

## THE ANTHROPOMETRIC TEST DUMMY

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### **Abstract**

*This paper deals with the construction and preparing of the crash dummy destined for rear impact crash tests. The main criteria's considered for this dummy are: low production costs and increased simplicity in comparison with other existent anthropometric dummies. At the present times, better an better mathematical models are developed for cinematic during collisions but these have need to be validated in to experimental test. This requires testing and calibration of different segments and parts in order to reduce the error range of the measurement data. An important role is identified in the preparation and management of the experimental phase.*

**Keywords:** anthropology, dummy, crash test, vehicle rear-end impact, ...

### **1. Generalities**

This paper describes the construction of an anthropometric dummy, necessary for testing rear-end impact and vehicle-pedestrian collision types, experiments to be realized by the Department of Vehicles and Engines, Transilvania University of Brasov.

The research on this matter is being used at the basis of two doctorate thesis, offering the possibility of accumulating new information through the materials for biomechanics, vehicle dynamics, road traffic and dynamics of road traffic accidents courses and for continuous engineering research by the previous and following generations of students.

There are presented several aspects regarding the construction of the dummy, aspects related to the usefulness and purpose of it.

### **2. Dummy anatomy**

The dummy skeleton is composed primary by metallic parts giving it good structural properties, imitating the human model. This skeleton is covered by sanitary silicon gel giving him the appropriate external human form. The silicon was chosen as its characteristics mimic the behaviour or human tissue.

The component parts are described as follows:

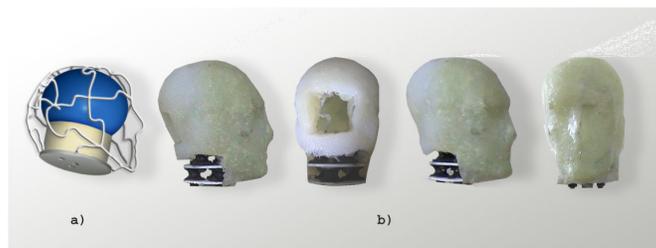


Fig. 1.1. Lab constructed anthropomorphic head :  
a) Metallic structure; b) Silicon covered (profile)

**The head** is based on a steel wire structure, covered with a silicon, assuring the biomechanical fidelity as well as the repeatability of the head reaction to the impact with hard surfaces. Inside the head there is an triaxial accelerometer placed in the mass center, offering data about brain accelerations during an impact. Knowing the head and thorax impact acceleration, the NIC (Neck Injury Criterion) can be determined. [3]

The neck injury criterion (NIC) is calculated as follows:

$$NIC(t) = a_{rel}(t) \cdot 0.2 + (v_{rel}(t))^2, \text{ where}$$

$$a_{rel}(t) = a_x^{T1}(t) - a_x^{Head}(t), \quad v_{rel}(t) = \int a_{rel}(t) dt, \quad \text{and} \quad (1)$$

$a_x^{T1}(t)$  = acceleration versus time measured in the antero - posterior (x) direction at the height of the first thoracic vertebra (lower neck accelerometer)

$a_x^{Head}(t)$  = the acceleration versus time measured in the antero - posterior (x) direction at the height of the c.o.g. of the head (head accelerometer), i.e. near the first cervical vertebra

The acceleration signals shall be filtered according to CFC180. The maximum value of NIC(t) within an interval of 150 ms after the beginning of the sled acceleration shall be determined and documented as the NIC max value. If the head, after contacting the head restraint, reverses its direction of relative movement at a point in time before 150 ms, the upper end of the interval of NIC(t) for the determination of NIC max shall be limited by this point in time.(for rear-end impact)[2]

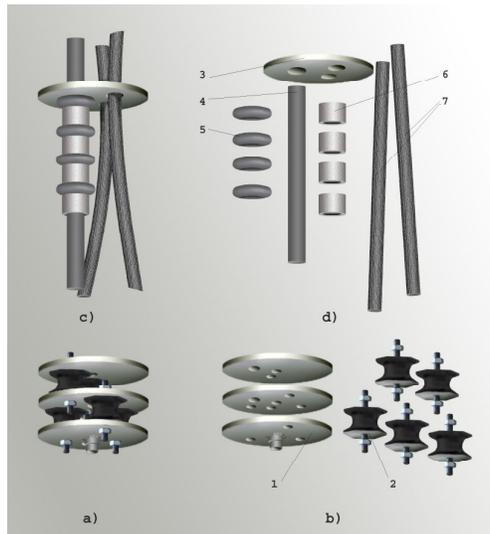


Fig. 1.2. Neck variations

- a) First neck variant (the degrees of freedom are somewhat restricted)
- b) Exploded assembly: 1. metallic disks; 2. rubber buffers.
- c) 2<sup>nd</sup> variant (increased biofidelity)
- d) Exploded assembly: 3. metallic disk ; 4. rubber stick; 5. rubber fillings; 6. metallic bushings; 7. elastic rubber covered flexible tube

**The manikin neck** is being realized in two variants: first one, more rigid and a somewhat limited degrees of freedom and the second one with increased biofidelity (fig 1.2.).

The neck is formed of two flexible parts (fig.1.2.d 4,7) , designed with biomechanical criterias in mind, with relaxed flexion and extension response. It is formed by four rigid metal vertebrae and four rubber shaped garnitures (butyl elastomer). The rubber garnitures have been

chosen for their relaxation characteristics and for the realization of biomechanical hysteresis. The metallic ends assure the connectivity with the head and thorax, because, especially during longitudinal impacts (frontal or rear-end), when bending and shearing moments appear, stressing the organs. The frontal and lateral response mimics the human response. [3]



Fig. 1.3. Superior limbs assembly

- a) metallic skeleton assembly of the dummy's bras/hand before and;
- b) after being covered with silicon gel.

**The arms** are instrumentation free, as it has been proved that their trajectories during impact are harder to predict and thus the measurements would not be conclusive. The second reason would be the low injury risk level the arms have during an impact, in comparison with other body regions. [3]



Fig. 1.4. Thorax assembly

- a) metallic skeleton;
- b) casting mould for the silicon cover;
- c) silicon gel covered thorax assembly.

**Thorax assembly (Chest and belly, fig. 1.4. a, b, c)** The ribs are represented by steel riveted metallic plates, adjustable to simulate the human form, and covered with a silicon gel to ease the impact, applied on the interior and exterior surface, thus assuring the chest dynamic response to the frontal distributed impact. The silicon material attached to the frontal rib part helps to the force distribution.

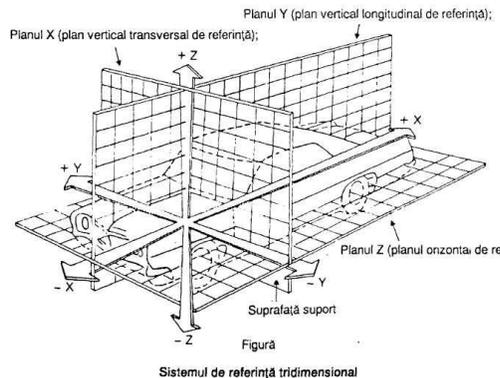


Fig. 1.5. Isometric reference system [R 25 ECE-ONU]

The chest structure minimizes the human force reflection answer for the direct impacts, distributed on the sternum. The dummy's back spine is realized from an aluminum pipe and an iron counterpart, telescopic assembly that allows a variable setting for the thorax height. (fig. 1.4. a; fig. 1.8. \_5)

**The Pelvis** has been casted also with silicon gel block and has two cylindrical joints with (one) two friction surfaces (fig. 1.4. a; fig.1.8. \_5,6,7 ) offering movement possibilities between the two planes: x – referential vertical/transversal and y – referential vertical/longitudinal according to fig. 1.5. These joints offer the possibility of simulating the moment that appears in the man's hip. The momentum setting is done by a nut/screw constriction.

**The ankle** is not fitted with sensors. The possible injuries of this area are to be appreciated analyzing the deformation degree of the bridge of the pedal.

**The knee joint.** It can be assimilated to a cylindrical joint fitted with two friction surfaces. These mechanical joints allow the transmission of axial forces but not of torsion moments, which is true for both the knee and ankle.

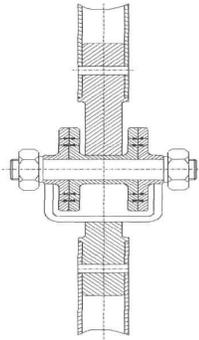


Fig. 1.7. Knee joint

The solution advantage is offered by the rigidity of the parts and the missing movements between the friction surfaces, the constriction force between the nut and the surface is transmitted also between the leading and leaded disks, generating a friction momentum for which the value can be thus regulated.

$$d = \left( \frac{M_{nec}}{0.2 \cdot \tau_{at}} \right)^{1/3} \quad (2)$$

One must take into consideration a predimensioning calculation for the disks mounted ax. The resulted moment does not vary based upon the relative position between the tibia and the femur.

When constricting the nut, beside momentum  $M_{t1}$ , given by the friction between the thread's turns, the friction momentum  $M_{t2}$ , given by the nut and the support surface, must also be taken into consideration. The constriction force  $F$  produces a uniform distributed pressure on the ring contact surface (fig.5.5):

$$P = \frac{4 \cdot F}{\pi(D^2 - d^2)} \quad (3)$$

Where  $D$  is the external friction surface diameter between the leading disk and the leaded one, and  $d$  is the ax hole diameter between the disks.[1]

Notating with  $\mu$  the friction coefficient between the nut and the support surface, we will have the friction momentum given by the formula:

$$M_{t2} = \int_{\frac{d}{2}}^{\frac{D}{2}} \int_0^{2\pi} \mu \cdot p \cdot r^2 \cdot dr \cdot d\varphi = \frac{F}{3} \cdot \pi \cdot \frac{D^3 - d^3}{D^2 - d^2} \quad (4)$$

The established momentum,  $M_{t2}$  is identical with the one in the knee joint,  $M_{\alpha}$ , which we want to obtain. The constriction force  $F$  of the friction disks can be determined:

$$F = \frac{3M_{\alpha} \cdot \frac{D^2 - d^2}{D^3 - d^3}}{\mu} \quad (5)$$

The total momentum which has to be applied for the nuts constriction or unbinding in order to regulate the joint momentum is given by the formula:

$$M_t = M_{t1} + M_{t2}, \quad (6)$$

where, from the statistical data, we have  $M_{t1} \cong 0.08 \cdot F \cdot d$  (7)

The wrench necessary moment  $M_{ch}$

$$M_{ch} \cong 0.08 \cdot \frac{3M_\alpha \cdot \frac{D^2 - d^2}{D^3 - d^3}}{\mu} \cdot d + M_\alpha \quad (8)$$

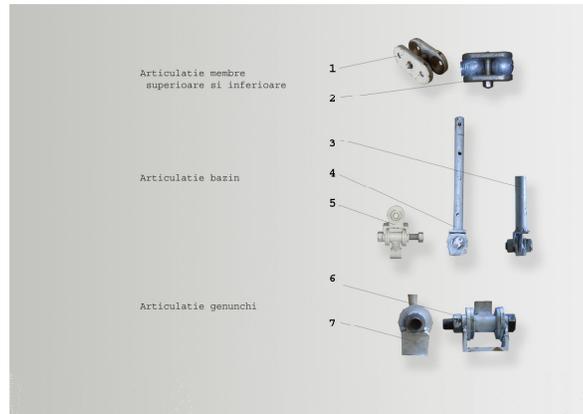


Fig. 1.8. Dummy's joints

1,2 – spherical joints limited by metall plates;  
 3,4 – cylindrical joint; 5 –pelvis joint assembly  
 6,7 – cylindrical joint with two friction surfaces

**Spherical joints** (Fig. 1.8.\_1,2). This setting allows for regulating the friction momentum in the joints and obtaining a 3D movement of the upper limbs, lower limbs at the hip joint (allowing relative movements between the lower limbs, canceling the disadvantage of the cylindrical joint at the knee level) .

**Cylindrical joints** (Fig. 1.8.\_3,4,6,7). This mounting type allows for simulating a constant momentum in the joint. The cylindrical joints have been used at the thorax and knee levels.

### 3. Dummy development

In order to cover the metal skeleton with sanitary silicon gel, first, it was necessary to build-up the moulds.

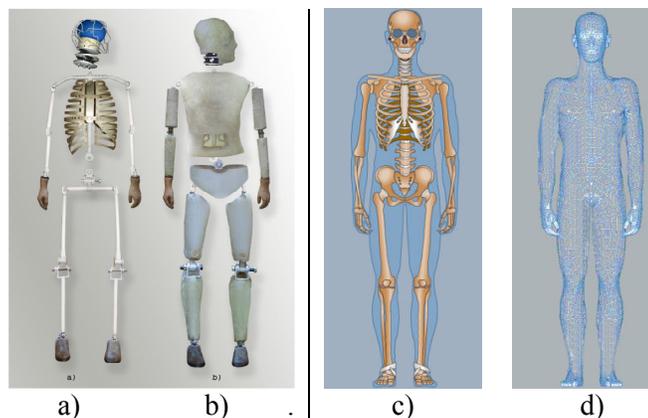


Fig. 1.10. Biodummy built, Human Body: a) Skeleton of dummy; b) Dummy multi-cast; c) Human Skeleton [4]; d) Human Shape [4].

In order to mimic the human form, 80 kg of modeling plaster have been used (for moulds) and a sample of a show window manikin, also used in experiments, but only before 1940. For mould casting, it was necessary to cover the show window manikin into cellophane sheets, for a clean separation after drying a to be able to form a separation plan in the vertical transversal plan y. (Fig. 1.11.\_8,9)

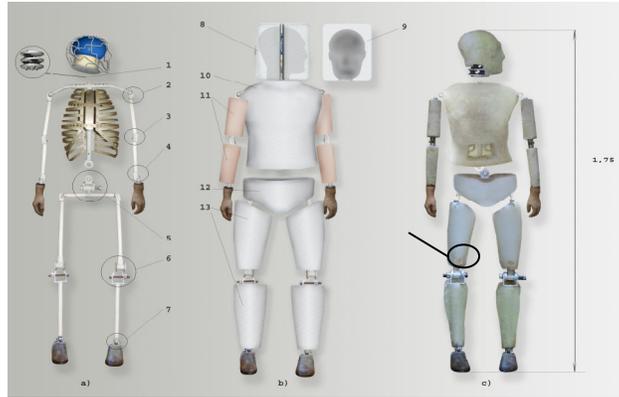


Fig. 1.11. Dummy casting process:

- 1. Neck joint assembly; 2,3,4,7. Spherical joints; 5,6. Cylindrical joints;
- 8,9. Side, frontal view head mould (plaster); 10. Thorax mould (plaster); 11,12. Upper limb mould (cardboard); 12. Pelvis mould (plaster); 13. Lower limb mould (plaster). 14. Plastic distance pieces.

After the moulds have dried they have been corrected and covered with cellophane so that the silicon gel would not unite with the moulds. In order to respect the biofidelity requirements, plastic distance pieces have been used to sustain the metallic skeleton in the mould. ( Fig. 1.11.\_14.).

For casting, 200 sanitary silicon tubes have been used (280 ml/tube), injected layer by layer into the moulds.

**Technical sheet for silicon gel:** resistant to aging, does not change size in contact with water, does not crack, resistant to color decay, water and UV radiation. Working temperature +5°C up to 40°C. Resistant temperature: -30°C up to +150°C. After applying it, it can be smoothed for the first 5 minutes with a tool covered with soap solution. It creates a surface crust after 13 minutes, for a normal 23°C and 50% relative humidity. Dry-up time: approximate 13 minutes per 1.5 mm silicon gel layer. The effective dry-up time for the developed manikin was about 2 months at a temperature between 18°-20°C.

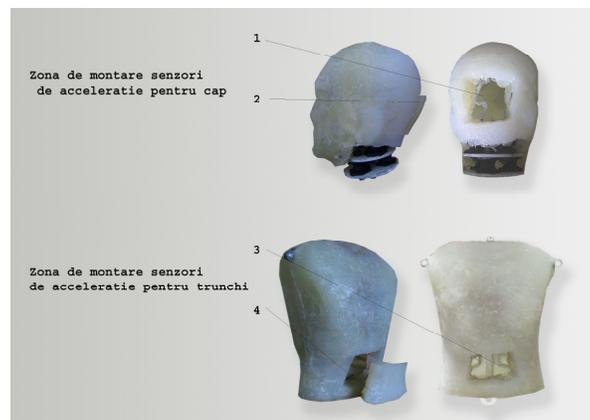


Fig. 1.12. Accelerometer mounting cavities/placeholders

- 1. Head cavity; 2. Head inspection lid; 3. Thorax cavity ; 4. Thorax inspection lid.

In order to obtain the sensor mounting cavities, cellophane wrapped balloons have been inflated inside the metal skeleton, thus saving up the necessary space and form inside the dummy. The advantage is that the cavities were well preserved not requiring further cleaning or repairs.

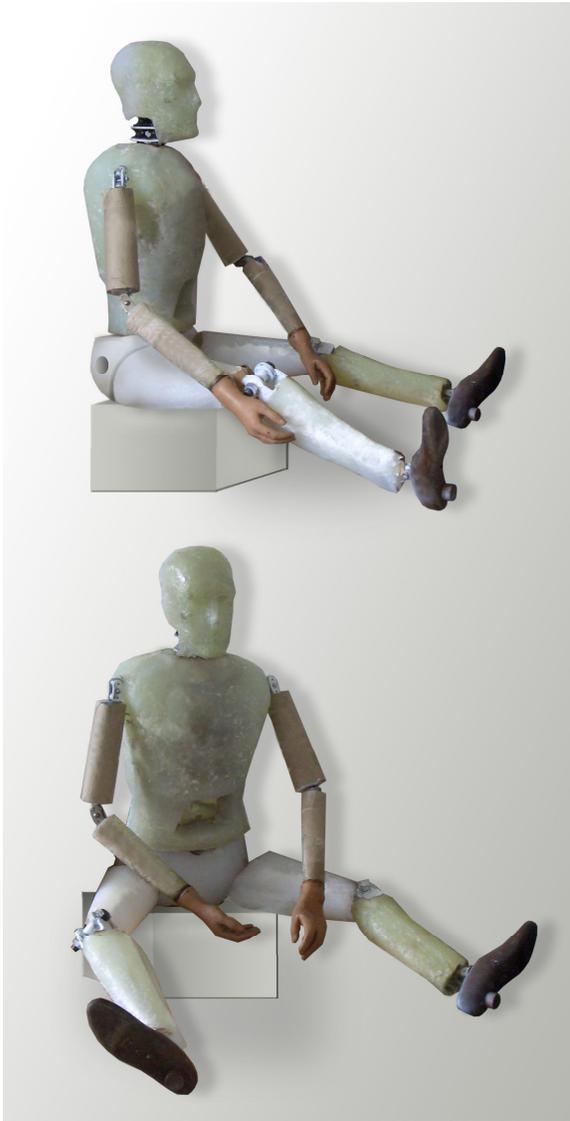
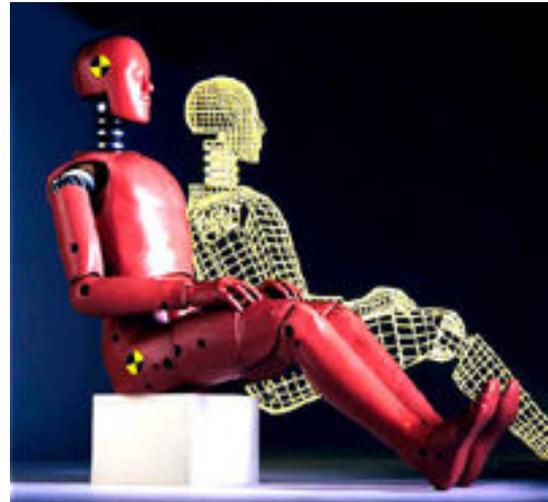
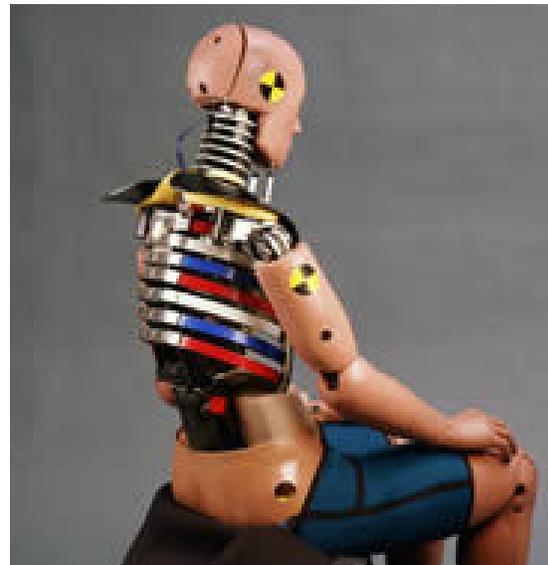


Fig. 1.13. The anthropometric dummy built



Hybrid III 50th Male Dummy [7]



RID2 Rear Impact Dummy [7]  
The dummy developed today

## Conclusions

The advantage of the dummy solution here presented can be found in the low production costs compared with other test dummies developed. The design is simple, while the device mounting is solely for the research programme for which it was built.

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