LATERAL AND OBLIQUE IMPACT INFLUENCE ON VEHICLE- AND OCCUPANT PROTECTION

U. Seiffert, R. Weissner and F. Börsch
Research and Development
Volkswagenwerk AG, Wolfsburg, Germany

ABSTRACT

Due to greater protection of occupants in frontal collisions owing to enforcement of restraint system usage, side impacts ascend to increased attention. One important conclusion of the various tests in simulating accidents of this type, as opposed to frontal accidents, is that the possibility of improving the protection of occupants is much smaller. The results of various lateral impact tests are given in a summarized form.

INTRODUCTION

Vehicle design can still be further optimized by improving those areas which concern themselves with accident avoidance and mitigation of injuries. One important factor for the determination of the performance of vehicles in this regard is an accurate accident analysis which should provide at least the following information on an equal basis:

- description of the accident configuration
- data on the vehicles involved
- data on the persons involved
- data of environment

Today these data are often unavailable in a form ready for use. A detailed discussion of this problem is given in (1).
If we examine the accident data available, we find that after the occupant protection in frontal collisions is provided, protection in side collisions has the highest priority for vehicle occupants.

ACCIDENT STATISTICS

The accident data for Germany show the following distribution (2):

<u>Injuries (per year)</u>

car passengers	261.875	58,7 %
pedestrians	65.370	14,6 %
motorcycles/bicycles	103.236	23,1 %
trucks, busses	16.438	3,6 %
total	446.919	100,0 %

Fatalities (per year)

car passengers	6.609	45,3 %
pedestrians	4.457	30,5 %
motorcycles/bicycles	3.095	21,2 %
trucks, busses	443	3,0 %
total	14.604	100,0 %

The distribution of the accidents in Europe and USA regarding type of collision is shown in table 1 (3):

Europe

type of collision	Source		A	B	C	D	E	F	G	H	I	mean value***
	Front	%	60,7	60,6	57,1	54,0	58,2	64,0	35,7	65,0	59,0	57,1
	Side	%	24,9	20,3	28,6	28,2	24,0	17,0	33,5	18,6	29,0	24,9
	Rear	%	14,4	16,6	8,2	9,8	10,7	16,0	8,7	7,8	6,5	11,0
	Rollover	%	-	-	6,1	8,0	7,1	-	4,9	8,6	5,5	6,7
	Other	%	-	2,5	-	-	-	3	17,2	-	-	0,3 *

USA

type of collision	Source		J	K	L	M	N	O	P			mean value***
	Front	%	49,0	58,1	53,0	48,8	46,9	62,8	50,2			52,7
	Side	%	17,0	28,0	14,0	15,1	12,8	26,5	10,8			17,7
	Rear	%	29,0	7,8	6,0	3,8	7,2	4,3	24,1			11,7
	Rollover	%	4,0	6,1	23,0	21,2	19,5	4,5	-			13,1
	Other	%	1,0	-	4,0	11,1	13,6	1,9	14,9			4,8 **

remarks: the total of each column is 100 %

* = this is not the mean value from A to I
** = this is not the mean value from J to P
*** = the mean values do not consider the partial high differences in number of cases for each single source

Table 1: Distribution of accidents for type of collision

After a considerable improvement of frontal crash protection, specifically with the optimization of vehicle structure in combination with the occupants restraint system (3, 4), the side collision takes on more relative importance in respect to injuries and fatalities. Two presentations (5, 6) at the last ESV-conference deal with this problem.

The necessary data for an effective improvement of vehicle performance in a side collision should be given as follows:

- weight of the vehicles involved
- impact speeds
- impact directions
- impact areas
- injury pattern and severity
- environmental conditions

THEORETICAL CONTEMPLATIONS

There are at least two different assumptions that can be made regarding side impacts of two vehicles:

1. the side structure of the impacted vehicle is ideally rigid and all deformation is absorbed by the striking vehicle, or

2. the side structure of the struck vehicle deforms and the striking vehicle is considered to be absolutely rigid.

In both cases the impact speed of the interior surface of the struck vehicle against its occupants cannot be predetermined exactly. This is based on the fact that the impact speed of the door interior against the occupants for a low side structure strength of the impacted car can be as high as the impact speed of the striking car. For an extremely high side strength without intrusion the occupants impact speed can also exceed the velocity change of the struck car. For a real accident the above situation in general does not occur.

In fact, in the most cases, both processes are combined; at first, the occupants impact against door interior directly due to intrusion of the side structure, there after a second impact due to velocity change of the struck vehicle. These kinematic processes can be described as a "lateral-bi-pulse-phenomenon".

Based on this experience the following requirements should be fulfilled:

- The impact areas in the vehicle interior should be designed in such a way, that the occupant contact areas should not increase the injury severity.

- The deformation of side structure should be kept as small as possible to guarantee a minimum survival space.

- A contact between neighbour-occupants should be prevented by an appropriate seat design.

TEST PROCEDURES

For evaluation of vehicle performance in side collisions there are a high number of different test procedures possible, for example:

- impact of the vehicle against a fixed undeformable pole

- impact of a movable non-deformable barrier

- impact of a movable deformable barrier

- impact of a real vehicle

For these test modes useful parameters of impact area, impact direction and impact velocities have to be chosen. These data should be evaluated from field statistics; as a result there should be considered a test procedure simulating the most critical real world accident type.

TEST RESULTS

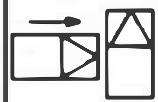
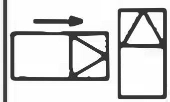
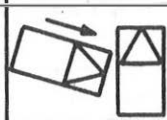
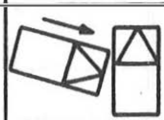
<u>Real World Accidents in Simulation</u>

In order to evaluate todays vehicle performance, four different test modes are presented as follows:

Under an impact angle of 90° and 75° with impact velocities of 40 km/h and 64 km/h a running car hit (with its longitudinal axis) the side structure of a stationary car at the projection of the drivers seat reference point on the outer surface. During crash all car- and occupant-data were recorded.

The results of the four car to car side tests are listed in a summarized form in the following tables.

Data of Cars (type VW-Golf / 2-door sedan)

test modes			test 1		test 2		test 3		test 4	
										
criteria			car 1	car 2	car 3	car 4	car 5	car 6	car 7	car 8
curb weight of car	m	(kg)	780	780	780	780	780	780	780	780
angle of impact	α	(deg)	0	90	0	90	-15	75	-15	75
impact velocity	V_i	(km/h	42,3	0	64,8	0	40,3	0	64,6	0
angular velocity *	$\dot{\alpha}$	(1/s)	0	0	0	0	0	-26	0	-32
change of velocity in x-direction	V_x	(km/h	24,7	0	39,6	0	22,5	4,3	39,7	0
change of velocity in y-direction	V_y	(km/h	0	23,6	0	33,7	0	18,7	0	34,9
maximum acceleration in x-direction **, ***	A_x	(g)	12	5	30	10	12	8	18	9
maximum acceleration in y-direction **, ***	A_y	(g)	-	16	-	27	-	12	-	18
maximum deformation outside of car	S_o	(mm)	90	265	278	490	88	345	260	345
maximum deformation inside of car	S_i	(mm)	-	210	-	460	-	335	-	275
maximum deformation inside at SR-point	S	(mm)	-	175	-	400	-	240	-	260
condition of doors (2-door sedan)	left		o.k.	jammed	o.k.	jammed	o.k.	jammed	o.k.	jammed
	right		o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.

* rotation seen from above: clockwise is positive

** acceleration data: A_{max} for $t \geq 3$ ms

*** x-direction is identical with vehicles longitudinal axis
y-direction is perpendicular to the vehicles longitudinal axis

Table 2: Car to car side collision - data of cars

Data of Occupants

For judgement of occupant loads 50-percentile dummies (according to US-Part 572) were positioned on the front seats of all cars. The impacted side of the rear seats of the struck car was occupied by an additional unrestrained dummy. All front seat dummies were restrained by a three point belt with automatic locking retractor.

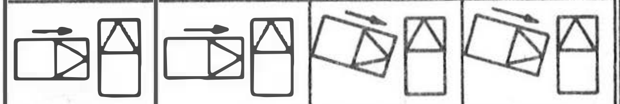
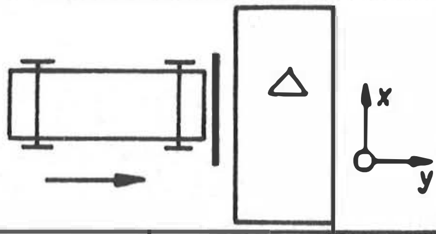
test modes						test 1		test 2		test 3		test 4	
													
criteria						car 1	car 2	car 3	car 4	car 5	car 6	car 7	car 8
occupants of impacted car	driver	head	Head Injury Criterium	HIC	-	-	76	-	142	-	48	-	332
			res. acceleration	A_{res}	(g)	-	27	-	40	-	25	-	48
		chest	Severity Index	SI	-	-	150	-	325	-	175	-	420
			res. acceleration	A_{res}	(g)	-	44	-	70	-	48	-	65
		pelvis	Severity Index	SI	-	-	325	-	770	-	460	-	910
			res. acceleration	A_{res}	(g)	-	56	-	100	-	80	-	95
	front passenger	head	Head Injury Criterium	HIC	-	-	51	-	335	-	44	-	280
			res. acceleration	A_{res}	(g)	-	28	-	95	-	16	-	50
		chest	Severity Index	SI	-	-	112	-	580	-	40	-	250
			res. acceleration	A_{res}	(g)	-	50	-	105	-	25	-	55
		pelvis	Severity Index	SI	-	-	70	-	270	-	75	-	170
			res. acceleration	A_{res}	(g)	-	35	-	70	-	30	-	54
	rear passenger	head	Head Injury Criterium	HIC	-	-	106	-	175	-	213	-	270
			res. acceleration	A_{res}	(g)	-	48	-	42	-	72	-	60
		chest	Severity Index	SI	-	-	30	-	162	-	38	-	75
			res. acceleration	A_{res}	(g)	-	15	-	55	-	20	-	25
		pelvis	Severity Index	SI	-	-	70	-	712	-	150	-	180
			res. acceleration	A_{res}	-	-	38	-	105	-	40	-	30
occupants of impacting car	driver	head	Head Injury Criterium	HIC	-	53	-	160	-	51	-	138	-
			res. acceleration	A_{res}	(g)	15	-	27	-	17	-	23	-
		chest	Severity Index	SI	-	-	-	112	-	37	-	105	-
			res. acceleration	A_{res}	(g)	18	-	23	-	18	-	20	-
		femur	force left	Fl	(kN)	0,6	-	1,8	-	1,0	-	1,2	-
			force right	Fr	(kN)	0,6	-	1,5	-	1,6	-	1,3	-
	front passenger	head	Head Injury Criterium	HIC	-	53	-	174	-	48	-	98	-
			res. acceleration	A_{res}	(g)	17	-	25	-	15	-	20	-
		chest	Severity Index	SI	-	50	-	75	-	35	-	60	-
			res. acceleration	A_{res}	(g)	17	-	25	-	16	-	17	-
		femur	force left	Fl	(kN)	0,6	-	1,1	-	1,1	-	1,3	-
			force right	Fr	(kN)	0,8	-	1,5	-	1,0	-	1,1	-

Table 3: Car to car side collision - data of occupants

Results of Series-production-cars (FMVSS 208)

According to the US-test procedure FMVSS 208 the following results have to be considered for a test with a production car:

21/5

car criteria 		
curb weight of car	m (kg)	895
angle of impact	α (deg.)	90°
impact velocity	v_i (km/h)	33,3
angular velocity	$\dot{\alpha}$ (1/s)	0
change of velocity in x-direction	Δv_x (km/h)	0
change of velocity in y-direction	Δv_y (km/h)	22,7
maximum acceleration in x-direction	a_x $(9{,}81\ \frac{m}{s^2})$	0
maximum acceleration in y-direction	a_y $(9{,}81\ \frac{m}{s^2})$	30
maximum deformation outside of car	s_o (mm)	122
maximum deformation inside of car	s_i (mm)	52
codition of doors	left door right door	o.k. o.k.

dummy criteria			driver	left rear passenger
head	head injury criterium	HIC -	397	219
	result. acceleration	$a_{res.}$ (g)	100	55
chest	severity index	SI -	650	200
	result. acceleration	$a_{res.}$ (g)	130	60
femur force	left	F_l (kN)	1,0	1,0
	right	F_r (kN)	1,0	1,0

Table 4: Results of lateral impact tests (FMVSS 208)

The test results show that the car data as well as occupant data differ strongly from the loads of that in a real road accident. In general the recorded data exeed the limits, given by FMVSS 208, due to the fact that the impact surface of the rigid barrier does not correspond to a vehicle's impact area. The barrier impact surface is comprised of a rigid front plate with a width of 1981,2 mm and a heigth of 1524 mm. As a result of the barrier dimensions the intrusion of the test car is reduced by more than 50 % as compared to a real accident. Therefore the occupant impact is given by one strong impact against the interior compartment. An occupant rebound is not present, as analysed in the real accidents with a secondary impact against vehicles interior.

Summarizing this test mode does not represent sufficient enough the processes, which have to be considered in real accidents.

Test Results from Experiments with ESVW's

The two tests described below demonstrate that effective occupant protection during a side collision can be achieved for extremely severe test conditions.

It has to be pointed out, that due to the lack of data the economic feasibility of the verified measures is not yet proven on the basis of benefit-/cost-considerations.

According to the two basic possibilities of the structure behaviour

- the side structure of the car (ESVW I) does not absorb energy during the side impact

- the side structure of the car (ESVW II) absorbs a tolerable amount of energy during the side impact

the following tests were selected.

Deformable, movable Barrier against ESVW I

The stationary ESVW I (m = 1410 kg) was impacted by the deformable, movable barrier (m = 2460 kg) with an impact speed of v_i = 52,7 km/h under an impact angle of 45° from behind in the middle of the driver's door. The maximum deformation of the compartment perpendicular to its longitudinal axis was only 60 mm.

The ESVW I was occupied by four 50-percentile male dummies (Sierra 292-1050).

The following table gives the results for the two dummies positioned on the impact side of the vehicle:

	Max. Resultant Acceleration (g)			HIC	SI
	Head	Chest	Pelvis	(Head)	(Chest)
Driver	13	12	10	20	20
Front Passenger	20	12	12	20	20
Rear Passenger	28	20	23	90	50

Table 5: Results of occupants ESVW I

Identical Car against ESVW II

The stationary ESVW II (m = 1118 kg) was impacted by a "identical car" with an impact speed of v_i = 51,1 km/h under an impact angle of 45° from the front in the middle of the passenger's door. The maximum deformation of the compartment perpendicular to the longitudinal axis was 190 mm.

The ESVW II was occupied by three 50-percentile male dummies (Sierra 292-1050).

The following table gives the results:

	Maxim. Resultant Acceleration (g)			HIC	SI
	Head	Chest	Pelvis	(Head)	(Chest)
Driver	22	13	19	50	30
Left Rear Passenger	20	18	5	50	40

Table 6: Results of occupants ESVW II

CONCLUSION

A realistic simulation of real world side impacts belongs to the most difficult problems of vehicle testing. Due to the fact that there is no considerable information for suitable test configurations, given by a useful accident analysis, there are various test modes possible.

A high importance for the accident performance is given in a wide range of possible impact angles (from 0° to 180°) as well as impact areas (near or far to the center of compartment).

The experience in measurement devices for tolerable biomechanical loads for frontal impacts, given by the dummies today, is not valid enough for that one in side collisions.

We recommend the following test procedure:

Impact with a movable non-deformable barrier, with a contoured impact surface which simulates an average car, and is directed with an impact angle of 90° with its longitudinal axis against the seat reference point of the front passenger of the stationary car.

The impact speed of the barrier should be less than 40 km/h. The barrier's mass should be selected, which corresponds to the statistical average car weight which is compatible with future legislation from countries advocating more significant safety requirements.

REFERENCES

(1) Bundesministerium für Forschung und Technologie
"Technologien für die Sicherheit im Straßenverkehr"
Bonn 1976

(2) Statistisches Bundesamt
"Statistisches Jahrbuch 1975"
Wiesbaden 1975

(3) Weissner, R.
"Bewertung und Erprobung von Gurtsystemen beim Frontalstoß"
Dissertation, TU Berlin 1976

(4) Seiffert, U.
"Probleme der Automobilsicherheit"
Dissertation, TU Berlin 1974

(5) Hartemann, F. et al
"Description of Lateral Impacts"
6th ESV-Conference 1976, Washington

(6) Danner, M.; Langwieder, K.
"Car/Vehicle Side Impacts - A Study of Accident Characteristics and Occupant Injuries"
6th ESV-Conference 1976, Washington