The ability of flexible car bonnets to mitigate the consequences of frontal impact with pedestrians

Sebastian Stanisławek[1], **Tadeusz Niezgoda**[2]

[1, 2] *Faculty of Mechanical Engineering, Military University of Technology*
Kaliskiego Street 2, 00-908 Warsaw, Poland
e-mail: sebastian.stanislawek@wat.edu.pl, tadeusz.niezgoda@wat.edu.pl

Abstract

The paper presents the results of numerical research on a Toyota Yaris passenger sedan hitting a pedestrian. A flexible car body is suggested as an interesting way to increase safety. The authors present a simple low-cost bonnet buffer concept that may mitigate the effects of frontal impact. Computer simulation was the method chosen to solve the problem efficiently. The Finite Element Method (FEM) implemented in the LS-DYNA commercial code was used. The testing procedure was based on EEVC regulation. A flexible bonnet buffer shows its usefulness in preventing casualties in typical accidents. The HIC_{15} parameter is 675 only when such a buffer is installed. In comparison, an accident involving a car without any protection produces an HIC_{15} of 957, which is very dangerous for pedestrians.

Keywords: pedestrian safety, bonnet buffer, computational mechanics

1. Introduction

Accidents involving pedestrians are a major global cause of traffic-related injuries [1]. Especially in poorly developed countries, pedestrian fatality is high compared to vehicle occupants. Even in Europe, where the situation is relatively good, 15% of casualties are pedestrians and 10% are cyclists [2]. These facts have resulted in numerous programs to improve vehicle design or systems that mitigate the consequences of accidents. Statistics show that most pedestrians are struck by the front of vehicles; however, other scenarios are more complex and depend on many factors. To respond to this threat, automakers have implemented changes in the design of the front of vehicles. Bonnet ornaments are usually removed and exterior mirrors are mounted on springs. Special attention is paid to bonnet fastenings to enable easy collapse when impacted by a pedestrian. In many designs, a free space between the bonnet and the engine is provided to allow it to deform easily. Active systems that can detect pedestrians are a key development in this field. Such systems can distinguish humans and other objects and stop the car automatically. Another kind of system lifts the bonnet when an accident has already occurred and head impact is anticipated [3]. Despite all these approaches, only some vehicles have a high level of safety. Moreover, such systems are usually restricted to mitigating frontal impact, while in reality more complex scenarios may occur. Therefore, the requirement for an inexpensive yet versatile solution has still not been achieved. A flexible car body could be an interesting method to increase pedestrian safety. Therefore, in this paper the effect of flexible bonnets on pedestrians during accidents is investigated.

2. A flexible bonnet concept

The European Enhanced Vehicle-Safety Committee (EEVC) has developed test specifications and rating systems for assessing pedestrian injuries during impacts with the front of vehicles. Such tests include a series of tests using impactors designed to mimic a collision at a speed of 40 km/h. They describe a situation in which a pedestrian is situated laterally and a car first hits one of his legs. Tests are conducted on the leg, upper leg, and most importantly, the head, as head trauma is most commonly responsible for casualties. The injury threshold HIC_{15} (Head Injury Criteria) is 1,350 and no less than two-thirds of the total number of measurement points on a vehicle should exceed 1000 [4]. Compared to other standards, the accepted values are relatively high, especially when it is considered that HIC_{15} more than 1,000 usually leads to serious brain damage. Most cars cannot pass more rigorous tests than these; therefore, pedestrians are currently in serious danger during accidents with even vehicles moving slowly.

A flexible bonnet is suggested in order to mitigate the effects of accidents, especially head trauma. This simple and inexpensive solution could be implemented on vehicles of all types. The concept is presented in Fig.1.

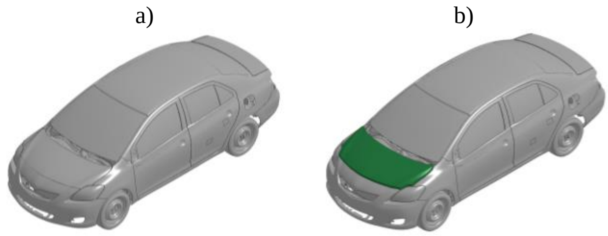

Figure 1: A concept of a flexible bonnet: (a) reference car, (b) car with a buffer

3. Numerical model

A computer simulation method was chosen in order to investigate the problem. The Finite Element Method (FEM), implemented in the LS-DYNA commercial code typically used in crash and blast analyses [5] was used with an explicit (central difference) time integration algorithm. A Hybrid III (5% centile) dummy model and a model based on a 2010 Toyota Yaris passenger sedan were used to simulate the phenomenon of side impact. In the reference version, a vehicle hits the pedestrian; in the tested version, a 30mm buffer made of low-density foam is additionally mounted on the vehicle bonnet (Fig. 2).

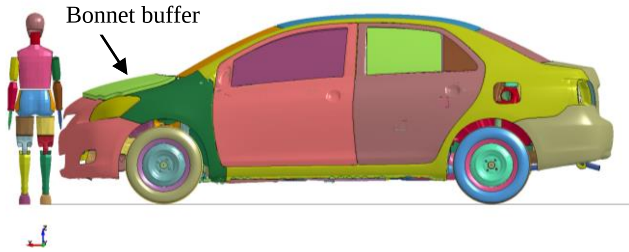

Figure 2: Numerical model of Toyota Yaris passenger sedan and a dummy: (a) reference variant, (b) a buffer is mounted on the bonnet

A detailed finite element model of a vehicle containing 919 parts developed through reverse engineering was obtained from [6]. The initial speed of the vehicle was set at 40km/h. A human dummy was obtained from [7]. An additional buffer that covers the bonnet was modelled with a low-density foam material model that is typically used to represent highly compressible foams [7].

4. Results

The obtained results show that a pedestrian hit by a car moving at a relatively low speed suffers serious trauma. As can be seen in Fig. 3, the front bumper hits the lower legs of the dummy, causing rotation. This implicates that the upper part of the body hits and significantly deforms the bonnet. At the most critical moment of the phenomenon, the head hits the structure. Such an event is expected to result in injuries to the head and neck. This situation seems to be less drastic when a bonnet buffer is mounted, as the foam material seems to mitigate the impact; however, based on only this examination, it is hard to estimate the usefulness of such a buffer. Analyses made it possible to measure the HIC_{15} parameter, which is presented for both versions in Fig. 4. It is clear that the flexible structure on the car helps increase pedestrian safety as the maximum HIC_{15} value is significantly lower when it is installed.

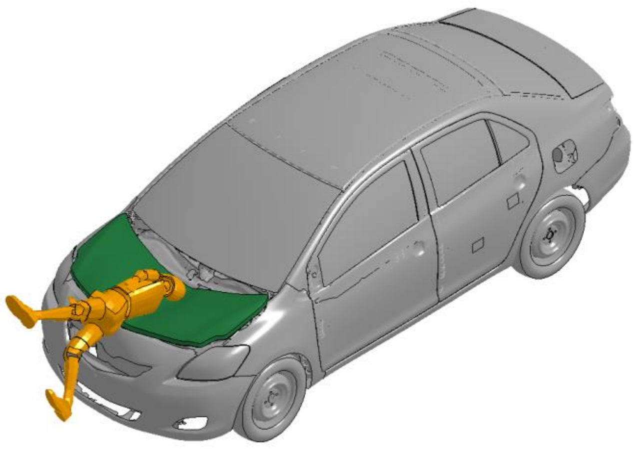

Figure 3: Most critical moment of accident when dummy's head hits the bonnet buffer

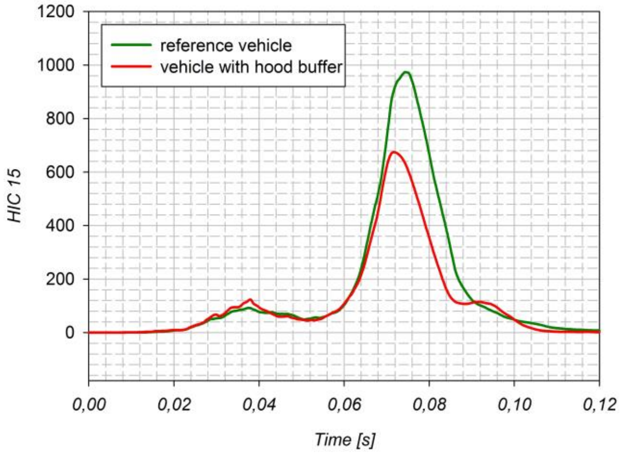

Figure 4: HIC_{15} parameter

5. Conclusions

Accidents with pedestrians usually cause serious trauma. In the most probable scenario, a pedestrian is hit by a vehicle's front bumper, causing him to fall on the bonnet or windshield, thereby hitting it at high velocity. This leads to serious brain injuries as, even though most vehicles are designed according to current regulations, these standards are low and therefore cannot guarantee pedestrian safety. Therefore, a flexible car body design may be a good solution for this problem. In this paper, the usefulness of a flexible bonnet buffer to protect a typical accident victim is presented. The HIC_{15} parameter is 675 only when such a buffer is installed. In comparison, an accident involving a car without any protection produces an HIC_{15} of 957, which is very dangerous for pedestrians. Further investigations are essential to verify the threat posed by other impact points. Moreover, analysis of other parts of the dummy body should be carried out.

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