I. INTRODUCTION

Powered Two Wheelers (PTWs) riders account 17% of all traffic fatalities in the European Union [1]. Besides the head, thorax was reported in some studies as the most severely injured body region [2-3]. Airbag jackets were proposed as a potential solution to increase motorcyclists’ safety and protect the thorax [4]. Most of the currently available airbag devices in the market are certified by the European Standard EN 1621-4 for motorcyclist protective clothing against mechanical impacts [5]. This standard, attending to the maximal force transmitted to a rigid anvil in a series of drop-tests, assigns three different levels of protection to any airbag tested. However, the correspondence of the boundary conditions of this procedure to those occurring in a real accident [6-7] is questionable and the biomechanical basis to establish those force thresholds is unknown. As a preliminary step for the development of an improved test procedure, it is the aim of this work to compare the assessment of four wearable airbags using EN1621-4 to the assessment of their performance in a more realistic impact situation. This study was conducted as a comparative ranking using Finite Element (FE) simulations.

II. METHODS

Four different conceptual airbag models were numerically tested following the procedure and certification criteria established in the standard EN1621-4 [5] (Fig. 1). In addition, a rider-to-object impact configuration was simulated using the same airbags coupled with the model Global Human Body Models Consortium (GHBMC) Pedestrian v1.6 50th percentile. In this configuration, the GHBMC impacts frontally a fixed cylinder (Fig. 1a) with a radius of 100 mm at an impact velocity of 30 km/h [6]. The same process was conducted using a FE model of the 50th percentile Hybrid III dummy (Fig. 1b). For both models, the values of maximal chest deflection were measured and for the simulations with the GHBMC, strain-based prediction of possible rib fractures was done [8].

Inflation pressure and inflated thickness of an airbag determine the chest deflection during an impact [9]. Therefore, two combinations of airbags with two different thicknesses and pressures were modelled in FE: 3.5 cm and 2 bar (A1), 3.5 cm and 3 bar (A2), 8.5 cm and 0.265 bar (A3) and 8.5 cm and 0.65 bar (A4). Length and width dimensions are the same for the four airbag models.

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Limitations of the Standard Test Procedure for Assessing the Protection of Motorcyclist Airbag Jackets in a Realistic Impact Scenario

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Fig. 1. EN1621-4 Protection levels [5].

<table>
<thead>
<tr>
<th>Overall Mean value</th>
<th>Level 1</th>
<th>Level 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single strike</td>
<td>≤ 4.5 kN</td>
<td>≤ 2.5 kN</td>
</tr>
<tr>
<td></td>
<td>≤ 6 kN</td>
<td>≤ 3 kN</td>
</tr>
</tbody>
</table>

Fig. 1. EN1621-4 Protection levels [5].

Fig. 2. Rider-to-object impact configuration with airbag for a) GHBMC Ped v1.6 and b) FE Hybrid III dummy.

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III. INITIAL FINDINGS

Transmitted force values and level of protection for each airbag model shown in the simulation of the EN 1621-4 impact procedure are presented in Table I together with the maximal deflection values and estimated rib fractures obtained from the rider-to-object simulations. Airbags A3 and A4 reported level 2 of protection. Airbag A2 reported level 1 and airbag A1 would not pass the EN1621-4 test.

Results show similar maximal chest deflection values measured for A1 and A2: 100 mm in both cases of Hybrid III simulations and 80 mm in both simulations with the GHBMC. Airbag A4 shows the best performance reporting 74 mm and 97 mm maximal thorax deflection for the GHBMC and Hybrid III simulations, respectively. Despite its better rating in the EN 1621-4 test procedure, A3 presents slightly worse performance in comparison with the other airbags, 83 mm deflection in GHBMC simulation and 103 mm in Hybrid III calculation. Attending to the strain-based analysis, two fractures would be expected for the airbags A2 and A3. No fractures would be reported for the cases A1 and A4.

Table I

<table>
<thead>
<tr>
<th>Airbag model</th>
<th>Force transmitted (kN)</th>
<th>Protection level</th>
<th>Hybrid III chest deflection (mm)</th>
<th>GHBMC chest deflection (mm)</th>
<th>Rib fractures</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>25</td>
<td>Fail</td>
<td>100</td>
<td>80</td>
<td>None</td>
</tr>
<tr>
<td>A2</td>
<td>3.2</td>
<td>L1</td>
<td>100</td>
<td>80</td>
<td>2nd L, 3rd L</td>
</tr>
<tr>
<td>A3</td>
<td>1.2</td>
<td>L2</td>
<td>103</td>
<td>83</td>
<td>3rd L, 3rd R</td>
</tr>
<tr>
<td>A4</td>
<td>1.4</td>
<td>L2</td>
<td>97</td>
<td>74</td>
<td>None</td>
</tr>
</tbody>
</table>

IV. DISCUSSION

This work tried to find a relationship between current thorax airbag standard test results and protection performance in a more realistic impact situation. The impact conditions are in agreement with the findings of two recent studies and can be understood as being of medium severity [6, 7].

The presented results indicate some limitations of the current standard EN 1621-4 for the evaluation of airbag effectiveness. Attending to the maximal chest deflection measured in the simulations using the GHBMC, it has been found that an airbag classified initially as fail (A1) in the certification test presents almost the same deflection peak value as another (A2) approved by the test and classified as a level 1 protector. A possible explanation could be that the higher pressure of A2 for the same inflated thickness appears to generate a stiffer protector that is able to absorb a lower amount of energy. In addition, for two airbags which would be rated with the same level of protection (A3 and A4), the maximal chest deflection obtained differed in 8 mm despite the opposite trend in force transmitted. Two rib fractures would be expected regarding to A3 results and none to A4 suggesting that the lower pressure combined with the high thickness of A3 is producing a flat airbag not capable of absorbing such an amount of energy. In terms of maximal thorax deflection, the values obtained from the simulations with the FE model of the Hybrid III dummy show the same trends as those obtained for the GHBMC. Absolute values are to be treated with care until specific (re-)validation of applied models is done.

Attending to the biomechanical parameters here evaluated, the results obtained indicate that the standard test method is not sensible enough to distinguish the optimal inflated thickness/pressure combination. Therefore, the values of transmitted force might not be considered as the only indicator of the potential thorax protection, and the introduction of a complementary test based on biomechanical measurements like chest deflection should be considered. The simulations conducted with the FE model of the Hybrid III dummy follow this recommendation and they represent the first step in the development of an advanced, yet cost-effective test procedure for the evaluation of frontal thorax airbags for motorcyclists.

V. ACKNOWLEDGEMENTS

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VI. REFERENCES
