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THE FIDELITY OF DUMMIES IN PEDESTRIAN COLLISIONS

Introduction

The simulation of vehicle accidents serves essentially the following purposes:

- Study of the progress of events during the impact phase (slow motion)

- Optimization of the impact event for reduction of the severity of the consequences of the accident

- Determination of the laws involved for purposes of reconstruction of actual accidents, particulary for in-depth research, and also for practical forensic purposes.

Although the vehicle and the accident surroundings can be realistically represented, the human victim of the accident must be simulated. This is usually performed by means of anthropometrical dummies. The validity of the conclusions reached and the applicability of the simulation depend above all on the simulation suitability of the dummy. In this study, pedestrian accidents are used to investigate just simulation suitability.

Method and objective

It is only very rarely possible to determine the principles involved from the study of an actual accident. First, one is unable to study the impact phase, which very rapidly transpires and which exceeds the human capability of perception. Secondly, the input variables such as initial velocity and impact positioning can as a rule only be approximately reconstructed from a retrospective standpoint. The basis of this study therefore was the intention of representing the human pedestrian by dummies which characterize extremes in their properties which influence the kinematics involved. These extremes must in all certainty be characteristics which a human cannot exhibit. See FIG. 1. These characteristics are in particular the following:

- Movability

- Yieldingness.

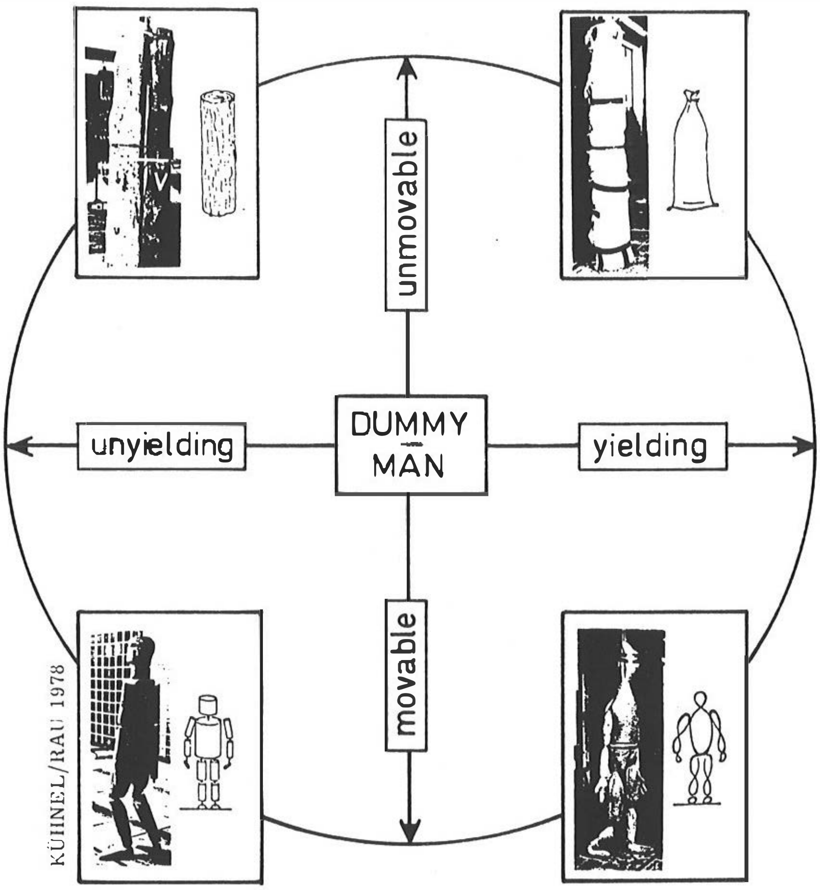


FIG. 1: Characteristics of used dummies and man

Dummies were developed and constructed which are harder and more rigid than humans, and others were built which are more yielding and more movable than human beings. If the distribution ranges of the results occurring in the experiments are explainable by those heretofore determined in dummy tests, or if they go as far as even to coincide, then one may assume that a human being involved in an accident will behave according to the same principles. Furthermore, proof is offered that the previous results with dummies are correct and applicable.

The following comparative data were used in accident description:

- Final position
- Dents in the vehicle (position and form)
- Time and distance histories
- Course of motion.

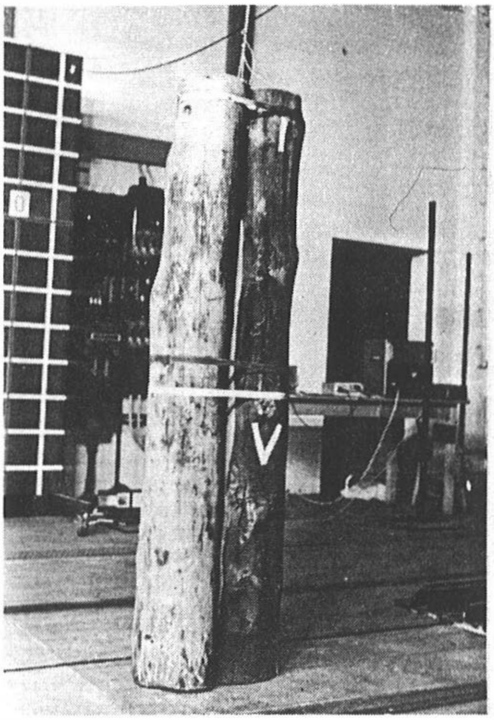


FIG. 2: Wooden beam

'IG. 3: Sand bag

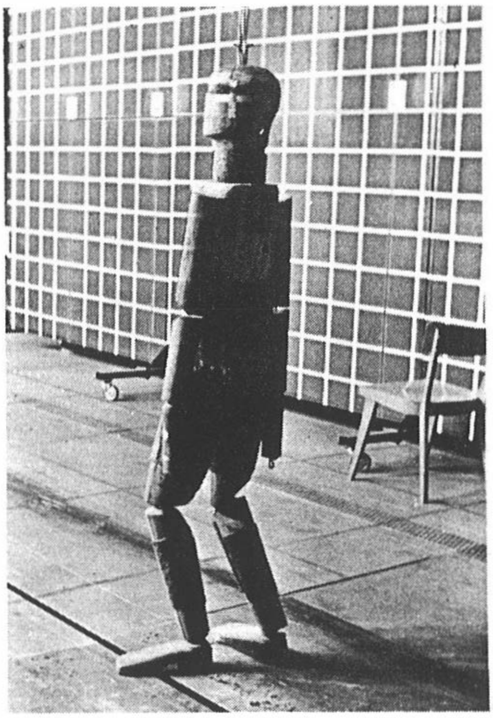
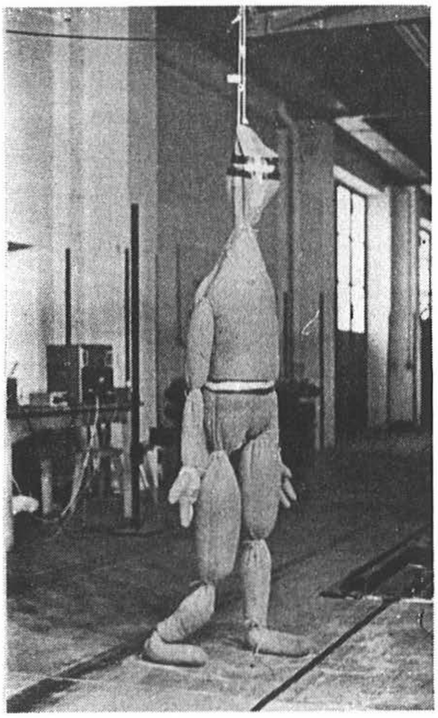


FIG. 4: Wooden jointed dummy



'IG. 5: Sand-filled jointed dummy

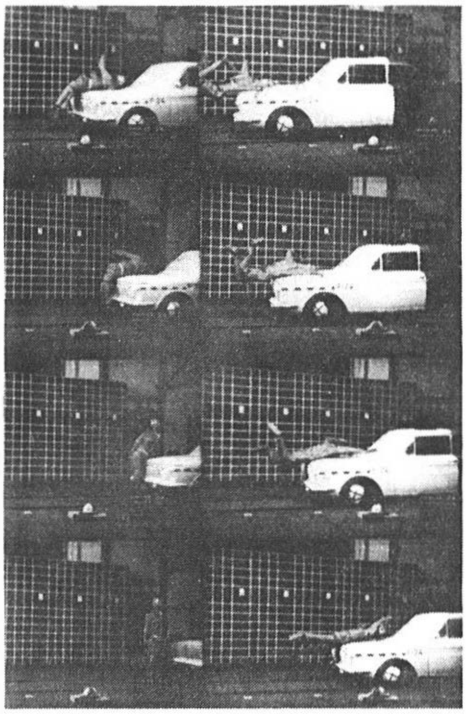


FIG. 6: Impact wooden jointed dummy/square shaped vehicle at 45 km/h

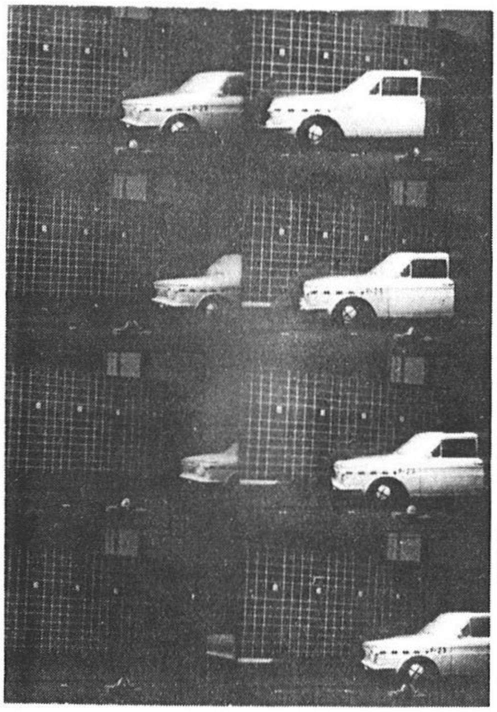


FIG. 7: Impact sand-filled jointed dummy/square shaped vehicle at 45 km/h

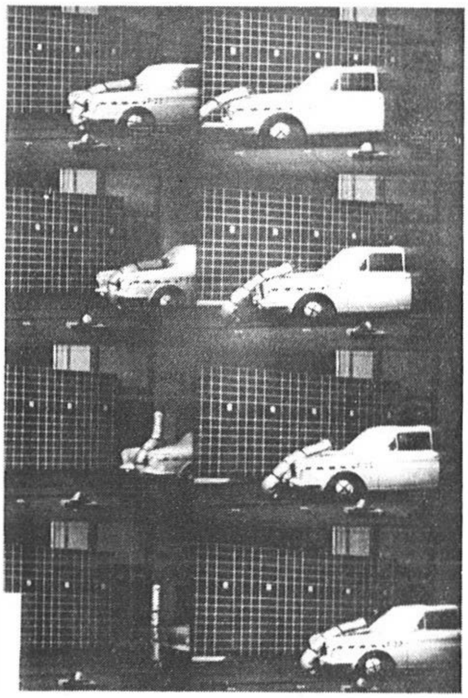


FIG. 8: Impact sand bag/square shaped vehicle at 45 km/h

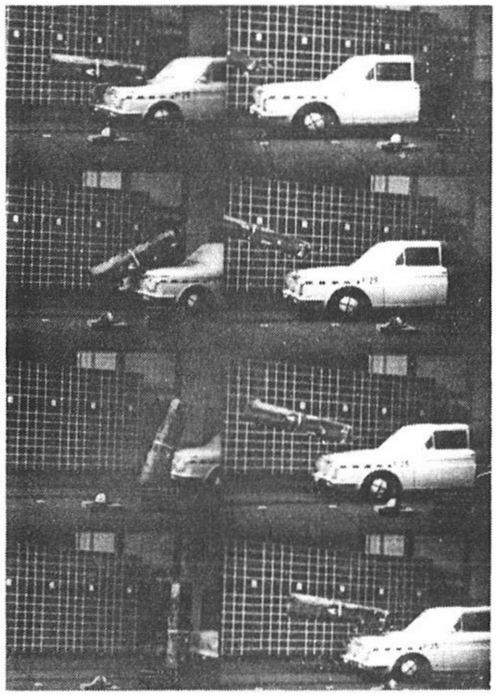


FIG. 9: Impact wooden beam/ square shaped vehicle at 45 km/h

The following four dummies were constructed for verification of the test dummy characteristics:

- Hard and unmovable (wooden beam, FIG. 2)
- Soft and unmovable (sand bag, FIG. 3)
- Hard and jointed (wooden jointed dummy, FIG. 4)
- Soft and jointed (sand-filled jointed dummy, FIG. 5).

The dummies do not differ in weight, distribution of mass, and moment of inertia.

The dummies were struck by two types of vehicles: a Ford 12 M and a Volkswagen Beetle. The collision velocities were approx. 25 km/h and approx. 45 km/h. The vehicles were fully braked at the moment of impact.

The experiments were recorded with two high-speed cameras. Loading values were not measured for the dummies: this was not the objective of the experiments (considerable measuring problems would have arisen at any rate for the sand dummies).

Test results

The kinematics of the primary impact are represented for the Ford in the following figures (45 km/h collision velocity). The wooden jointed dummy (FIG. 6) behaves in a well-known manner, similar to that of the standard 50 % dummy. The dummy folds around the front end of the vehicle until the head strikes. The rotation, and thereby the lifting of its center of mass, is however considerably less accentuated, since the joints transfer no moments. It unwinds and slides down toward the front. The sand-filled, jointed dummy (FIG. 7) initially behaves similarly. Because of its yielding structure, however, little kicking up of the legs occurs. Upon sliding down toward the front, the torso and legs form almost a right angle. The sand bag (FIG. 8), which of course has no rigidity, at first bends in at the "hip ", whereby the upper third remains vertical. Then the upper part strikes the hood of the vehicle, and the lower part is pulled along afterward. It falls away from the vehicle in an oblique position.

The wooden beam dummy (FIG. 9) is subject through the vehicle front end to simultaneous horizontal and rotational acceleration. As a result of its rigidity, the impact is considerably more elastic than for the other dummies. The "head" strikes only after the "hip" have separated again. A shoring effect occurs through the head impact and lifts the dummy as far as vehicle roof height. At the same time, the rotation about the lateral axis is almost completely terminated, so that the dummy moves away from the vehicle with its legs upward.

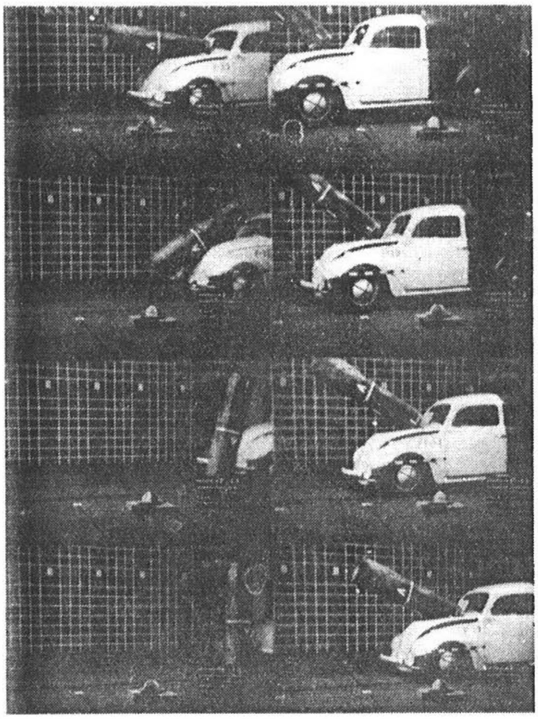


FIG. 10: Impact wooden beam/square shaped vehicle at 45 km/h

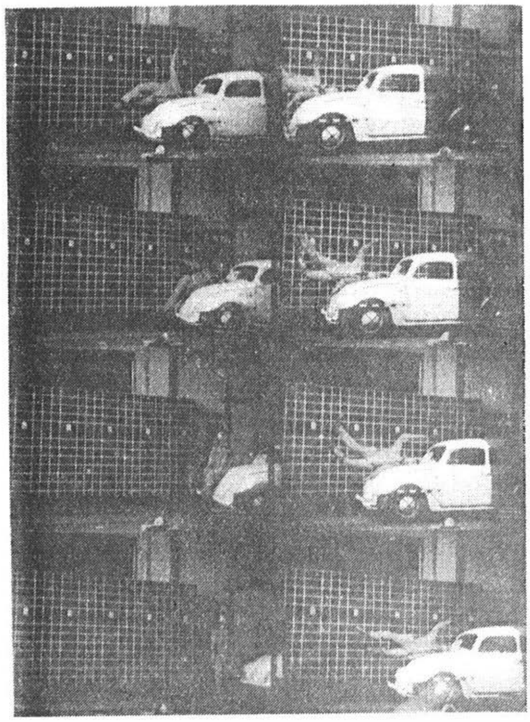


FIG. 11: Impact wooden jointed dummy/curved shaped vehicle at 45 km/h

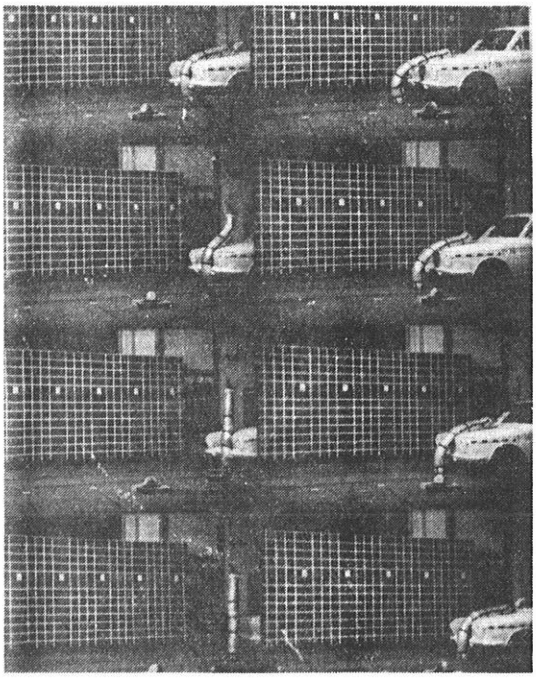


FIG. 12: Impact sand bag/square shaped vehicle at 25 km/h

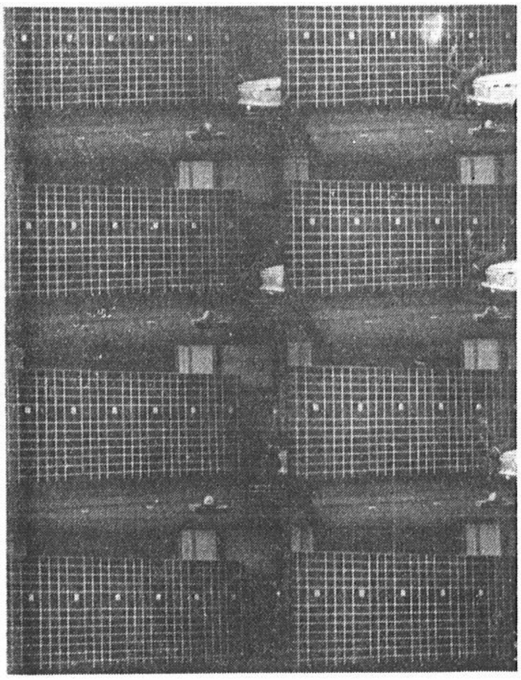


FIG. 13: Impact wooden jointed dummy/square shaped vehicle at 25 km/h

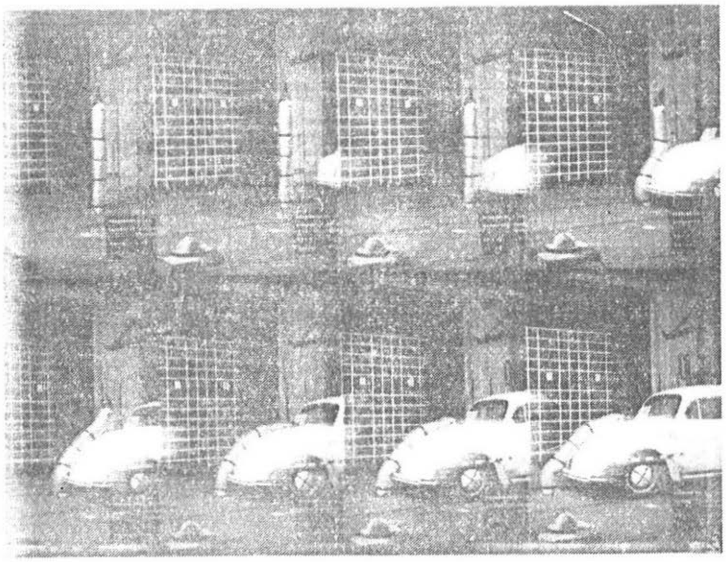


FIG. 14: Impact sand bag / curved-shaped vehicle at 25 km/h

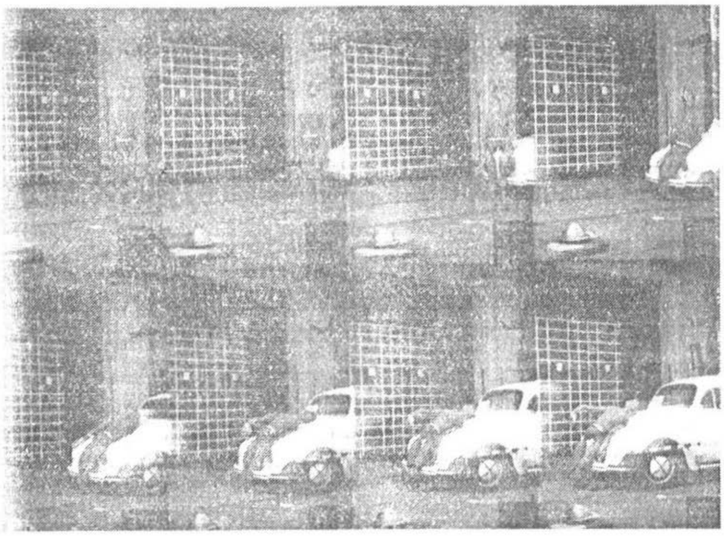


FIG. 15: Impact sand-filled jointed dummy / curved-shaped vehicle at 25 km/h

If the impact in this case is now compared with that of the Volkswagen Beetle (FIG 10), then a greater rolling motion is observed for the wooden beam, since the primary impact occurs far below the center of mass and since less translation occurs. The shoring effect and therefore the lifting are greater, and the rotation is not diminished by the "head" impact. The wooden jointed dummy in this case (FIG. 11) behaves here once again very similarly to the standard dummy; the rotation and lifting, however, are again very much less accentuated. Under identical impact conditions, the center of mass of the standard dummy reaches the roof level with legs straight upward.

The influence of the vehicle body form on the kinematics of the sand-filled dummies at low collision velocities is depicted in FIGS. 12 to 15. It is readily apparent that the sand bag experiences a greater angular momentum. The sand-filled, jointed dummy wraps around the front end of the vehicle.

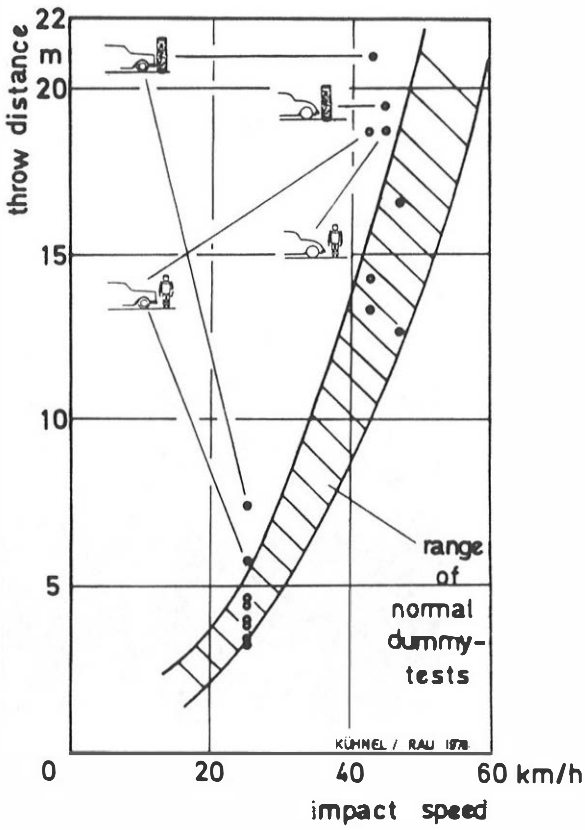
Principles observed

The results of all experiments were entered on existing, well-known diagramms from experiments with standard dummies. FIG. 16 shows the trajectory length (distance between point of impact and final position) of the dummies. It becomes immediately apparent that the hard dummies travel farther at the same collision velocity than do the others, because of their elastic behavior. The wooden beam travels the farthest, since it of all the dummies also experiences the greatest lift and therefore a correspondingly longer path of flight. See FIG. 17. The yielding dummies lie at the lower limit of the distribution range, whereas the wooden jointed dummy lies either at the upper limit or outside the limit (i. e., for high velocities). The shortest trajectory length occurs for the sand-filled, jointed dummy, which also absorbs the least angular momentum and which upon braking simply slides down toward the front.

If one assumes that the lack of yielding in the wooden dummies is essentially responsible for the great length of the normal range, then one can conclude that the human being with certainty lies within the distribution range of the standard dummy experiments.

The position of the head is another variable for velocity determination in accident reconstruction, particularly in the optimization of vehicle front ends. It is well-known that the dent point approaches the windshield with increasing collision velocity. Its position is also dependent on pedestrian size and on vehicle form. It has proved advantageous to take as reference value not the distance from the forward edge of the hood, but the distance from the street surface to the middle of the head dent-the so-called coil distance. The following has been demonstrated in our experiments (1) (5): the coil distance lies at the lower limit of the distribution range for square-shaped vehicles. See FIG. 18. This applies as well for this series of experiments. It is obvious from the figure that the yielding sand bag produces the greatest coil distance for impact onto a curved-shaped vehicle, followed by the wooden jointed dummy / curved-shaped vehicle, and the square-shaped vehicle / sand bag. The combination of yieldingness and movability obviously leads to the same effect. In both cases, the lower leg is not wrapped under the bumper (FIGS. 11, 12 and 13), with the result that sliding upward up to head impact is less impeded than for example for the sand-filled, jointed dummy. See FIG. 14.

Upon the collision of a square-shaped vehicle against wooden beam, the beam is accelerated to such an extent (as a result of its elastic behavior) by the forward edge of the hood that it travels faster than the vehicle. It has separated at the "hip" before the "head" impacts. Since the vehicle remains behind it, the "head" strikes much closer in the area of the vehicle front end. On the basis of the behavior of the extremecase dummies described in detail, it can be concluded here as well that the standard dummy range includes the case of the human being.



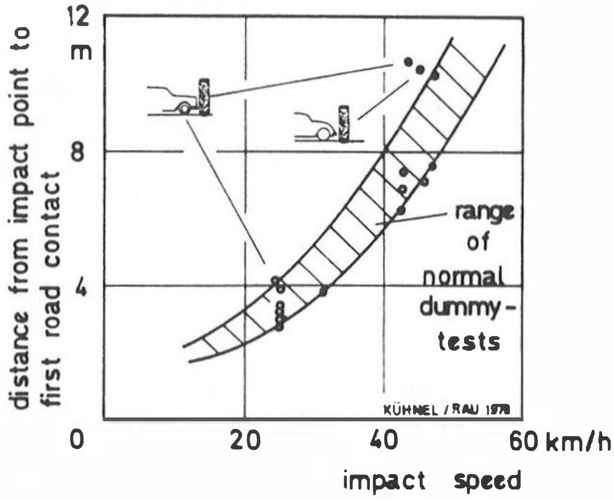
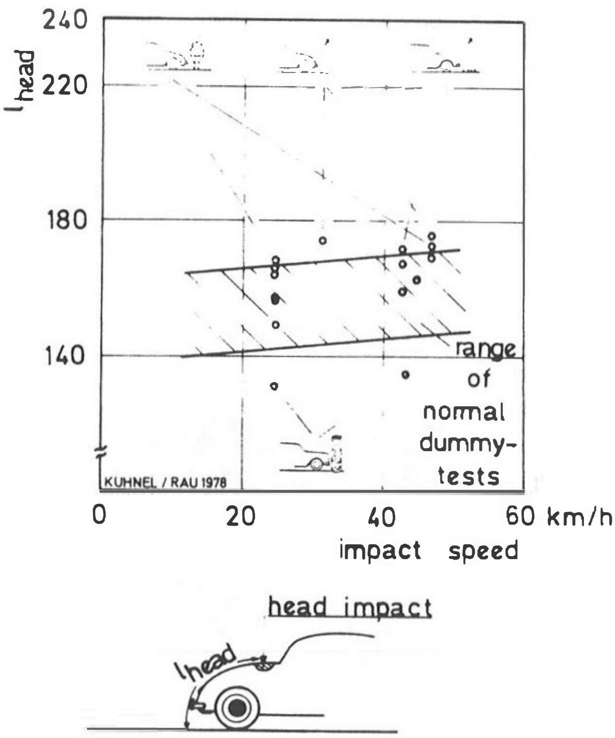


FIG. 17: Distance to first road contact of dummy versus impact speed ↑

FIG. 16: Throw distance of dummy versus impact speed ←



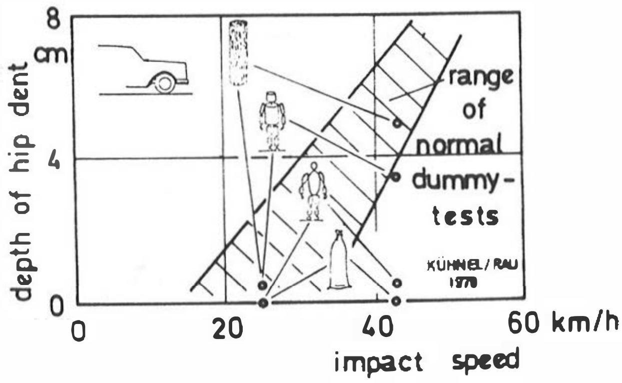


FIG. 19: Depth of hip dent at front end of square shaped vehicle versus impact speed ↑

FIG. 18: Coil distance of head dent versus impact speed ←

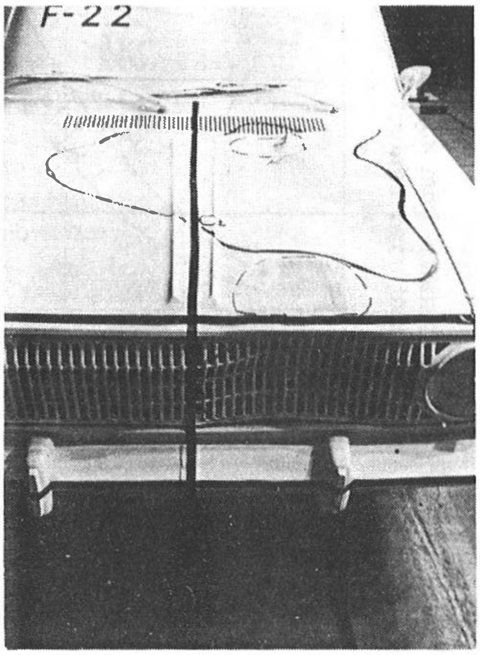


FIG. 20: Hip dent from sand bag at 45 km/h

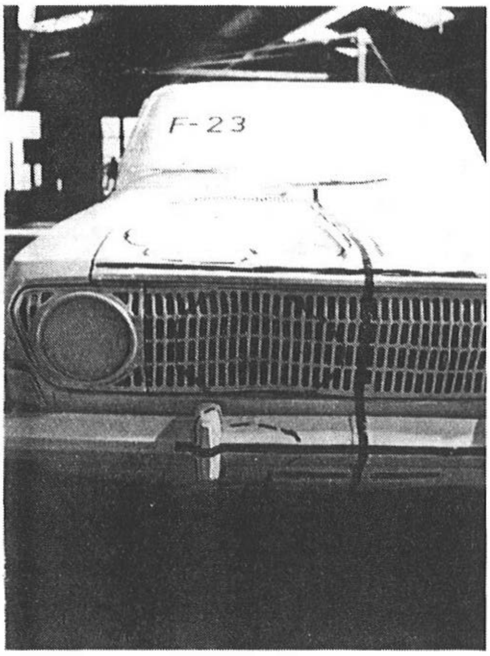


FIG. 21: Hip dent from sand-filled jointed dummy at 45 km/h

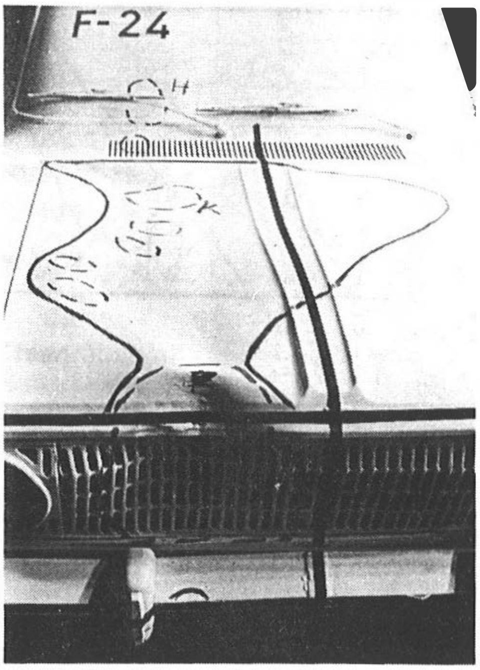


FIG. 22: Hip dent from wooden jointed dummy at 45 km/h

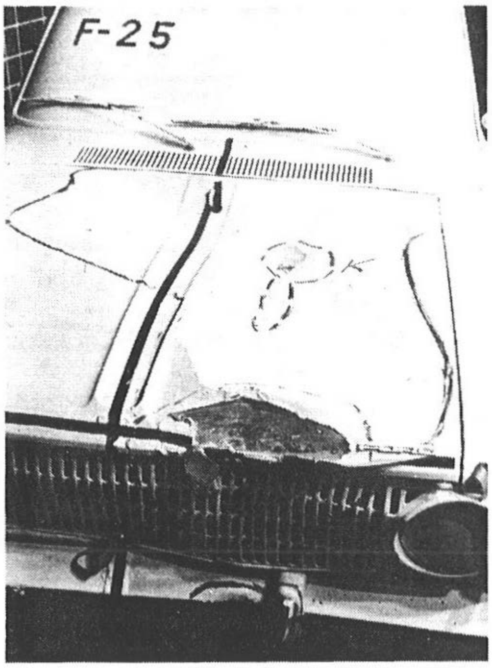
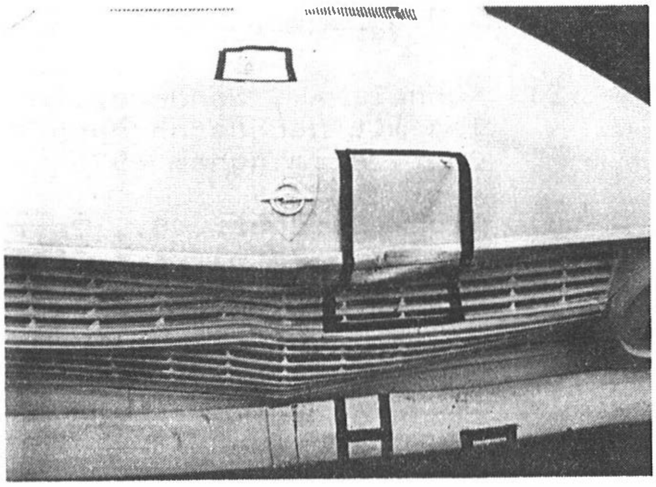


FIG. 23: Hip dent from wooden beam at 45 km/h

Depth of dent

Use of the dent depth for reconstruction of an accident is a controversial matter. A distribution range can nevertheless be given for standard dummies. See FIG. 19. It is evident that the dents become deeper for greater velocities. FIG. 19 applies only to square-shaped vehicles.

FIG. 24: Hip dent from normal dummy at 45 km/h



It is known from child dummy experiments that sometimes no dents occur even for high impact velocities (up to 60 km/h). The yieldingness of the dummy has, however, a strong effect on the depth of the dent (FIGS. 20, 21, 22, 23 and 24). The wooden dummies lie approximately in the distriburion range, while the yielding sand-filled dummies lie lower. Since the yieldingness of the human being lies between that of the wooden and the sand-filled dummies, it can be assumed that the dummies cause deeper dents for equal collision velocities than does the human being.

This signifies for the reconstruction of an accident that for equal dent depths the collision velocity in an actual case was considerably greater than in the simulated case. Conversely, one cannot assume a low collision velocity from slight vehicle deformation.

Conclusion

This investigation demonstrates that the distribution ranges for standard and extreme dummies coincide if one can explain the values lying beyond on the basis of the extreme dummy characteristics. In particular, the combination of rigidity and immobility (wooden beam), which least resembles the human being, leads to kinematic deviations which can be explained. If one orders the human being with his characteristics between the other dummies, then he lies exactly in the distribution range of the standard dummy. In the case of the depth of dents, the distribution range of the dummy lies above those values to be expected for the human being.

It can finally be concluded that the standard dummy well simulates the human being, especially for purposes of accident reconstruction.

References

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