BEHAVIOUR OF SIDE IMPACT DUMMIES USED AS PEDESTRIANS IN ACCIDENT RECONSTRUCTIONS

D. CESARI - M. RAMET - R. ZAC

ORGANISME NATIONAL DE SECURITE ROUTIERE

Laboratoire des Chocs et de Biomécanique

BRON - FRANCE

-:-:-

1. AIM OF THE STUDY

Evaluation of pedestrian safety is generally made through the analysis of car to pedestrian dummy tests. For these tests, the adult dummy generally used is a Part 572 fitted with a pelvic kit allowing a standing posture. The comparison between Part 572 and cadaver in realistic pedestrian test conditions shows differences in kinematics and impact response between the two models. These differences have been especially pointed out in the KOB programme (1) and have been found to be mainly due to the greater stiffness of the Part 572 dummy compared to human living and to cadavers.

During the same time several dummies have been developped to give a better response as car occupants in side impact. These dummies are softer especially at the thorax and shoulder levels. It is sure that the dummy improvement for side impact would give a better response in pedestrian accidents situation. For this reason, it was decided to duplicate some of the accident reconstructions with side impact dummies.

This paper gives comparisons between cadaver tests, Part 572 dummy tests, and tests conducted with 3 different 50th percentile side impact dummies. This comparison is made on kinematics of the models, and on the values of protection criteria recorded on head, chest and pelvis.

2. SELECTED ACCIDENTS

Three real pedestrian accidents have been selected in the materials used for the KOB programme. These selected accidents correspond to two main types of car profile (2).

The first selected accident is a collision between a Renault 4 and a pedestrian. The pedestrian was a 75 years old male (height : 164 cm, weight : 65 kg) who was crossing a street from the right to the left in front of a car. The pedestrian was struck on the legs by the bumper. His hips, head and chest impacted the car on the front bonnet. He sustained injuries on the head : fracture of the base of the skull (AIS 3), and on the legs : fracture of the left leg (AIS 2). The data of the selected accidents are listed in table 1.

The second selected accident is a collision between VW Golf and a pedestrian. The pedestrian was a 78 years old male (height : 175 cm, weight : 75 kg). He was crossing a road diagonally from left to right and was struck from behind by the car. He sustained the following injuries :

	PEDESTRIAN DATA					CRASH CONDITIONS	
Type of vehicle	Sex	Age	Height	Weight	Injuries	Position	Speed
Renault 4 case 3.3	M	75	164	65	Head : fracture of the base of the skull (AIS 3) Lower limbs : fracture of the left leg (AIS 2)	Pedestrian struck on the left side	40 km/h
VW Golf case 3.6	M	78	174	75	Head : temporal fracture (AIS 3) Thorax : 8th and 9th right and left rib fractures (AIS 2)	Pedestrian struck from behind	35 km/h
VW 1302 Case 3.1	F	67	165	70	Head : cerebral concussion (AIS 2) Lower limbs : fractures of both legs (AIS 2)	Pedestrian struck on the left side	35 km/h

Table 1 : Data of selected accidents

- head : facial laceration due to windshield breakage and right temporal fracture (AIS 3)
- thorax : fracture of the 8th and 9th left and right ribs (AIS 2)
- arms and legs : multiple bruises and tears (AIS 1)

The third selected accident is a collision between a VW 1302 and a pedestrian. The pedestrian was a 67 years old female (height : 165 cm, weight : 70 kg). She was crossing a street from the right to the left. She was hit on the legs by the bumper and her hip, chest and head impacted the front bonnet of the car. She sustained injuries on the head (cerebral concussion, AIS 2) and on the legs (fracture of both legs, AIS 2).

3. TEST PROGRAMME AND METHODOLOGY

The tests with cadavers and with Part 572 (Hybrid II) dummies were conducted in the frame of the KOB programme (1) whereas the tests with side impact dummies were performed by ONSER as a part of EEC phase III biomechanic programme.

The number of tests performed is listed in table 2

Accident	Cadaver	H II	HSRI	ONSER	MIRA
Renault 4 (3.3)	3	3	3	2	1
VW Golf (3.6)	3	3	3	2	1
VW 1302 (3.1)	1	3	3	2	1
Total	7	9	9	6	3

Table 2 : Number of performed tests

We were not able to perform any test with the APROD dummy because this dummy was not available during the period of EEC phase III biomechanic programme.

Each selected accident has been reconstructed with the 4 dummy types and with the cadavers under the same crash configurations (impact speed, car braking pedestrian posture). These conditions are close to the values listed in table 1.

4. RESULTS

The results of the 18 performed tests with side impact dummies are compared with the results of Part 572 (H II) dummy tests and of cadaver tests published in the KOB report.

The results of these 18 pedestrian tests are analysed in two directions : comparison of kinematics in the first part of the collision (car impact) and protection criteria values analysis.

4.1. Analysis of kinematics

Each dummy having its own properties it is interesting to analyse separately their kinematics. This analysis can be made in two steps : first, the overall kinematic of head, chest and pelvis and the position of the head versus thorax at the impact on the car. The drawings giving the dummy kinematics in pedestrian tests are in appendix.

4.1.1. Kinematics of HSRI dummy (4)

We have conducted 9 tests with the HSRI dummy for this programme (3

reconstructions of each selected accident). Only two of the three reconstructions of the R4 reconstructions were analysed ; in the third one, a camera failed during the test. The HSRI dummy seems to go not so far as the cadavers of the reference test ; this dummy has no mobile arm and no shoulder, but a thorax with a limited possibility of deflection. This gives a neck bending before head impact. This bending is not so important as for part 572 dummy, but more important than for cadavers. The kinematics of the HSRI dummy in VW Golf reconstructions were similar to those of cadavers and other dummies. In these tests the pedestrian is hit from behind, and the stiffness of the spine in P.A. is great on dummies and on human living.

In the reconstructions of VW 1302 accident, the HSRI dummy is hit on its side, but its head hit the windshield with the face. This rotation along the Z axis is allowed by the absence of arm on this dummy.

4.1.2. Kinematics of ONSER dummy (5)

Six tests have been conducted with the ONSER dummy (2 for each accident reconstruction). If we consider the R4 reconstruction, the overall head kinematic of the dummy is included between the trajectories of cadaver tests and the trajectories of Part 572 dummy tests described in KOB report. In fact, the ONSER dummy head impact point on the car is located farer than in Part 572 dummy tests, but not so far than with cadavers. This is due to the stiffness of the backbone of the dummy. In these tests the pedestrian dummy is hit on its side ; the tests with ONSER dummy show an important motion of the shoulder during its contact with the car bonnet. In the reconstructions of VW Golf accidents, there is no difference between the cadaver kinematics and the several dummies kinematics. In this accident, the pedestrian was hit from behind. In this direction the dummies - and the human living - have a limited possibility of deformation of the backbone in such direction. In the reconstructions with the VW 1302, the ONSER dummy shows a great collapse of the shoulder on the impacted side, compared to the Part 572 dummy. This kinematic is comparible to the cadaver kinematic. During the last part of the kinematic corresponding to the contact between the car and the pedestrian, the dummy head, because of the shoulder collapsing and of the thorax deflection, hit the car bonnet without neck bending.

4.1.3. Kinematics of MIRA dummy (6)

Only 3 tests (one for each accident) have been conducted with the MIRA dummy in this programme. Nevertheless it is possible to point out some particularities of this dummy. This dummy is fitted with shoulder allowing and important motion of the shoulder, but in pedestrian tests the impacted shoulder does not seem to collapse correctly. This limits the head impact speed on the bonnet. The overall kinematic seems not very different from other dummies.

4.2. Results concerning protection criteria

Head, chest and pelvis triaxial accelerations were recorded in all the tests. On the cadavers, the head acceleration was recorded either with 9 accelerometers from which was calculated the acceleration at the center of gravity or by one triaxial accelerometer close to the center of gravity ; the thoracic acceleration was recorded with a triaxial accelerometer screwed on T4 vertebra and the pelvic acceleration with a triaxial accelerometer screwed on the sacrum. On the dummies, the accelerometers were screwed at the locations indicated by the manufacturers, i.e. at the center of gravity of the head, inside the thorax at T4 level, screwed to the spine, inside the pelvis at the level of the sacrum.

			Resultant acceleration max/3ms			
Test n°	Model	HIC	Head (g)	Thorax (g)	Pelvis (g)	
C1	Cadaver	419	126/51	106/83	135/122	RENAULT 4
C2	"	871	162/07	65/28	91/66	
C3	"	954	152/114	40/32	45/35	
D1	H II	843	128/108	58/42	42/30	
D2	"	660	111/85	55/41	55/47	
D3	"	548	102/76	41/35	67/33	
PCL 01	HSRI	1082	103/95	26/25	42/29	
PCL 02	"	828	90/83	24/23	40/24	
PCL 03	"	419	76/68	23/22	43/30	
PCL 04	ONSER	325	43/37	39/26	39/29	
PCL 05	"	393	79/72	29/20	36/27	
PCL 06	MIRA	382	64/58	21/19	26/21	
MS 199	Cadaver	3108	277/160	118/	49/48	VW GOLF
MS 200	"	1332	250/115	147/	45/36	
MS 207	"	1201	134/95	287/	78/55	
1065/2	H II	1692	250/154	65/46	32/18	
1065/3	"	957	240/104	71/50	39/34	
1065/4	"	1651	280/96	43/40	36/30	
PCL 11	HSRI	705	80/77	39/37	34/24	
PCL 12	"	564	76/72	37/35	48/35	
PCL 13	"	468	68/65	32/31	40/37	
PCL 14	ONSER	708	136/67	47/27	50/42	
PCL 15	"	1103	142/92	55/45	76/50	
PCL 16	MIRA	360	141/36	16/15	43/30	
C1	Cadaver	816	127/80	59/25	34/28	VW 1302
D1	H II	560	69/55	54/44	106/53	
D2	H II	320	61/53	26/25	98/33	
D3	H II	355	48/44	31/20	111/41	
PCL 21	HSRI	443	65/61	35/34	35/23	
PCL 22	"	466	58/55	30/29	29/27	
PCL 23	"	320	57/48	26/25	27/24	
PCL 24	ONSER	1176	137/110	34/26	40/32	
PCL 25	"	1277	206/75	32/27	48/37	
PCL 26	MIRA	290	75/56	47/15	20/18	

TABLE 3 : Protection criteria values

From these data, HIC, maximal and 3 ms accelerations have been computed. These results are listed in table 3. The values of a protection criterion concerning a specific body area in a specific test, depend from two main parameters : the dummy dynamic responses and the stiffness of the car area hit by the body region. So, it is not possible to compare directly the dummies using protection criteria values.

Concerning the R4 reconstruction, HIC values are in the same order of magnitude for ONSER and MIRA dummies whereas they are higher on HSRI dummy, Hybrid II dummy and on cadavers.

Concerning thorax and pelvis protection criteria in tests with R4, the values are not very different for the side impact dummies. The lowest values were recorded on the the MIRA dummy. The values recorded on the Hybrid dummy were higher, and those recorded on the cadavers are more scattered than those recorded on dummies.

There is a large scatter in the values of protection criteria recorded on dummies and cadavers in VW Golf reconstructions. In these reconstructions, the dummy was hit from behind. This crash configuration can explain a greater disparity in the results : the parts of the dummies on which are fixed the thoracic and pelvic accelerometers can be hardly impacted during the dummy kinematic ; on the cadavers, the accelerometers are external and they can be directly impacted.

As for the reconstruction of R4, the values recorded on the MIRA dummy are lower than those recorded in the other dummies.

Results of the VW 1302 reconstructions show a great difference in HIC values from one dummy to anothers. The highest values are recorded on the ONSER dummy which had a large possibility to collapse his shoulder when it impacts the hood which allows a higher head impact speed. Only one cadaver test was performed for this accident. The HIC value corresponding to ONSER tests, but clearly higher than those of the tests with other dummies. There is less difference for the other protection criteria which remain very low. The lowest values of all protection criteria are recorded on MIRA dummy.

5. DISCUSSION

The results of the pedestrian tests conducted with side impact dummies compared to the results of cadaver and Hybrid II tests show different responses.

The side impact dummies have a better kinematic than the Hybrid II, referred to cadavers; this is specially true when the pedestrian is hit on its side (case R4 and VW 1302) for which the shoulder collapses when the dummy rotate on the hood ; however the shoulder of the MIRA dummy jammed before its complete motion, probably because the forces acting on it were not completely perpendicular to the body symetrical plane.

The thoracic deflection and the shoulder collapsing allow a more realistic head impact on the hood or on the windshield. The thoracic deflection of the HSRI dummy was not so important as it was designed for, but this dummy was fitted with the original Taylor shock absorber which has been replaced later by the new and more efficient ACE shock absorber.

Nevertheless the side impact dummies kinematics are different from the cadaver mainly because the too great stiffness of the dummy thoracic spine : this high rigidity does not allow the dummy to "follow" the car profile, and the cadaver does.

Injury criteria recorded on dummies head are scattered, but the values depend from the head speed at impact and the head damping characteris-

tics but also from the force deflection characteristics of the area hit by the head on the car, and these characteristics can vary greatly for two close points, and the use of HIC emphasizes these differences.

The values of thoracic acceleration of side impact dummies are lower than those of Hybrid II, in relation with the higher thoracic deflection capability of side impact dummies.

The pelvis of side impact dummies were not especially designed, except the pelvis of the MIRA dummy which recorded the lowest values of pelvic acceleration.

6. CONCLUSION

The results of accident reconstruction tests conducted with three side impact dummies used as pedestrian, and their comparison with previous similar tests conducted with human cadavers and with Hybrid II dummy allow to point out the following remarks :

- all the dummies sustained the pedestrian tests without noticeable damage
- the side impact dummies have a better behaviour in pedestrian tests than the Hybrid II dummy
- the HSRI dummy allows a head motion more realistic than the Part 572 dummy but limited by the thoracic deflection capability for the model used in these tests
- the ONSER dummy has a large capability of shoulder collapsing and of thoracic deflection which seems to allow a good head motion relative to the torso, even if its neck seems too stiff
- the MIRA dummy gives lower injury protection criteria values under the same crash configuration, and its shoulder does not seem to collapse as much as it was designed for.
- all the dummies have a too rigid spine in lateral bending ; the spine stiffness gives a specific overall dummy kinematic compared to cadaver kinematics

ACKNOWLEDGEMENTS

The work on the evaluation of side impact dummies in pedestrian tests, which is the basis of this paper, has been partly supported by the European Economic Community, in the phase III of the Biomechanic Programm, for which we are grateful.

REFERENCES

1. LENZ K.H.
Joint biomechanical research project KOB
Unfall-und Sicherheitsforschung Strassenwerkehr
n° 34, 1982

2. LANGWEIDER K. and al.
Patterns of multi-traumatisation in pedestrian accidents in relation to injury combinations and car shape
8th ESV, Wolfsburg, 1980, pp 854/878

3. FAYON A. and all
Developmnet and performance of the APR dummy (APROD)
Peugeot SA/Renault, 8th ESV, 1980, pp 451/462

4. BURGETT A.L., HACKNEY J.R.
Status of the National Highway Traffic Safety Administration's Research and Development and Rulemaking Activities for upgrading side impact protection
7th ESV, Paris 1979

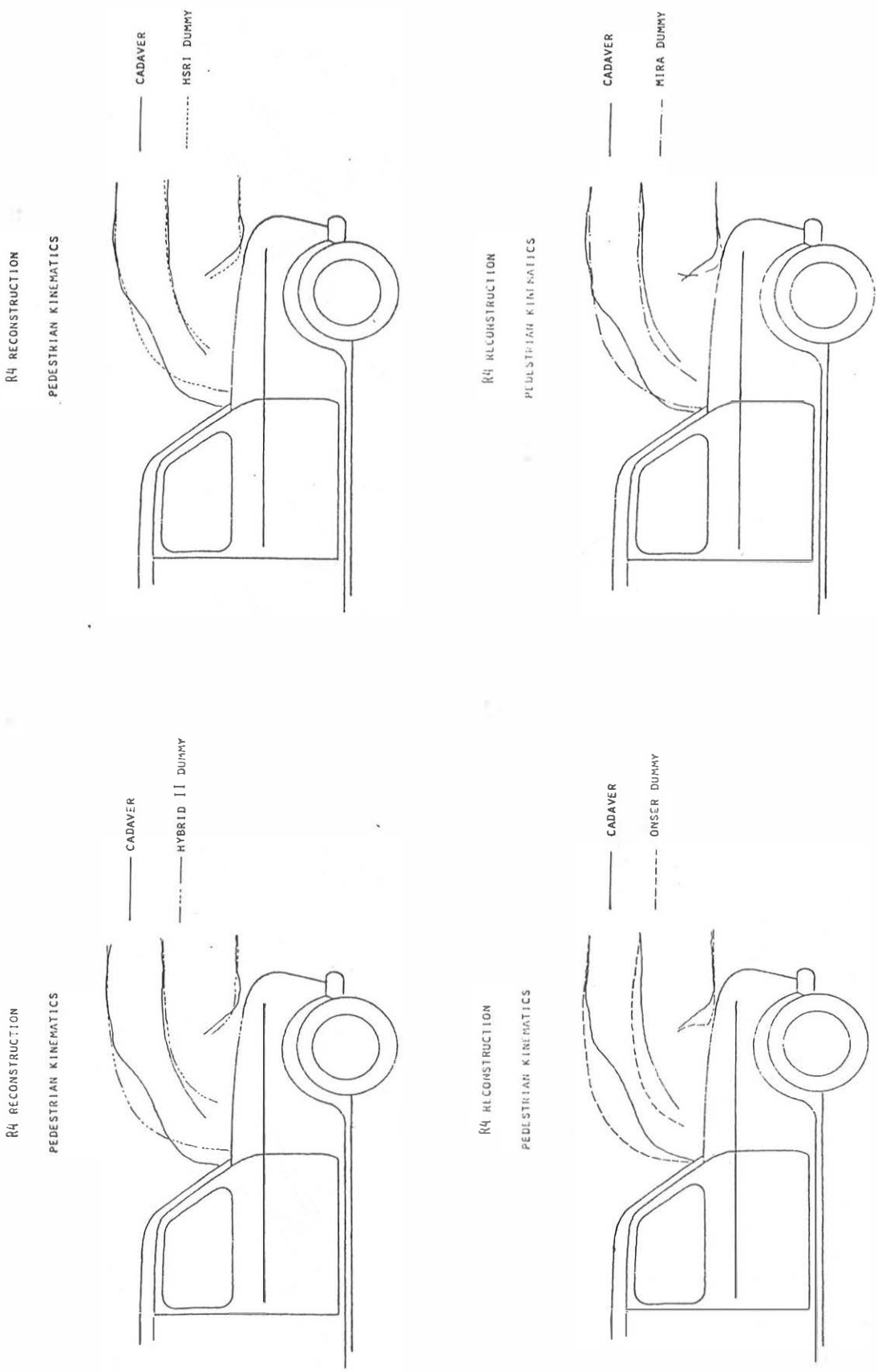
5. COTTE J.P.
The ONSER dummy - A research tool for safety
8th ESV, 1980, pp 463/471

6. NADA M.
Development of side impact dummy
Interim report EEC phase III
Report nº 480822 MIRA, 1981

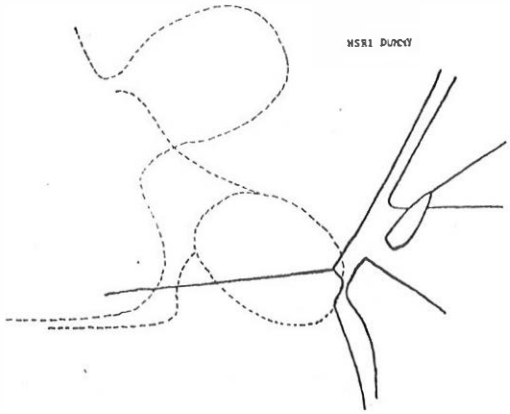
APPENDIX

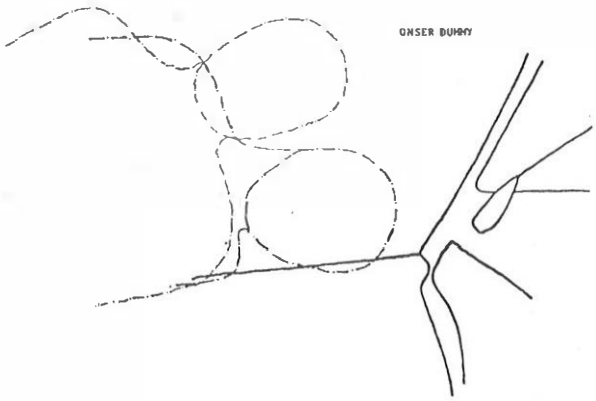
A - Dummy/cadaver kinematics in the reconstructions of R4 accident (case 3.3)

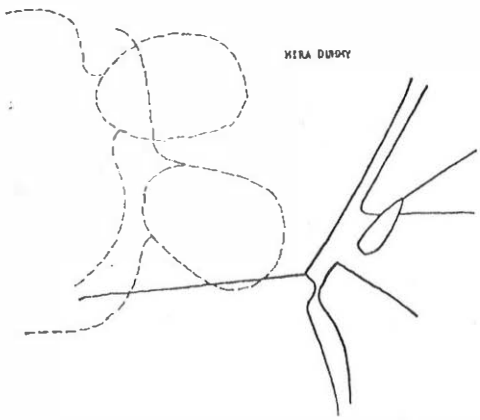
B - Head/thorax motion of side impact dummies in the reconstructions of R4 accident (case 3.3) and of VW 1302 accident (case 3.1)



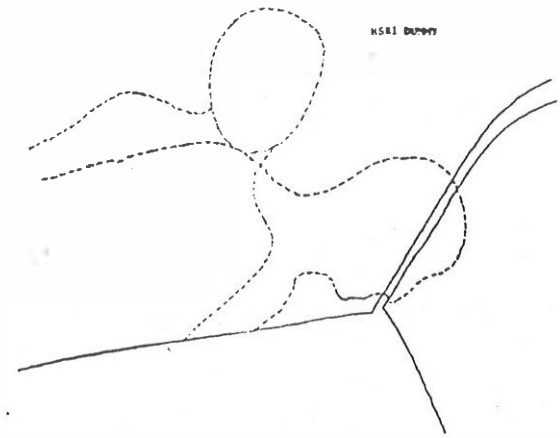
Appendix A - Dummy/Cadaver Kinematics

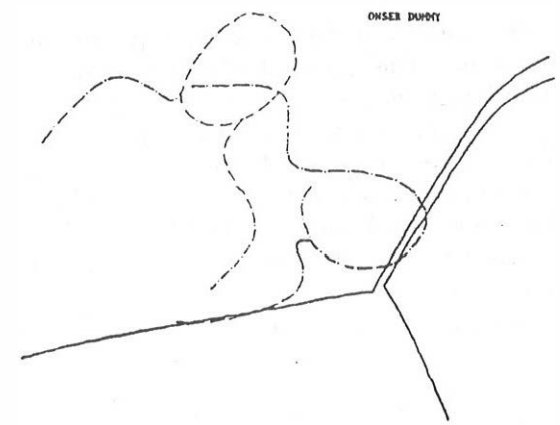


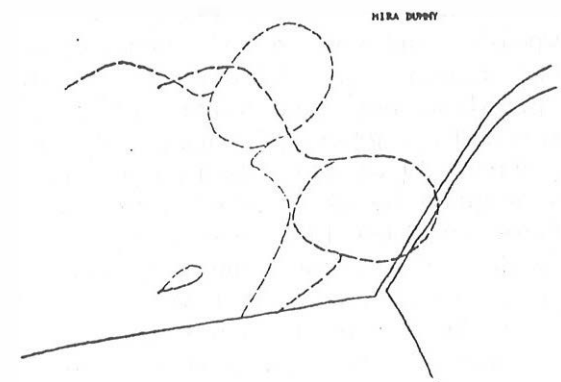




Appendix B: Head/Thorax motion of side impact dummies
(Reconstructions of RA Accident - case 3.3)







Appendix B . Head/Thorax motion of side impact dummies
(Reconstructions of V.W 1302 accident - case 3.1)