SIDE-COLLISIONS, COMPARISON OF DUMMY LOADINGS WITH INJURIES OF REAL ACCIDENTS

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ABSTRACT

The relationship between injury severity on the AIS (abbreviated injury scale) and one of the characteristics designating accident severity was investigated on the basis of 60 vehicle-vehicle side collisions. The injury severity curve obtained in this way was compared with the corresponding curve for dummy load values in order to arrive at a correlation between injury severity and dummy loading. The dummy loading values were in this case determined by the use of mathematical models which had been calibrated by means of the results of experimental tests.

INTRODUCTION

The mechanical loading values measured for test dummies in crash experiments presently form the basis for the evaluation of the crashworthiness of motor vehicles. The functional relationship between dummy loading and actual injury severity is, however, for the most part unknown. At the present time, the toleration limits for the human body defined as long ago as 1970 to 1972 by the American government in Federal Motor Vehicle Safety Standard (FMVSS) 208 are still accepted. On the basis of more recent knowledge gained in the field of biomechanics, however, these values have been called into question from various sides. The figures in the above Standard, moreover, represent only the limit values for mechanical loading leading to fatal injury. The correlation between loading and injury in the subcritical area - knowledge of which is urgently necessary for the optimization of passive safety - is yet to be found. The attempt is made in the following to establish this relationship by means of the comparison of injuries occurring in actual accidents with dummy loading values obtained by computation.

Injury severities for individual bodily parts as a function of accident characteristic values were determined from 60 lateral collisions arising from actual vehicle accidents and were separated according to occupants in the vehicle struck, and in the vehicle striking. By means of mathematical simulation models which have been calibrated with the results of experimental testing, the relationship between dummy loading and accident severity was determined. A relationship between injury severity and dummy loading can be shown by means of comparison of the two curves.

INJURY SEVERITY

The accident data used as basis for this investigation were collected from 60 vehicle-vehicle lateral collisions involving occupants using safety belts. These collisions were selected from a total of approximately 1700 in-depth cases studied by the Technical University of Berlin and the Medical College of Hanover. These collision data were assembled directly at the accident sites by research teams in Berlin and Hanover working under a study directed by the Bundesanstalt für Straßenwesen (German Federal Institute for Roads and Highways).

In order to restrict the distribution of the injury data, only those lateral collisions were selected which fulfill the aditional conditions shown in Fig. 1 as follows:

- only car-car-side collisions
- impact area between A- and C-pillar
- impact angle between 2-4 o'clock and 8-10 o'clock

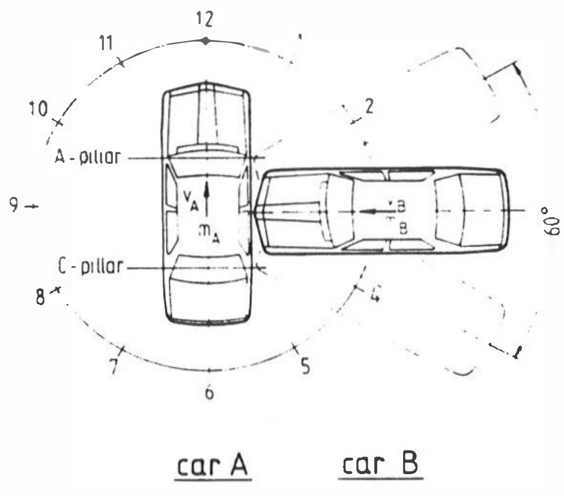


Fig. 1 Definition of the side impact

In all the lateral collisions thereby chosen for analysis, the main deformation of the vehicle struck lies in the compartment area. Lateral collisions in the area of the front and rear axle, which result in different loads on the occupants, were therefore not considered.

The collision velocities and changes in speed of the vehicles

Δv_B m/s	Number of Injuries																				
	AIS (head)							AIS (chest)							AIS (pelvis)						
	0	1	2	3	4	5	6	0	1	2	3	4	5	6	0	1	2	3	4	5	6
0- 4	10	5	1					15	1						13	3					
4- 8	29	12	4					36	7	2					37	7	1				
8-12	17	7	6	2				20	10	1	1				23	8	1				
12-16	2	4		1				2	1	1	1	1	1		3	3	1				
16-20		1			2	1			1	2		1				2		2			
> 20																					

Table 1: 104 occupants in the striking car

$\mu \cdot v_B$ m/s	Number of Injuries																				
	AIS (head)							AIS (chest)							AIS (pelvis)						
	0	1	2	3	4	5	6	0	1	2	3	4	5	6	0	1	2	3	4	5	6
0- 8	10	6	2					5	5	7	1				8	7		3			
8-16	10	5	3					9	5	2			2		12	1	2	1	1	1	
16-24	3	2	2					4	2			1			4		1	1		1	
24-32		1	2					2		1						1	1			1	
32-40																					
> 40																					

Table 2: 46 occupants in the struck car (near side)

Δv_A m/s	Number of Injuries																				
	AIS (head)							AIS (chest)							AIS (pelvis)						
	0	1	2	3	4	5	6	0	1	2	3	4	5	6	0	1	2	3	4	5	6
0- 4	6							5	1						6						
4- 8	14	5	7					21	4	1					25	1					
8-12	9	10	1	1				13	5	2			1		13	5	1	1		1	
12-16	2							1	1						1	1					
16-20		2						1	1									1			
> 20			1	1				2							2						

Table 3: 51 occupants in the struck car (off side)

were reconstructed by means of a computer program at the Technical University of Berlin, with consideration being taken of the post-crash motion and of the vehicle deformation (1).

The injuries of the occupants in the striking vehicle were plotted over the change of velocity Δv_B of the vehicle. The influence of the mass ratio and of the collision velocity on the injury severity is included in this characteristic.

In the struck vehicle, the occupant injuries on the vehicle collision side and on the side opposite the collision were separately considered. As has been demonstrated, the injury severity of the occupant on the collision side is strongly dependent on the rigidity ratio of the frontal and lateral vehicle structure (2). Under the assumption that structural rigidities are approximately proportional to vehicle masses, the product of the mass ratio and the collision velocity $\mu \cdot v_B$ is an injury-specific characteristic for the occupant sitting on the collision side.

The injuries of the occupants on the side opposite the collision have been represented as a function of the velocity of the struck vehicle Δv_A .

Tables 1 to 3 show the injury frequencies, broken down by occupant position, injury severity, and characteristic value. It is evident that for a constant characteristic, a broad range of injury severities still occurs. A narrowing-down of this spread is possible only be means of further classification of the accident material, e.g., according to angle of collision, initial velocity of the struck vehicle v_A , occupant physiology, etc. This is, however, not possible with the small number of cases available for study. The number of 104 occupants in the striking vehicles is just barely sufficient to determine a tendential dependence of AIS injury severity on velocity change Δv_B . With greater injury severity, however, this determination becomes more and more uncertain on the basis of the small number of injuries.

Because of the separation of occupants in the struck vehicle according to collision side and side opposite the collision, the number of injuries is reduced approximately by half, with the result that a dependence on the specific characteristic ($\mu \cdot v_B$ or Δv_A) can hardly still be determined.

An evaluation of the data and comparison with corresponding curves for dummy loading values shall be performed later.

DUMMY LOADINGS

The dependence of the dummy loading values on the specific characteristics was determined with the aid of mathematical models. In this case, existing data on experimental tests (two 90° crash tests with ALDERSON dummies, VIP 50 A, performed by VOLKSWAGEN) served as points of support for the plots sought (3). The input parameters of the models were coordinated in such a way that the supporting points were sufficiently exactly reproduced. The mathematical models then provided the closed curve plots by interpolation and extrapolation.

Fig. 2 shows simulation models applied. Two-dimensional models were involved, with the result that only the perpendicular collision could be simulated.

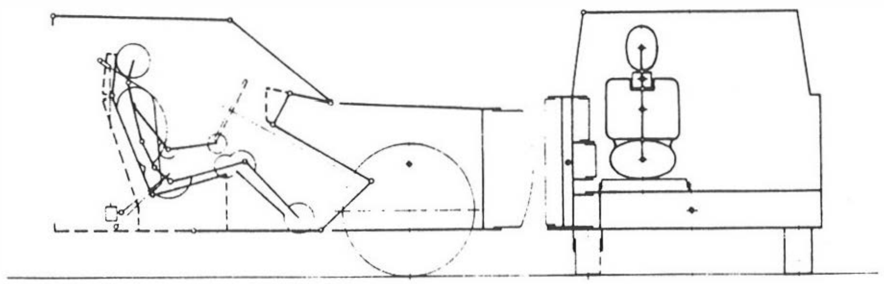


Fig. 2 Mathematical models

The movement of the two vehicles was described by means of a 3-mass system with 4 degrees of freedom, with consideration being taken of the relative movement of the lateral structure (intrusion). The essential input quantities are the vehicle masses, the structural rigidities, and the collision speed of the striking vehicle. The velocity of the struck vehicle at the point in time of the collision was zero.

The reaction of the occupants to changes in the vehicle movement values was determined with the aid of rod systems with point masses and swivel joints. The occupant contours were represented by circles and ellipses. The occupant model in the striking vehicle consists of 8 masses with 10 degrees of freedom, while that in the struck vehicle has 4 masses with 6 degrees of freedom.

By means of the mathematical models, the occupant loading values for four different mass ratios, each at four collision velocities, were calculated. Assumption was made that the rigidities of the vehicle structures change in proportion to the vehicle masses. Fig. 3 shows the path of force characteristics of the vehicle structures for the masses chosen. The mass of the struck vehicle was kept constant. The mass ratios are $\mu = m_B/m_A = 0.7 / 1.0 / 1.26 / 1.55$ and the collision velocities are $v_B = 25 / 40 / 55 / 70$ km/h.

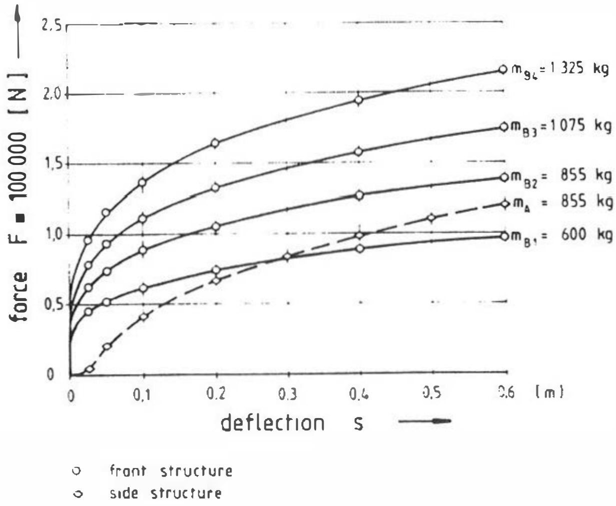
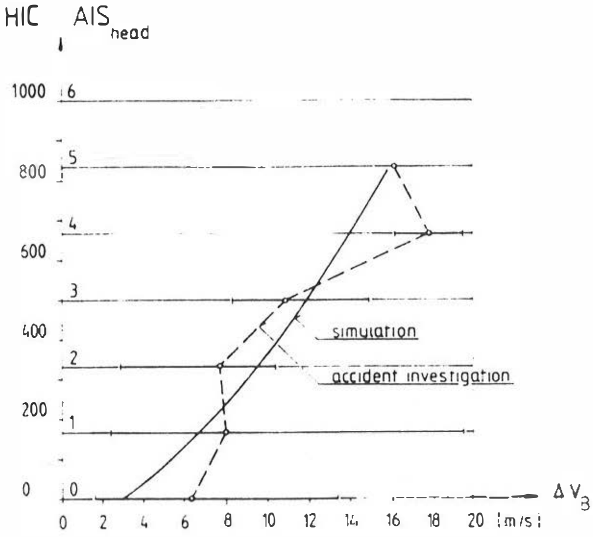


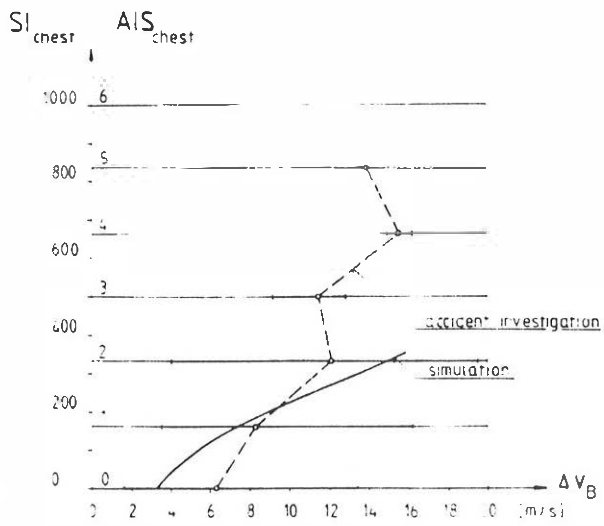
Fig. 3 Force deflection charakteristics of car struktures

COMPARSION DUMMY LOADINGS - INJURIES

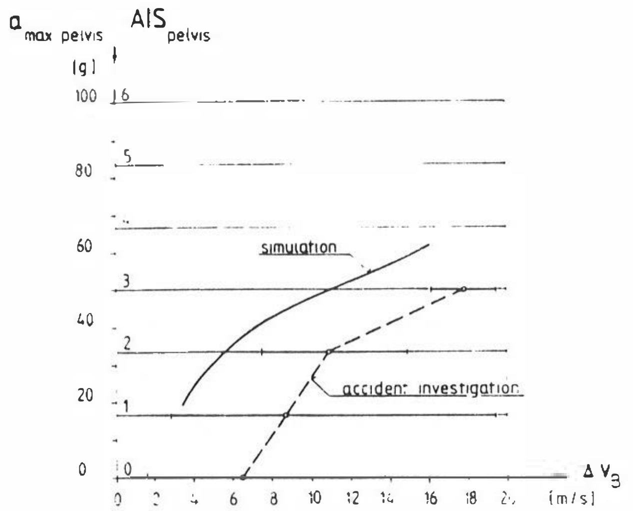
Figs. 4 and 5 show the dummy loading values determined by the simulation models and the injury severity for head, chest, and pelvis obtained from the accident analysis in dependence on the specific accident characteristics Δv_B and $\mu \cdot v_B$. The curves of injury severity were thereby determined from Tables 1 and 2 by taking the arithmetic mean of the characteristic values per AIS class. Because of the small number of serious injuries, the plots above AIS 3 are no longer reliable, with the result that



striking car (104 passengers)



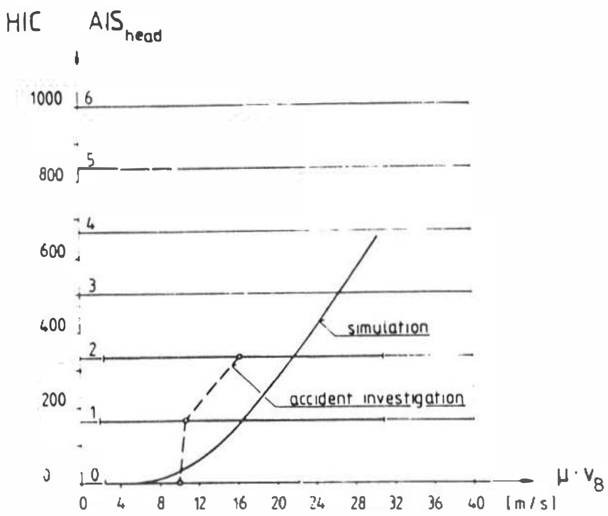
striking car (104 passengers)



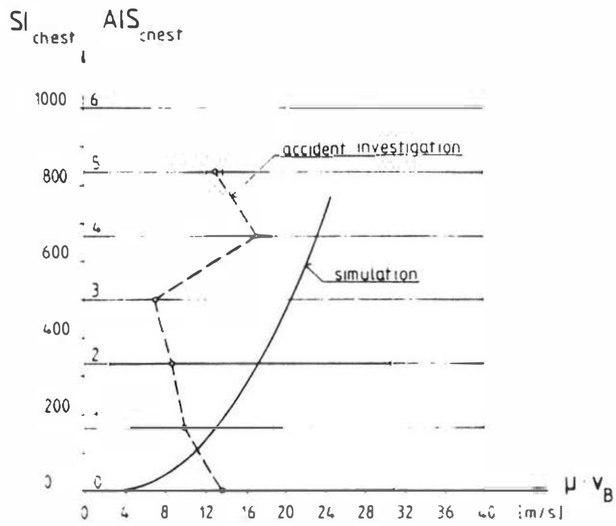
striking car (104 passengers)

Fig. 4

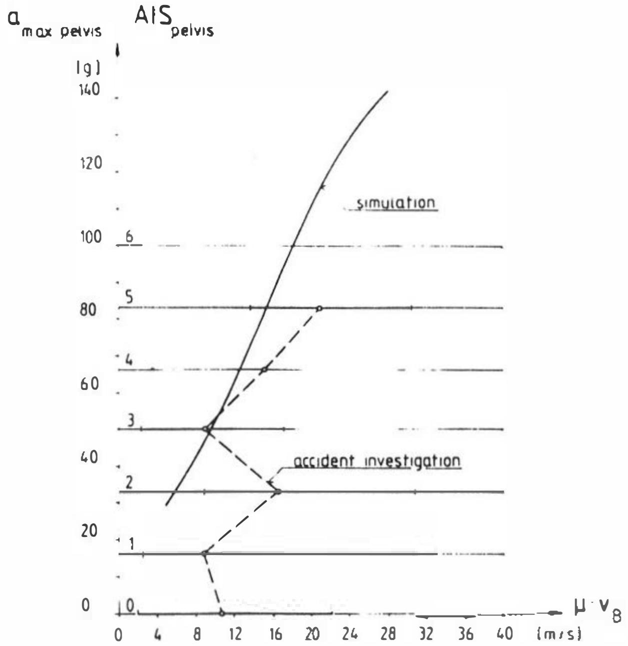
Comparison between accident and simulation of striking car (104 occupants)



struck car (46 nearside occupants)



struck car (46 nearside occupants)



struck car (46 nearside occupants)

Fig. 5

Comparison between accident and simulation of struck car (46 near-side occupants) no sufficiently accurate conclusions can be made concerning the loading limit values.

The scale of ordinates in the diagrams was chosen in such a way that the loading limits defined in FMVSS 208 correlate with the AIS 6 fatal injuries. In this case, the critical pelvis acceleration was fixed at 100 g, since no loading limit values are available for the pelvis. Fig. 4 shows the results for the occupant in the striking vehicle: the curve for head injuries coincides approximately with the calculated loading curve, but obvious deviations occur for the chest and pelvis. An AIS 3 injury severity thereby corresponds approximately to a head load of HIC = 500, to a chest load of SI = 250, and to a pelvis acceleration of 65 g.

The tendency may be derived from the plots that the loading limits of HIC = 1000 measured in tests on the dummy were set too low, and that SI = 1000 for the chest was set too high. Extremely great pelvis acceleration values of the dummy agree with minor injury severity: this demonstrates the high limit loading of the pelvis.

The results for the occupant on the collision side of the struck vehicle are shown in Fig. 5. A relationship between loading values and injuries may no longer reliably be determined because of the too wide spread of the injury data and the small number of cases available for study.

The extremely great pelvis acceleration values even for low AIS values were apparent here as well.

SUMMARY

The relationship between injury severity and accident characteristic was determined from 60 vehicle-vehicle lateral collisions with the main deformation in the passenger compartment area. Breakdown was thereby made into occupants in the striking and in the struck vehicle.

In addition, the dependence of the dummy loading values on the accident characteristic values was determined by simulation models calibrated from crash tests.

The functional relationship sought between injury severity and dummy loading can be found only with the aid of a greater number of cases and by restriction of the spread of the data on occupant injuries through further classification of the accident data according to collision angle, vehicle type, occupant physiology, etc.

The following basic tendencies could, however, be determined:

- The presently applied loading values require more exact determination.
- The maximum permissible pelvis acceleration probably lies in the order of magnitude of 100 g.
- The dummy loading values correspond to AIS 3 injury severity as follows:

head:	AIS 3	≙	HIC	= 500
chest:	AIS 3	≙	SI_{chest}	= 250
pelvis:	AIS 3	≙	$a_{max,\ pelvis}$	= 65 g

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