Method Development for Assessing Risk of Thoracic Injury to Motorcycle Riders

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I. INTRODUCTION

The European Standard EN 1621 sets out requirements and test methods for motorcyclists' protective clothing against mechanical impact. The aim is to standardise the protection levels offered by motorcyclists' clothing in accident scenarios. The real-world relevance, however, has been questioned for EN 1621 passive impact protectors [1]. Part 4 of the standard (EN 1621-4) addresses mechanically activated inflatable protectors for motorcyclists (with an impactor of 5 kg falling at 4.5 m/s), and previous authors have pointed towards limitations in how representative the test procedures are when compared with likely real-world impact scenarios [2]. As part of their work within the PIONEERS Project, Aranda-Marco *et al.* [2] reported an alternative and higher energy rider-to-object impact configuration where a 50th percentile rider frontally impacts a fixed cylinder at 8.3 m/s. Rather than using a pass/fail force limit, as in the standard, the values of maximal chest deflection were measured and used to assess the risk of rib fractures. Thereby, an impact representing real-world conditions was coupled with a metric relating to human tolerance. The PIONEERS Project resulted in two further test method proposals. The first was a drop test where a guided impactor hits the anterior surface of a supine Hybrid III 50th percentile male (HIII-50M) chest (≤ 35 kg and 7 m/s for a cylindrical impactor) [3], and the second was a reversed drop test where the HIII-50M chest falls onto an impact anvil (19 kg and 6.6 m/s) [4]. Through this communication, we propose a frontal thorax airbag test method related to the real-life safety needs of motorcycle riders making use of the common HIII-50M dummy in conditions closer to its certification setup.

II. METHODS

Computational modelling was used to specify the impact conditions, but this communication focusses on a preliminary series of experimental tests. The testing translates the impact orientation from PIONEERS to the horizontal plane, and the dummy is in an unconstrained position close to that used for its thorax certification.

Test Method

A complete HIII-50M was used for this testing, including a shirt but no other clothing. Besides the arms, it was in the thorax certification position [5]. The upper arms abducted slightly, and the lower arms bent forward. The dummy was seated on double sheets of PTFE (polytetrafluoroethylene) on a test surface supporting the outstretched legs. A cylindrical test probe was used (diameter 152.4 mm [5-6]), with its longitudinal centreline being horizontal and perpendicular to the direction of travel. The midline through the probe was aligned 12.7 mm below the horizontal centre of rib number 3. A linear impactor propelled the cylinder (total mass 32 kg) horizontally at 5.9 m/s towards the dummy so that no lateral, vertical or rotational motion occurred during the impact. Figure 1 shows the test setup in the reference condition without thorax protection.

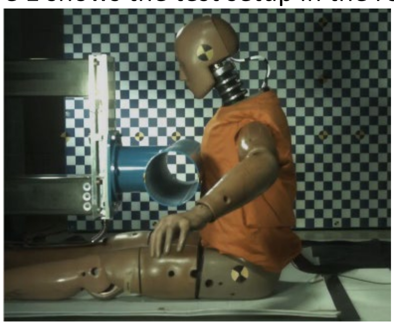

Fig. 1. HIII-50M in position before linear impactor loading to the thorax.

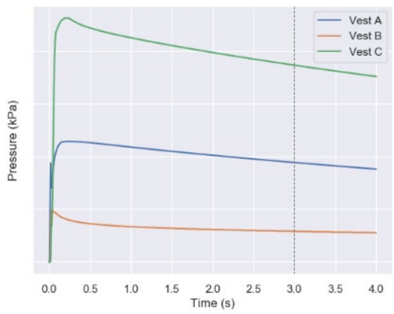

Fig. 2. Pressure progression in the tested vests. The black dotted line shows the inflation pressure at 3 s.

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Samples Tested

Three airbag vest products (Vests A-C), already available on the market, were used to benchmark performance. A prototype vest (Vest D) was also tested with a larger coverage area on the front of the chest than required by the EN 1621-3 protection zone templates and with no associated restrictions on pressure. Only Vest C has an EN 1621-4 level 2 chest certification. Static inflation pressure was used for the tests, via the laboratory supply of compressed air, after identifying the dynamic vest pressure 3 s after live deployment of the samples (Fig. 2). Vest pressure retention of 3 s is likely needed to cover the first chest-to-ground impact [7].

III. INITIAL FINDINGS

Table I shows the mean results and standard deviations (std) from the two tests of each setup. The reference test condition, without any vest, generated a chest deflection of 62.4 mm and a Viscous Criterion (V*C [8]) of 1.1 m/s. These values are associated with a substantial risk of multiple rib fractures and organ injuries. All four vests could reduce the loading measured in both criteria, although the extent varied from 7% to 36% in chest deflection.

TABLE I

PRESSURE INPUT AND HIII-50M DUMMY METRICS FOLLOWING PRELIMINARY THORACIC IMPACTS

	Airbag Pressure (kPa)	Chest Deflection (mm)	Viscous Criterion (m/s)
Reference test (no vest)	Not Applicable	62.4 ± 1.8	1.10 ± 0.01
Vest A	94	57.9 ± 0.4	1.02 ± 0.01
Vest B	29	52.1 ± 0.2	0.75 ± 0.04
Vest C	187	49.0 ± 1.7	0.51 ± 0.03
Vest D	100	40.2 ± 0.6	0.34 ± 0.01

IV. DISCUSSION

This work builds on prior recommendations to update the assessment of inflatable protectors with a higher impact energy test than in the EN 1621 standard. As such, it incorporates the use of a cylindrical impactor striking the HIII-50M chest. A high mass impactor of 32 kg was adopted, and the impact speed was limited to 5.9 m/s compared with [2-3] to avoid damaging the dummy in the reference condition. Nevertheless, the proposed test method can show the benefits of, and distinguish the performance between, different vests through the reduction of chest deflection and V*C. The size of effect between Vest D (prototype) and the reference tests indicates the potential for vests to mitigate the risk of thoracic injury for motorcyclists when similar loading is observed in real-world accidents. Vest C with EN 1621-4 chest certification offers the second largest reduction in HIII-50M metrics but uses the highest inflation pressure to achieve this (187 kPa). From these initial findings, such high pressures are not necessary to control thoracic injury risk but seem to be a constraint of other design choices combined with the performance requirements in EN 1621.

As with the HIII-50M thorax certification, this test method is sensitive to the whole dummy's initial position and response. Despite this, the repeatability of the small number of tests was good (see std in Table I). Impactor-to-arms contact could be observed in the reference condition due to minor arm angle variations and the impactor width (Fig. 3). To avoid this contact, an impactor only slightly wider than the HIII-50M chest should be used.

The HIII-50M dummy has a single point for its thorax compression criterion [8]. An unaligned loading point or direction will cause an underestimation of both chest deflection and injury risk. Therefore, this test method is limited to evaluating the effectiveness of protection at the chest centre. It does not assess or reward larger coverage areas, though contact points over the upper thorax may be common [9]. As such, and with this test method, we commend a continuing assessment of protection priorities for real-world impacts to motorcyclists.

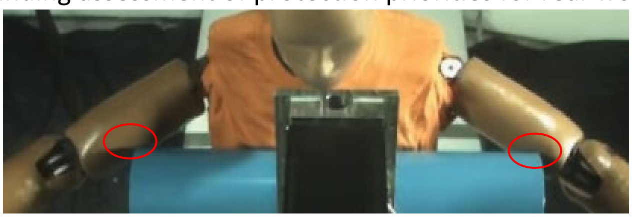

Fig. 3. Wide impactor-to-arms contact (red) shows the need for a maximum impactor width.

V. REFERENCES

[1] Albanese, *et al*., IRCOBI, 2016.
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[5] CFR 49, Part 572 (Subpart B), 1973 as amended.
[6] Kühn and Lang, GDV CAR 91, 2019.
[7] Ballester, *et al*., AAP, 2019.
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[9] Bourdet, *et al*., *I J Crashworthiness*, 2020.