New Experimental Test to Assess Wearable Airbag Head Impact Protection

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I. INTRODUCTION

Airbags have recently emerged as a promising option to enhance the protective capabilities of cyclist helmets, in particular by offering a larger volume to absorb impact energy [1]. The current EN1078 European standard drop test for bicycle helmets [2], consisting of a rigid headform falling onto an anvil, is not applicable to all airbags due to differences in size and shape. For instance, airbags integrated into cyclist backpacks [3-4] deploy around the head and the trunk and the use of a surrogate torso is necessary to maintain its position. Full, or half upper dummies have already been used to evaluate the shock absorption capacity of football helmets [5], baseball helmets [6-7] and boxing headgear [8]. In these cases, the opponent surface was propelled, using a linear impactor [5] or a pendulum [8], or pneumatically fired toward the dummy's head [6-7]. The use of the head, neck and torso parts of a dummy, such as the Hybrid III, ensures more biofidelic conditions by incorporating realistic inertia characteristics and allowing assessment of potential neck injuries [9-10]. However, this type of test has never been used to evaluate bicycle helmets or airbags. The aim of this study is to develop a new dummy impact test protocol for evaluating the absorption capacity of head airbags as well as the effectiveness of other safety devices such as classic helmets.

II. METHODS

Head impact tests on the upper body of a Hybrid III 50th percentile male dummy were conducted using a 16 kg pendulum. The impacting surface, made of steel, was flat and circular with a diameter of 130 mm, like one of the anvils used in EN1078. The pendulum was dropped from a height of 1.5 m above the head impact location, resulting in an impact velocity of 5.4 m/s, in accordance with EN1078. The lumbar vertebrae of the dummy were clamped in a vice, which was then screwed to a floor-mounted two-axis table to adjust the position of the dummy. A prototype of an airbag integrated into a backpack, which was developed by the manufacturer In&motion, and classic helmets certified EN1078 were tested. The airbag was inflated before the impact with an air compressor, and its pressure was monitored using a pressure sensor. The study included two types of configuration: side and rear impacts. Three rear impacts and one side impact were performed with a helmet. The helmets were not tested more than once for the same configuration. For each configuration, there were four tests conducted with the dummy wearing the deployed airbag (Fig. 1). For side impacts, the measured pressures just before impact were P0, 1.25*P0, 1.34*P0 and 1.91*P0, while for rear impacts they were 1.02*P0, 1.16*P0, 1.86*P0 and 1.93*P0. Head linear accelerations and angular velocities at the centre of gravity of the head were measured with a 3-axis accelerometer and a 3-axis gyroscope at a frequency of 10 kHz. The Head Injury Criteria (HIC_{36}) was calculated after processing and filtering the linear acceleration with a CFC 1000 filter.

Fig. 1. Experimental setup for the rear and side head impacts with the airbag and with the helmet.

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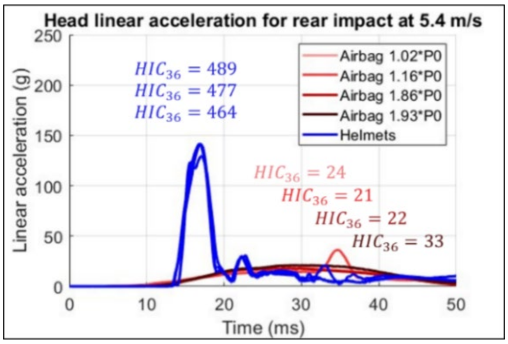
III. INITIAL FINDINGS



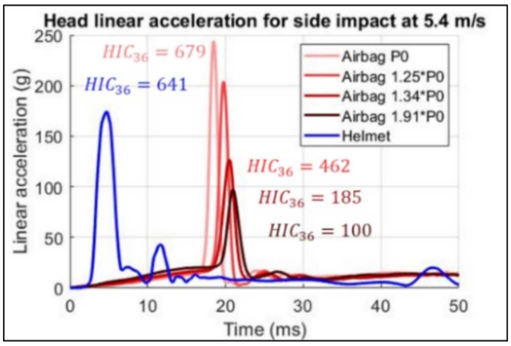


Fig. 2. Resultant head linear accelerations and HIC_{36} for rear and side head impacts.

For rear impacts, the use of the airbag decreased peak linear accelerations by 82% (24 ± 9 g vs 137 ± 7 g) and HIC by 95% (25 ± 5 vs 477 ± 13), as shown in Fig. 2. Angular velocity was also lower with the airbag than with the helmets (1084 ± 75°/s vs >1500°/s), while impact duration was longer. In side impacts, airbag's pressure had a great influence on head acceleration upon impact. At P0 and 1.25*P0, peak head acceleration was higher with the airbag (242 g and 202 g, respectively) than with the helmet (174 g). On the contrary, when the airbag pressure was 1.34*P0 and 1.91*P0, the peak linear acceleration was lower than with helmets (126 g and 97 g, respectively). Similarly, with an airbag pressure P0 the HIC_{36} was higher (679) than with the helmet (641), but when the airbag pressure was 1.25*P0, 1.34*P0 and 1.91*P0, HIC_{36} was lower (462, 185 and 100, respectively). The duration of the side impact was always longer with the airbag than with the helmet, and the higher the airbag pressure, the longer the duration of the impact.

IV. DISCUSSION

This study presents a new experimental protocol for evaluating the performance of different head protections, such as a classic helmet and a bulky airbag, using a dummy for more biofidelity and to account for head-neck-torso interaction. The airbag outperformed the helmets in rear impacts and in side impacts at certain pressure levels. Due to the big rear airbag volume, pressure had minimal effect on its performance during rear impacts, resulting in a low variability. The peak linear acceleration was approximately six times lower and the impact duration five times longer with the airbag compared to a helmet, which is in accordance with previous studies [1][11]. However, in side impacts, the airbag bottomed-out in all four tests. The shape of the airbag, with a relatively small volume at the sides and a gap around the user's ear, provided less protection in side impacts than in rear impacts. Thus, in side impacts, the lower the pressure, the earlier the bottom-out phenomenon occurred, as previously observed [1], resulting in higher linear accelerations and HIC_{36} values. Angular velocity was measured during the tests but the range of the sensor was 1500°/s and it saturated for all tests with a helmet, and for side impacts with the airbag. Replacing these sensors would be necessary because angular velocity is an indicator of brain injury [9][12]. The pendulum impact energy was 235 J, higher than that of EN1078 drop tests (<100 J), but some of that energy was absorbed by the deformation and movements of the head, neck and torso of the fixed upper body of the dummy. This fixed constraint resulted in lower head accelerations compared to previous EN1078 tests, where the rigid headform was unrestricted while impacting a fixed anvil with the same helmet. Future research could explore varying energy levels and assess neck injury risk with and without neck-protecting airbags by measuring neck loadings. Another perspective could be to perform tests with other impact shapes, such as the EN1078 kerbstone or larger flat impact surfaces more representative of road impacts, to assess the performance of airbags with more or less penetrating contact surface shapes, which are challenging for airbags [13]. This study demonstrated the potential of this new protocol for comparing different head protection devices and aiding in airbag development by offering insights into optimal pressure and design.

V. REFERENCES

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