The impact response of four PMHS to frontal impacts in reclined positions

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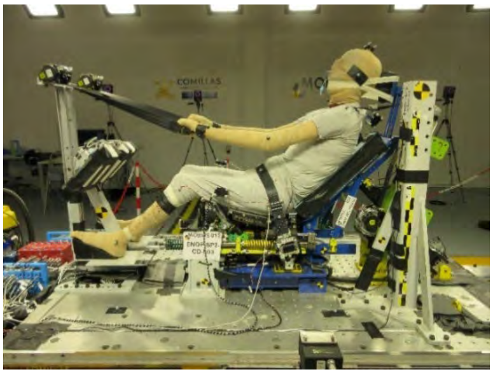
I. INTRODUCTION

There is growing interest in characterising the impact response of humans and crash test dummies in reclined positions during frontal impacts, as well in obtaining experimental data that can be used in the development and benchmarking of human body models (HBMs) [1-4]. The ENOP (Enable New Occupant Seating Positions) project aims to understand the implications of flexible seating positions, which involve several seat-pan and seat-back angles, on the occupant kinematics and potential new injury patterns. One of these positions corresponds with a seat-back angle of 45° and four PMHS were tested in this condition.

This paper presents preliminary information about these PMHS tests, the performance of the restraint system and considerations about the observed kinematics of the occupants.

II. METHODS

Four PMHS tests were performed in a hydraulic-type sled catapult (ENCOPIM, Barcelona, Spain) using a 35 g peak and 50 km/h delta-v over an almost 90 ms generic crash pulse [1]. An updated version of the semi-rigid seat (seat-pan angle: 15° from horizontal; anti-submarining pan angle: 32° from horizontal) designed by [5] was used, with increased stiffness (+30%) to control the rotation of the anti-submarining ramp. A rigid backrest at 45° from the horizontal plane and retracted right before the onset of the acceleration (t=-20 ms) was used to ensure a repeatable initial position of the test subjects (Fig. 1). The characteristics of the PMHS are shown in Table I.



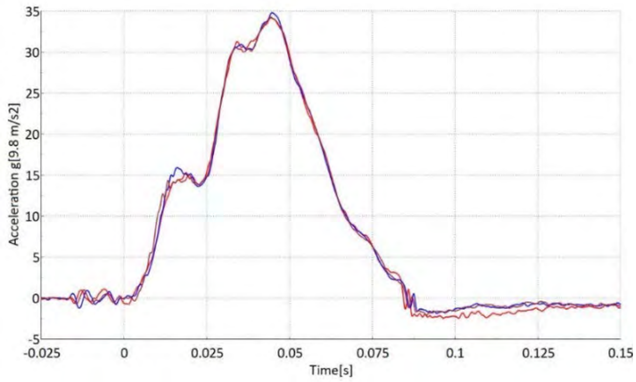


Fig. 1. Initial position of PMHS 3 and the test pulse used in the tests.

Test subjects were restrained by an advanced, seat-integrated, 3-point belt system with a crash locking tongue, consisting of a shoulder-belt retractor with 2 kN pretensioner (time-to-fire (TTF): 7 ms) and 4 kN load limiter, 2 kN lap-belt pretensioners and approximately 5 kN load limiters at each side of the pelvis (TTF buckle side: 9 ms, TTF anchor side: 17 ms) [6]. The anchorage points and the angle of the retractors of the seatbelt system were kept constant for all the PMHS, regardless of their anthropometry.

Retroreflective marker clusters were attached to the head, T1, T8, T11 and L2 vertebrae, to the pelvis and to the diaphysis of the femurs. Three-axial acceleration and angular rate sensors (ARS) were incorporated at the same locations. Rossette strain gauges were added to the pelvic iliac wings of the subjects. All these magnitudes were collected according to a coordinate system defined and filtered according to the standard SAE J211, with origin in the right rotation centre of the seat pan. The subjects were positioned so that the initial location of the hip joint and the angle of the pelvis and the head would be comparable between them, allowing some variability

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to account for the different anthropometries of the PMHS. A rigid body transformation between some external landmarks in the pelvis of the test subjects allowed for a detailed reporting of selected anatomical points prior to impact (ASIS, pubic symphysis, hip joint and pelvic angle). The initial position of the lumbar spine was also acquired via a lateral X-ray of the subject (Fig. 2).

TABLE I
CHARACTERISTICS OF THE PMHS

Test #	PMHS	Age	Height (cm)	Weight (kg)	Cause of death
M010	PMHS 1	69	184	66	Cardiac arrest
M011	PMHS 2	81	183	86	Urinary sepsis
M012	PMHS 3	74	174	67	Cardiac arrest
M013	PMHS 4	64	176	61	Gastric disease

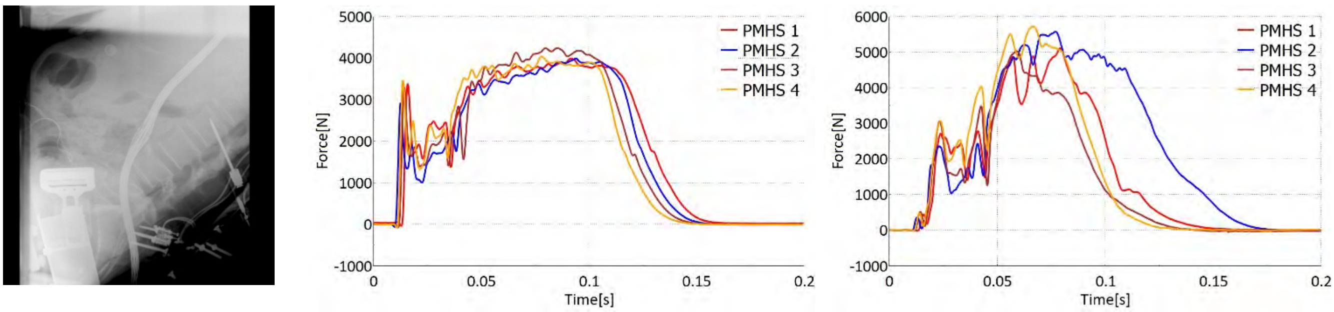

Fig. 2. Left: lateral X-ray of the lumbar spine of PMHS 4. Centre: time history of shoulder-belt forces measured at B3. Right: time history of shoulder-belt forces measured at B6.

III. INITIAL FINDINGS

After the complete definition of the ENOP test setup via Hybrid III sled tests, this setup was successfully used in the described PMHS tests. Four PMHS tests were completed with the occupant in a reclined position and with the backrest oriented at 45° from the horizontal plane. The restraint system used to arrest the forward motion of the PMHS performed according to its design specifications during the tests. The time history seatbelt force measured at the D-ring (B3) and at the lap belt (B6, anchor side) are included in Fig. 2, showing that the pelvic region of the subjects is exposed to belt loads of comparable magnitude to those sustained by the thorax of the occupants. In the case of the subject with the largest weight (PMHS 2, blue solid line in Fig. 2), the engagement of the shoulder belt with the thorax lasted for approximately the same time as for the other three subjects, but the lap belt demonstrated a much larger interaction time with the pelvic region of the occupant.

IV. DISCUSSION

The four analyzed PMHS tests showed that, under the action of the current restraint system that incorporates double load limitation in the lap belt, the pelvis of the subjects underwent a long forward excursion combined with rotation in the Y axis as estimated from the integration of the pelvic ARS (PMHS 1: 6.7 deg; PMHS2: 14.7 deg; PMHS3: 11.6 deg; PMHS 4: 10.6 deg). Note that these angle magnitudes were estimated up to times between 40 and 60 ms after the beginning of the acceleration, as in three out of the four tests the pelvic mount impacted the seat surface at around this time. The pelvis of PMHS 2 showed the largest forward excursion compared to the other subjects. It should be noted that the feet of the subjects were not restrained to the foot plate and, therefore, the seat assembly and the seat belt were the only restraints acting on the occupant during the test. The resulting kinematics challenged the use of the cluster of VICON markers attached to the pelvis.

V. REFERENCES

[1] Östling, *et al*., IRCOBI, 2022.
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