ANNALS of the ORADEA UNIVERSITY.
Fascicle of Management and Technological Engineering, Volume VI (XVI), 2007

DUMMY. BUILDING AND DESIGN

[1]Daniel Dragoş TRUŞCĂ, [2]Adrian Ovidiu ŞOICA
[1] TRANSILVANIA University of Brasov, Autovehicles and Engines Departament, B-dul Eroilor nr. 29, Brasov, Tel: 0040 / 0268 / 413.000, int. 156, e-mail: d.trusca@unitbv.ro,
[2] TRANSILVANIA University of Brasov, Autovehicles and Engines Departament, B-dul Eroilor nr. 29, Brasov, Tel: 0040 / 0268 / 413.000, int. 156, e-mail: a.soica@unitbv.ro

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

Abstract: This paper deals with the information, 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 validation is mean to be making with an anthropometric test dummy in a real condition simulation 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.

1. GENERALITIES

As resulting of the systematic studies on human volunteers, cadavers and improvement dummies, has established more injuries criterions for various parts of human body. The studies on the human injuries involve in the accidents shows necessity achievements of dummies which to reproduce more real the human body biomechanics characteristic.

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.

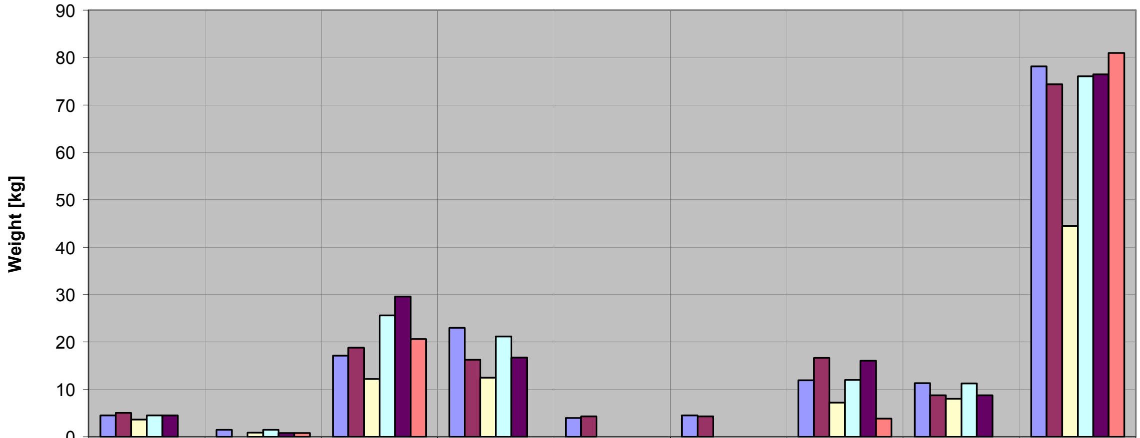
The research on this matter is being used at the basis of two doctorate thesis, offering the possibility of accumulating new information through the materials for biomechanics, vehicle dynamics, road traffic and dynamics of road traffic accidents courses and for continuous engineery research by the previous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

Figure 1. The anthropometric dummy built

2. THE DUMMY CARACTERISTICS

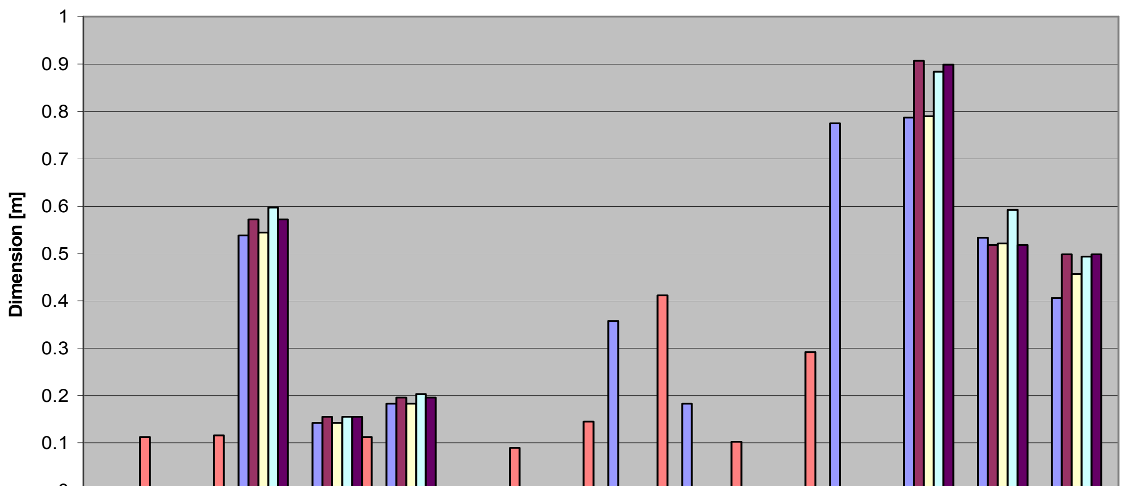
Analyzing the design of the present anthropomorphic test dummies he may assign the design line and the characteristics for the test dummy build for experimental phase.



	Head	Neck	Upper Torso /(arms_SID II, BioSID si	Lower Torso	Upper Arms	Lower Arms and Hands	Upper Leg	Lower Legs and Feet	Total Body
Hybrid III	4.54	1.54	17.19	23.04	3.99	4.54	11.97	11.34	78.15
Hybrid II	5.08	0	18.82	16.28	4.35	4.35	16.69	8.8	74.37
SID II	3.67	0.91	12.2	12.5	0	0	7.21	8.03	44.52
BioSID	4.5	1.5	25.6	21.2	0	0	12	11.3	76.1
DOT SID	4.5	0.8	29.6	16.7	0	0	16.1	8.8	76.5
RID	0	0.85	20.64	0	0	0	3.89	0	81

Assembly

Figure 2. Assembly weights for different tips of dummies



	Max. width front	Max. length of skull	Head Circumf erence	Head Width	Head Length	Neck diameter	Base to top of neck	Shoulde r width	Chest height whithout	Maximu m width of rib	Abdome n circumfe	Erect Sitting Height	Buttock to Knee Length	Knee Pivot Height
Hybrid III	0	0	0.538	0.142	0.183	0	0	0.358	0.183	0	0.775	0.787	0.533	0.406
Hybrid II	0	0	0.572	0.155	0.196	0	0	0	0	0	0	0.907	0.518	0.498
SID II	0	0	0.544	0.142	0.183	0	0	0	0	0	0	0.79	0.521	0.457
BioSID	0	0	0.597	0.155	0.203	0	0	0	0	0	0	0.884	0.592	0.493
DOT SID	0	0	0.572	0.155	0.196	0	0	0	0	0	0	0.899	0.518	0.498
RID	0.113	0.116	0	0.113	0	0.09	0.145	0.412	0.1027	0.292	0	0	0	0

reference

Figure 3. External dimensions for different tips of dummies

Table 1. Limits of weight values for different dummies tips

	Assembly Weights [kg]	
Segment of body	**max.**	**min**
Head	5.08	3.67
Neck	1.54	0.8
Upper torso	20.64	12.2
Lower torso (abdomen)	23.04	12.5
Upper arms	4.35	3.99
Lower Arms and Hands	4.54	4.35
Upper Leg	16.69	3.89
Lower Legs and Feet	11.34	8.03
Total Body	81	44.52

To human, weight of human bones represents 1/9-1/10 of totals weight, the dummy skeleton have 10 kg: 4.9 kg body + head, lower legs + upper legs joints 5.1 kg.

After finishing of mould casting of silicone over the metallic skeleton, the total weight of the dummy is a 56.1 kg. The calibration weight was resulting to be 13.2 kg (some parts is weight of measures installation)

Table 2. The distribution of lengths for different dummies tips in report with our dummy

Dimension of body segment	length [m]			
	Others dummies		Our dummy	
Design heights	**Max.**	**Min.**	**>Max.**	**<Min.**
Max. width front part of skull cap	0.113	-	0.163	-
Max. length of skull cap	0.116	-	0.182	-
Head Circumference	0.597	0.538	0.600	-
Head Width	0.142	0.113	0.163	-
Head Length	0.203	0.183	0.230	-
Neck diameter	0.09	-	0.115	-
Base to top of neck pivot	0.145	-	0.150	-
Maximum width of rib cage	0.292	-	0.310	-
Erect Sitting Height	0.907	0.787	0.940	-
Buttock to Knee Length	0.592	0.518	-	0.555
Knee Pivot Height	0.498	0.406	-	0.480

Maximal and minimal dimensional difference between our dummy heights and other dummies heights toward maximal and minimal heights is:
+0.005...+0.06 [m] /max. lengths;
-0.037…-0.018 [m] / min. lengths.

3. 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 behavior or human tissue. The component parts are described as follows:

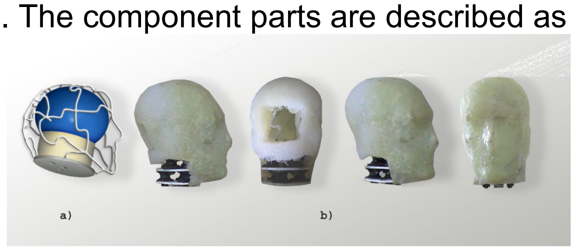


Figure 4. Lab constructed anthropomorphic head: a) Metallic structure; b) Silicon covered (profile)

The head is based on a steel wire structure, covered with 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.

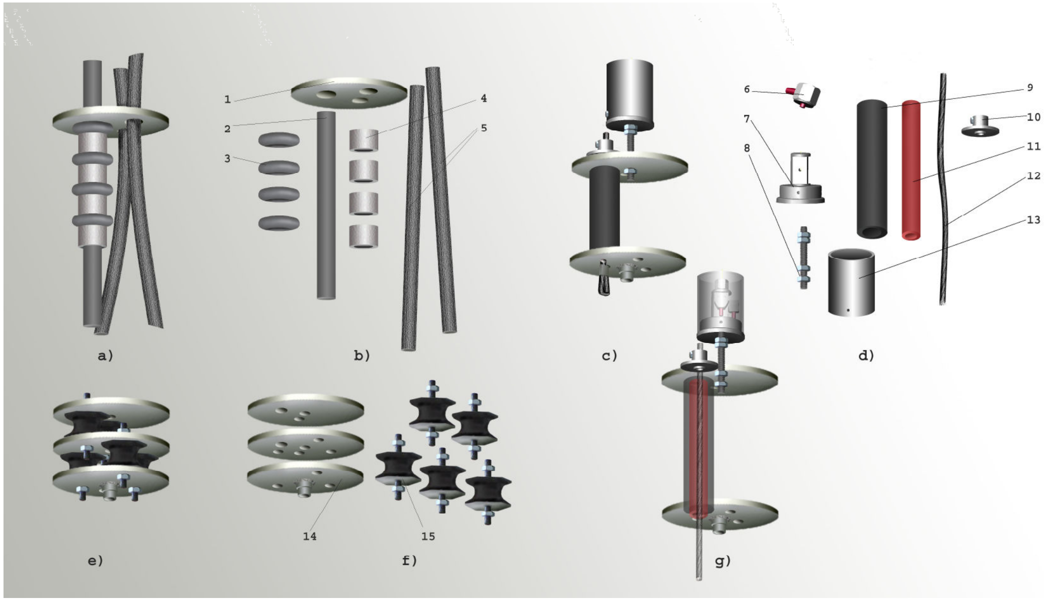


Figure 5. Neck variations:
a) Second neck variant (increased biofidelity); b) 2nd variant: Exploded assembly: 1. Metallic disks; 2. Rubber stick; 3. Rubber fillings; 4. Metallic bushings; 5. Elastic rubber covered flexible tube; c) 3rd variant-final neck (easy and resistant construction, increased biofidelity); d) 3rd variant-final neck: Exploded assembly: 6. Accelerometer; 7. Triaxial support; 8. bolt and adjustable nut; 9,11. Rubber tube; 12. Cable steel; 13. Protection carcass; e) first neck variant (the degrees of freedom are somewhat restricted); f) First variant: Exploded assembly: 14. Metallic disks; 15. Rubber buffers; g) Components assembly.

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 5.).

The neck is formed of two flexible parts (fig.5.d 9,11), designed with biomechanical criteria's in mind, with relaxed flexion and extension response. 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]

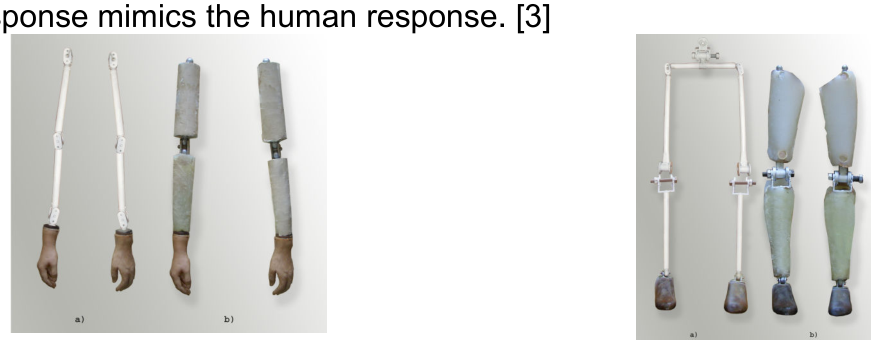


Figure 6. Superior and inferior limbs assembly
a) Metallic skeleton assembly of the dummy's bras/hand before and; b) after being covered with silicon gel.

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.

Figure 7. Thorax assembly

- ***a) Metallic skeleton;***
- ***b) Casting mould for the silicon cover;***
- ***c) Silicon gel covered thorax assembly.***

- ***a) Metallic skeleton with sensors installation***
- ***b) Assembly schematic;***
- ***c) Sensory attachment: 1. Protection carcass, 2. Triaxial accelerometer, 3. adjustable rod.***

Thorax assembly (Chest and belly, fig. 7.) 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. 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.

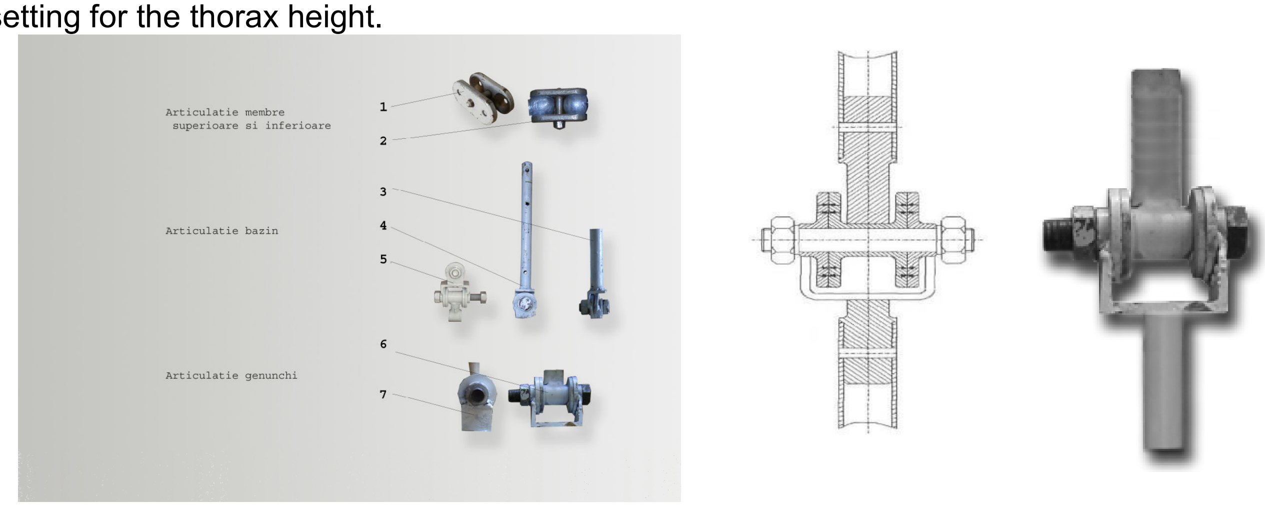


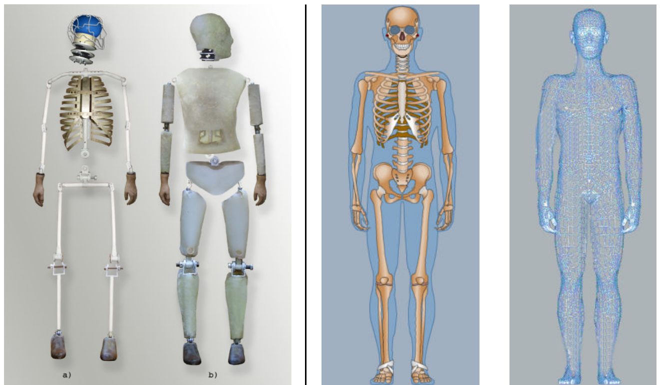
Figure 8. Dummy's joints
1,2 – spherical joints limited by metal plates;
3,4 – cylindrical joint; 5 –pelvis joint assembly
6,7 – cylindrical joint with two friction surfaces

Spherical joints (Fig. 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. 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.



a) b) . c) d) .

Figure 9. 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. 10.-8,9)

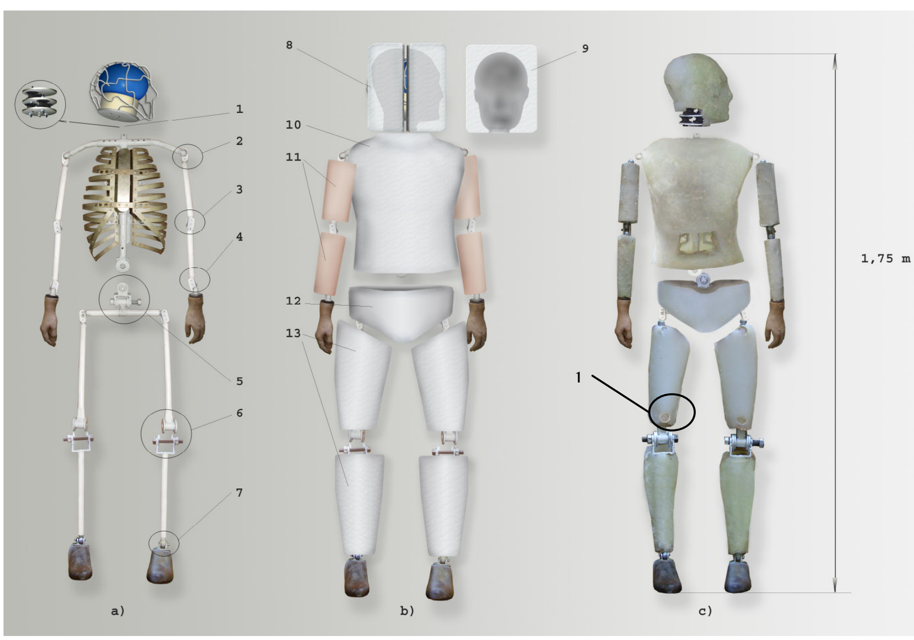


Figure 10. Dummy casting process:
1. Neck joint assembly; 2,3,4,7. Spherical joints; 5,6. Cylindrical joints;
8,9. Side, frontal view head mould (plaster); 10. Thorax mould (plaster); 11,12. Upper limb mould (cardboard); 12. Pelvis mould (plaster); 13. Lower limb mould (plaster). 14. Plastic distance 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. 10._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 +5ºC up to 40ºC. Resistant temperature: -30ºC up to +150ºC. 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 23ºC 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 18º-20ºC.

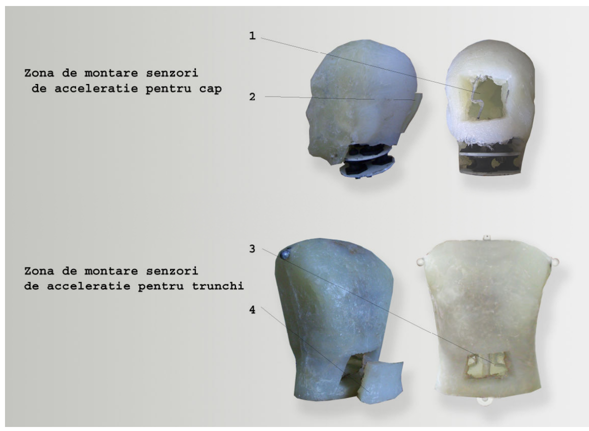


Figure 11. Accelerometer mounting cavities/placeholders
1. Head cavity; 2. Head inspection lid; 3. Thorax cavity; 4. Thorax inspection lid.

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.

4. 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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