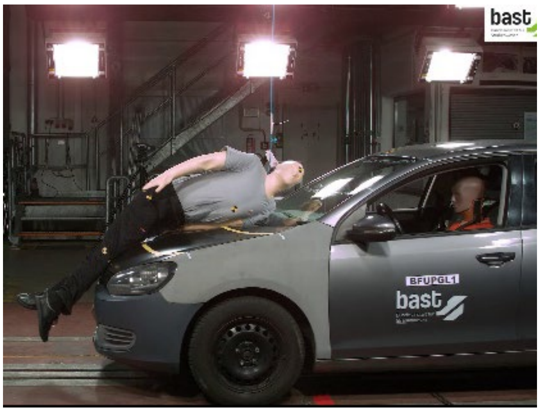

Fig. 2. Dummy position at maximum bonnet deflection during sedan impact.

A very different deformation pattern was observed in the SUV test, compare grey curve in Fig. 1. Scooping up and wrapping around the dummy caused the bonnet to bulge forward (see Fig. 3), reaching its maximum protusion (62 mm) after 60 ms. Subsequently, the bonnet swung back, with a maximum deformation of 72 mm at 105 ms after initial contact (Fig. 4). The overall plastic deformation remained at 33 mm (sedan: 2 mm).

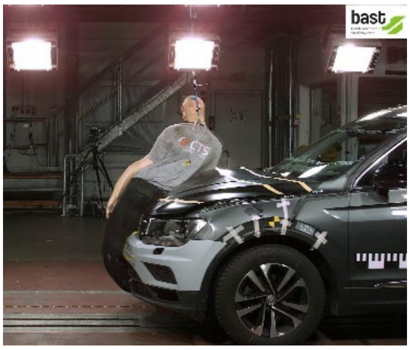

Fig. 3. Maximum protrusion during small SUV impact.

Fig. 4. Dummy position at maximum bonnet deflection during small SUV impact.

The bonnet deformation of the SUV was of predominant relevance as its maximum occurred approx. at the time of head impact (100 ms after initial contact, see Fig. 1), only slightly forward of the first head contact point (WAD 1780). Thus, the clearance at the head impact point was also compromised during the head impact. It should be noted that the DPPS of the SUV was unarmed, i.e. used in the undeployed position. With an armed and triggered system, due to the lower bonnet support, the deformation would be expected to be even greater (>72 mm).

III. DISCUSSION

Subject to further research, including further vehicle categories, the reported crash tests demonstrated that the bonnet deflection can have a high impact on the available clearance at the time and location of the head impact. While the deformation of the sedan bonnet was rather moderate and the head impact occurred in the windscreen, the head contact in the test with the small SUV was close to the maximum deflection both in terms of location and time. The smaller clearance is concluded to have a significant influence on the actual loadings in pedestrian headform tests, which has not yet been taken into consideration in the impactor tests according to legislation. Furthermore, also in those cases where the pedestrian head contact does not occur on the bonnet, additional clearance may contribute to reduce injuries to other body parts.

IV. REFERENCES

[1] Euro NCAP Pedestrian Testing Protocol 9.1, 2024.
[2] Zander, *et al*., DPPS-1-10
[3] UNECE GTR No. 9 Amendment 3, 2024.
[4] https://www.crashtest-service.com.