INFLUENCE OF BUMPER ADJUSTMENT ON THE KINEMATICS OF AN IMPACTED PEDESTRIAN

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VOLKSWAGENWERK A. G., RESEARCH AND DEVELOPMENT

1. Introduction

One of the most important areas in the field of passenger car safety is that of pedestrian protection. In order to get knowledge about kinematics and loadings of an impacted pedestrian, it is necessary to perform mathematical and experimental simulations of vehicle-to-pedestrian collisions. These simulations must be based on statistically secure parameters. Data of this kind are supplied by accident research. In recent publications, the extensive work which is done by the Volkswagenwerk AG concerning pedestrian protection has been described [1; 2; 3] .

This paper is related to a special problem of front end geometry and its influence on the kinematics of an impacted pedestrian: the adjustment of the bumper.

A test series (108 tests) was performed with a special test car which will be described in detail. Bumper distance was changed from 70 mm to 300 mm and bumper height from 210 mm to 410 mm, whereas the other geometric parameters of the test car remained constant and were similar to those of a VW-Golf. The impact speeds were 20, 35 and 50 km/h. The impacted pedestrian was a 50 % male dummy in a position relative to the test car which was the same for all tests. The aim of this investigation was to get detailed information about the kinematics of the impacted pedestrian as a function of bumper adjustment and impact speed. For this reason the front end of the test car was absolutely stiff in order to avoid a mix of the influences of the two parameters: Geometry and energy absorption capability.

2. Description of the Experiment Setup

Various ways in which vehicle-to-pedestrian collisions may be investigated systematically by mathematical and/or experimental simulation on the basis of accident research data were described in detail in [4] . The equipment used by VW for experimental simulations of vehicle-to-pedestrian collisions will be described shortly: Fig. 1 is an overall view of the entire facility. The individual components are now described below.

2.1 Dummy

For this study a 50 % male dummy made by Alderson, type VIP50A, was used for simulating the pedestrian.

2.2 Dummy Retention and Release Equipment

As can be seen from Fig. 1, the vehicle is made to collide with an upright dummy. For this purpose, we developed a device which will hold the dummy upright in a standing position. When a test is made, the equipment will release the dummy smoothly enough to ensure that the experiment is not adversely affected by any restraining forces.

As soon as the vehicle used for the experiment passes a laser light barrier, a retaining bolt is withdrawn by a solenoid from a wire loop connected to the dummy.
Fig. 2 shows the equipment used for retaining and releasing the dummy.

Fig. 1 Equipment Used for Simulating Vehicle-to-Pedestrian Collisions

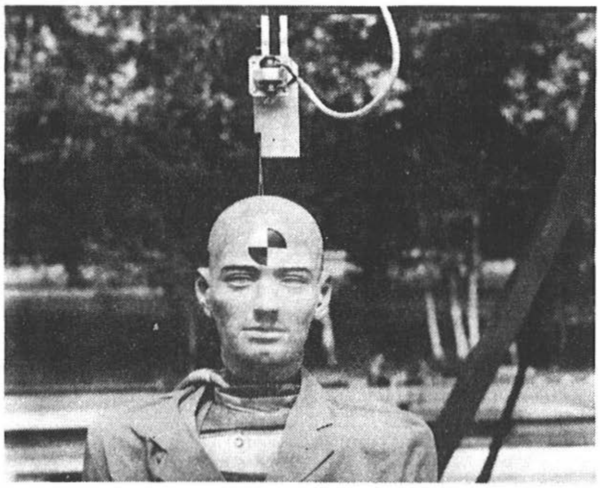


Fig. 2 Dummy Retention and Release Equipment

2.3 Equipment Used to Determine the Weight of the Suspended Dummy

The device described under 2.2 is attached to a beam clamped down at one end. This beam is fitted with strain gauges connected to a calibrated monitoring device which indicates the force which causes the beam to bend under the load of the suspended dummy. In this way, it is possible to adjust the load of the suspended dummy to exactly the same amount for all experiments, thus ensuring that the friction between the shoes of the dummy and the road is approximately the same in all experiments.
Fig. 2 shows the flexible beam used to determine the weight of the suspended dummy.

2.4 Test Vehicle

In the tests run for this study, a "synthetic vehicle" was used. This "synthetic vehicle" may be used for the simulation and analysis of all sorts of vehicle front geometries and their influence on the effects of a vehicle-to-pedestrian collision.
Fig. 3 shows a schematic drawing of the "synthetic vehicle".

2.5 Brake Activating Device

As soon as the vehicle makes contact with the dummy an automatic device activates its brakes. This device is shown in Fig. 4. It is triggered as soon as the vehicle passes a laser light barrier.

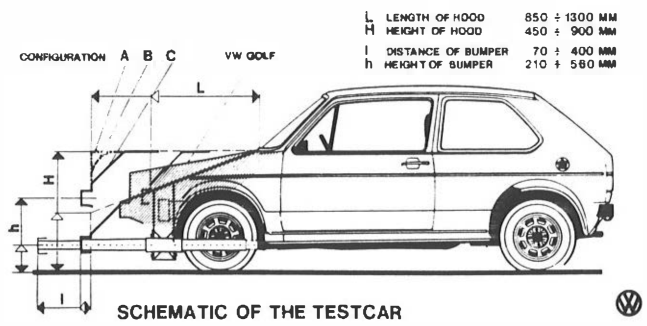


Fig. 3 Schematic Drawing of the "Synthetic Vehicle"

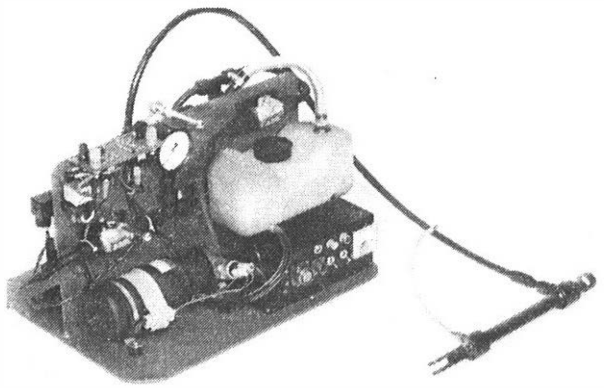


Fig. 4 Device Acitvating the Brakes of the Vehicle

2.6 Monitoring and Control Unit

At all stages experiments are centrally controlled and monitored by an electronic unit developed specifically for this purpose. The unit is shown in Fig. 5.

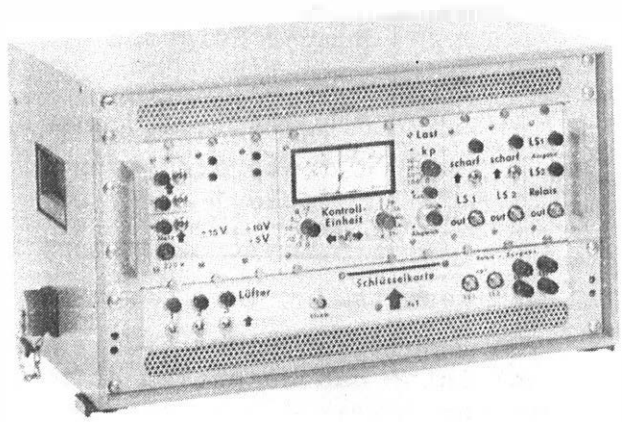


Fig. 5 Monitoring and Control Unit

3. Test Program

As has already been mentioned, any purposeful experiment program must be based on accident research findings. In accordance with the goal of this study, i. e.

- to get detailed information about the kinematics of the impacted pedestrian (50 % male dummy) as a function of bumper adjustment and impact speed,

the following parameters for the experiments were determined on the basis of [1]:

Impact Speed	:	20, 35, and 50 km/h
Impact Point	:	Vehicle front centre
Pedestrian Position	:	The 90°-position (walking straight ahead) was chosen for the test program (Fig. 1).

Pedestrian Anthropometry: Accident statistics show that dummies of different sizes (child and adult) must be used for vehicle-to-pedestrian collision tests. For this special program the 50 % male dummy was chosen.

Test Vehicle : The "synthetic vehicle" which was described in chapter 2.4 was used for the tests. The geometry of the front end was that of a VW Golf. For this special program we chose an absolutely stiff front end in order to eliminate the effects of energy absorption during the primary collision.
The bumper adjustment was varied in the following range:
Distance of bumper: 70 mm, 200 mm and 300 mm (l according to Fig. 3)
Height of bumper: 210 mm, 310 mm and 410 mm (h according to Fig. 3)

On the basis of the described test conditions, the following test matrix was determined:

	Impact Speed km/h 20	35	50
Combination of Bumper Distance l and Bumper Height h l/h	70/210 310 410	70/210 310 410	70/210* 310 410*
	200/210 310 410	200/210 310 410	200/210 310 410
*) The results of these tests are given in Table 1	300/210 310 410	300/210 310 410	300/210* 310 410*

4. Results

The results obtained from experiments simulating a vehicle-to-pedestrian collision can be broken down into kinematic data and load data pertaining to the dummy.
The following table and figures present the results of the tests with the following specifications:

Impact speed : 50 km/h
Bumper adjustment: l = 70 mm; 300 mm
h = 210 mm; 410 mm

Mainly two reasons caused this limitation of the data presentation:
- up to an impact speed of 35 km/h no significant differences of the results due to changes of the bumper adjustment could be found. One of the reasons seems to be the broad scatter of the results; this problem is described in detail in [2] .
- the limitation of this paper does not allow the discussion of several hundred data in detail but only indicates tendencies as results of the described experiments.

Table 1 presents the main data (load data and kinematic data) of the tests performed with an impact speed of 50 km/h and the bumper adjustments

l/h = 70/210; 70/410

and

l/h = 300/210; 300/410

IMPACT SPEED 50 KM/H		Test Nr.	Throwing Distance (m)	head: max. res. Accel. (g)	head: HIC	head: Impact Speed of the Head against the car (km/h)	Chest: max. res. Accel. (g)	Chest: SI	Pelvis: max. res. Accel. (g)	Throwing Height (mm)
BUMPER ADJUSTMENT l/h 70/210	prim. sec.	164	16,5	102 76	1478 500	54	155 63	1088 429	-- --	[illegible]
	prim. sec.	226	17,0	86 118	498 287	46	47 100	201 256	124 74	1575
	prim. sec.	228	16,5	147 76	1701 362	52	75 75	411 197	115 44	1204
	prim. sec.	249	16,6	124 90	1155 171	55	75 94	472 347	126 47	1575
70/410	prim. sec.	179	16,5	151 127	1687 790	55	105 24	676 90	115 162	1575
	prim. sec.	207	14,2	82 67	1275 119	--	69 75	265 105	148 52	1261
	prim. sec.	208	15,1	105 61	1619 174	48	86 59	469 87	150 60	1465
	prim. sec.	265	16,0	92 28	841 29	55	59 65	349 120	117 78	1465
300/210	prim. sec.	232	16,5	156 86	2857 591	68	89 42	411 101	155 67	1740
	prim. sec.	243	14,8	128 101	1565 324	70	47 52	174 50	172 28	1685
	prim. sec.	247	15,4	120 60	1556 102	71	104 51	556 121	170 155	1685
	prim. sec.	248	16,1	122 65	2950 140	75	105 120	565 505	166 70	1740
300/410	prim. sec.	199	16,0	115 ---	1376 ----	50	49 49	184 163	64 23	1685
	prim. sec.	201	15,4	161 173	1311 862	59	52 24	220 41	78 81	1740
	prim. sec.	205	14,8	135 120	1651 285	57	104 35	506 113	64 27	1905
	prim. sec.	206	15,7	75 58	953 163	56	48 58	222 104	65 73	2070

Table 1 Presentation of Test Results

An interpretation of the load data on the dummy is not the aim of this paper since they are not representative for any real car due to the stiffness of the used test car. Two important tendencies, however, might be mentioned: The bumper adjustment configuration l = 300 mm and h = 210 mm results in the highest head impact velocities against the car during the primary impact and consequently results in extremely high head loadings in terms of HIC. The dummy-loadings caused by the sencondary impact don't show any systematic dependency on the bumper adjustment. These two results correspond to the findings described in [5] .

The figures 6 to 14 show the kinematics of the dummy. Figures 6 to 10 show the movement of the head relative to the car and the head impact areas as a function of bumper adjustment. From these diagrams two important conclusions can be made: Obviously, the variation of the bumper height does not result in significant changes of the head impact area on the car, if all the other parameters are kept constant. On the contrary, the variation of the bumper distance influences the kinematics of the impacted dummy significantly. The head impact points come closer to the wind screen with increasing bumper distance.

Figures 11 to 14 show the movement of the head relative to the road during the entire test. These diagrams also indicate that bumper distance has a more significant influence on the dummy's kinematics than bumper height. The head-travel-histories don't differ from tests with the same bumper distances and different bumper heights. On the contrary, they differ significantly from tests with the same bumper heights and different bumper distances. In table 1, the values for the maximum vertical travel of the center of gravity of the dummy are presented. These values underline the findings mentioned above: An increasing bumper distance results in an increase of the dummy's "throwing-height". The throwing distance of the dummy, however, is not significantly affected by any changes of the bumper adjustment.

5. Conclusion

On the basis of tests with a 50 % male dummy and a special test car under special conditions, the following conclusion can be drawn:

- Bumper distance is of significant influence on the dummy's kinematics for an impact speed of 50 km/h; the variation of bumper height does not result in significant changes of the dummy's kinematics.
  Up to an impact speed of 35 km/h no influence of bumper adjustment variations on the dummy's kinematics could be found.
- An increasing bumper distance causes the head impact areas to come closer to the wind screen. This is nearly independent from the bumper height.
- In addition to the described tests, those with child dummies must be performed in order to answer the question, whether the described tendencies for the behaviour of the adult-dummy are the same for that of the childdummy. Those tests are of basic importance because any design which has a positive influence on the behaviour of the adult but a negative influence on that of a child would not have a positive effect on the total accident situation.

The results of this study can only be interpreted qualitatively. This is due to the very special test car and test parameters. The results, however, might be helpful for discussions about an optimal bumper adjustment taking into account the problems of car-to-car compatibility and pedestrian protection.

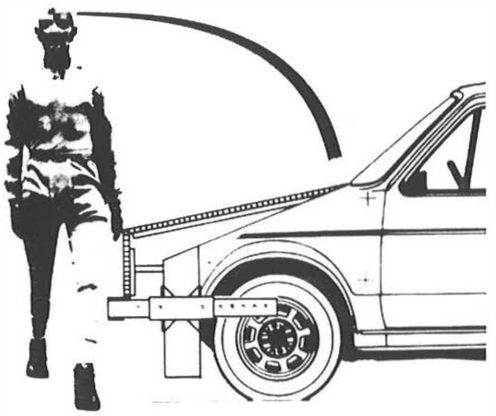


Fig. 6 Movement of the Head
Relative to the Car. l/h = 70/410

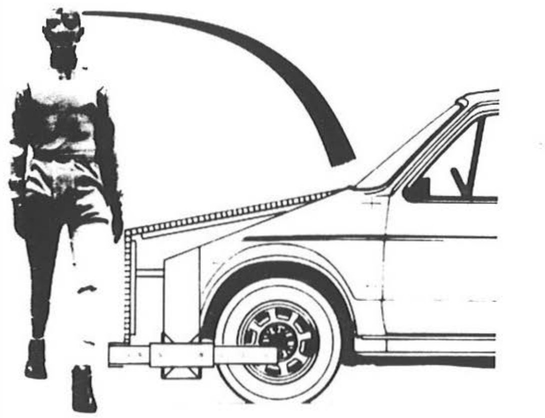


Fig. 7 Movement of the Head
Relative to the Car. l/h = 70/210

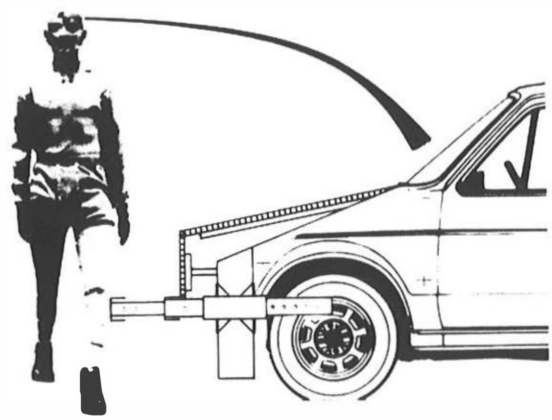


Fig. 8 Movement of the Head
Relative to the Car. l/h = 300/410

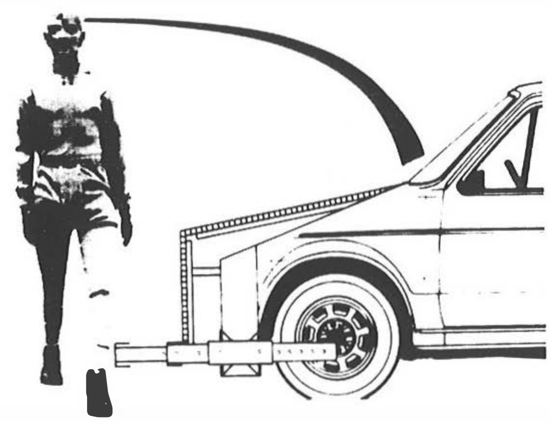
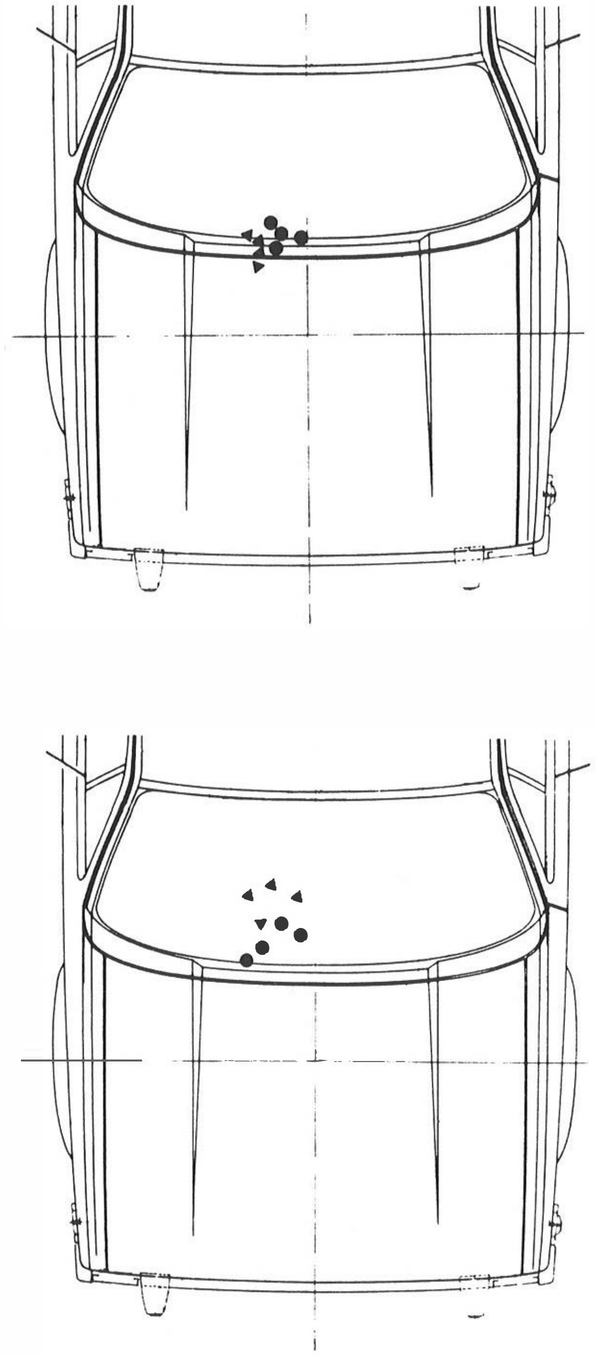


Fig. 9 Movement of the Head
Relative to the Car. l/h = 300/210



● 70 / 210 } = l/h
▲ 70 / 410 }

● 300 / 210 } = l/h
▲ 300 / 410 }

Fig. 10 Impact Areas of the Head

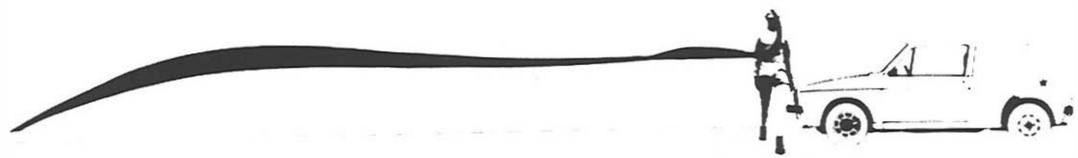


Fig. 11 Movement of the Head Relative to the Road. l/h = 70/410

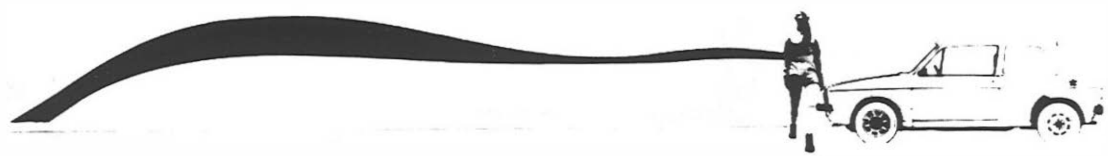


Fig. 12 Movement of the Head Relative to the Road. l/h = 70/210

Fig. 13 Movement of the Head Relative to the Road. l/h = 300/410

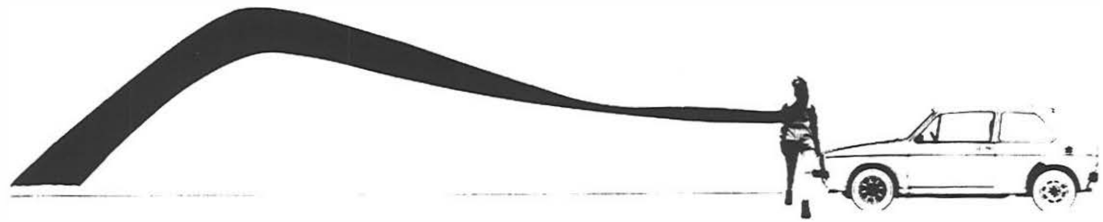


Fig. 14 Movement of the Head Relative to the Road. l/h = 300/210

6. References

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