Car to car side collision - a comparison of accident analysis and research work.

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Abstract:

We have compiled results of side impacts with BMW-vehicles in accident analysis and research work typical of the situation in the Federal Republic of Germany. The damages on the vehicle and the injuries of the occupants involved describe the present state of knowledge obtained from the accident analysis which serves for a constructive dealing with the problem. A comparison accident analysis/crash-test is established by selected cases. The discussion of the results entails issues with regard to the development work on the subject of side impact protection.

Introduction:

On the occasion of the ESV-Conference 1976 two European publications (1, 2) on car/car side-collision were submitted, however, containing contradictory details. Correlations are to be discussed in a comparative accident investigation on 45 BMW-car to car side collision vehicles and tests carried out at BMWs and Calspans (3).
At the same time gaps of the accident analysis and the development targets of future activities are to be discussed. Only those car/car side collisions are taken into consideration which show vehicle damage between the pillars A and C (that means compartment). Vehicle collision with " fixed ocstacles "(for example trees) are not part of the comparison.

Results of the accident analysis

The relative frequency of car to car side-collision with the impact area of the compartment is listed up in fig . 1 under column "collision frequency and injury risk in side impacts".

The French readings show a total percentage of 72% with an injury risk of 78 %; the HUK accident analysis show a total percentage of 53% and an injury risk of 52 %. A BMW/HUK accident analysis of 45 cases especially dealing with the chosen car/car side-collision produce readings which are the average of these figures.

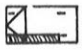
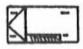
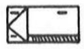
impact area / number of cases					total
France (1)	number of cases	29 %	29 %	14 %	72 %
	number of occupants	30 %	28 %	15 %	73 %
	severe and fatal injured	37,8 %	26,8 %	22 %	87,6 %
	injury-risk	26,5 %	20,6 %	32,1 %	78,1 %
Germany (2)	number of cases	13,3 %	32,9 %	7,1 %	53,3 %
	number of occupants	13,6 %	30,3 %	6,9 %	50,8 %
	severe and fatal injured	18,2 %	35 %	5,8 %	58,8 %
	injury-risk	20,2 %	18,3 %	13,2 %	52,4 %
BMW (4)	number of cases	13,3 %	46,7 %	8,2 %	68,2 %
	number of occupants	12,8 %	51,2 %	2,5 %	66,5 %
	severe and fatal injured	23 %	57 %	-	80 %
	injury-risk	30 %	22,5 %	-	52,5 %

fig. 1 - collision frequency and injury-risk in side- impacts

The accident analysis investigators have established a damage diagram of side impacts with the help of impact location and injury type of the occupants. According to fig . 2 the main deformations between pillar A and C can be identified near the H-point of the front seat row. The test results show that the level of deceleration does not depend on the exact position of the center line of the impacting vehicle, provided that this center line is located to the area near the H-point of the struck car.

The type of side impact treated in the analysis has been derived from figures (1 , 2 , 4).

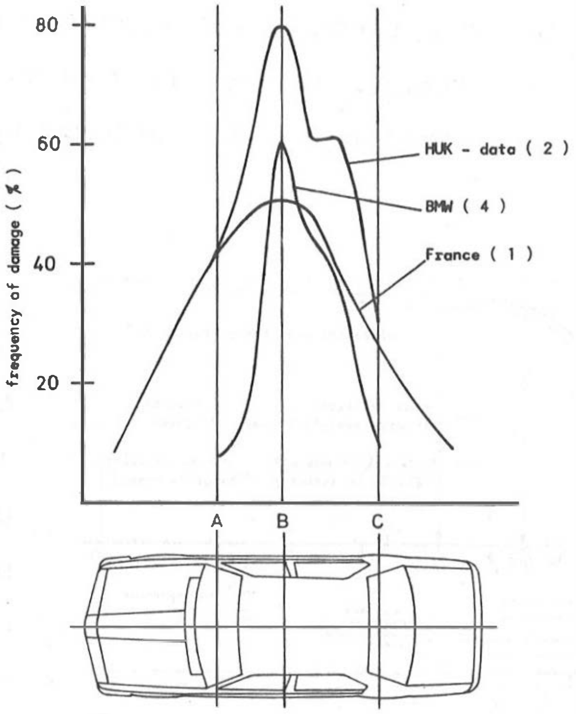


fig. 2 location of the main-deformation on the struck car

	Car/car	heavy truck	fixed obstacle	other obstacle
Peugeot/ Renault	66 %	8 %	16 %	10 %
HUK/Germany	65 %	5 - 7 %	------- 30 % ------	
BMW/HUK	90 %	5 %	------- 5 % ------	

+the BMW-cases are especially selected in cases with the impact area between pillar A and C .

fig . 3 - type of obstacles in side impacts

The car/car side-collision thus presents more than 65 % of all types of side impacts. The low percentage of car/truck collisions in the German statistics is striking. The mass ratio of the vehicles involved in the accidents is described in (1, 2, 4) and listed up in fig. 4 .

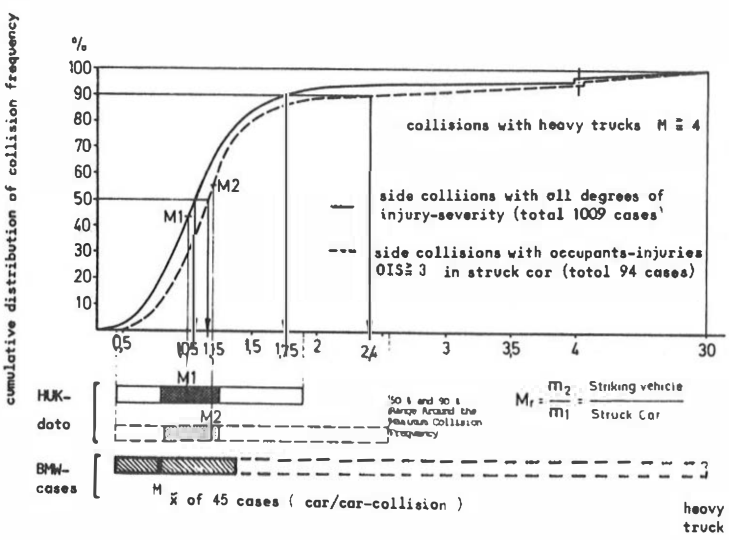


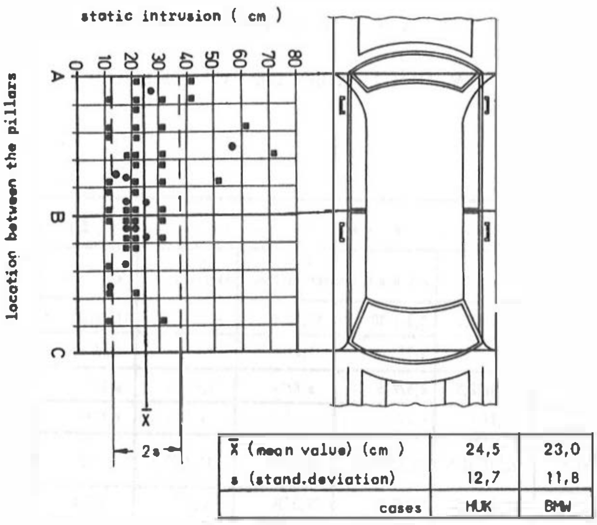
fig. 4 mass ratio in car/car-side impacts (copie of HUK - fig.)

The average mass ratio in car/car-side impacts seems to be in the range of M= o, 8 and M=1, 15 . The statements of the accident analysis become doubtful by the determination of the analysed impact speed of both the impacting and the struck vehicle. Despite ignoring the errors which each investigation team incorporates in the speed determination, the indicated figures in fig. 5 are to give a first, rough limitation of the speed range of side impacts. The estimated collision speed of side impacts is seperately derived from the test results and corrected in fig. 7 inside the plane of accidents.

	0-15 km/h	16-30 km/h	31-45 km/h	46-60 km/h	total %
HUK (2)	19, 9	36, 4	26, 4	12, 9	95, 6
BMW/HUK HUK (4)	9, 5	42, 8	40, 0	4, 8	97, 1
France + (1)	5, 0	45, 0	35, 0	10, 0	95, 0
+ these figures are converted to the HUK indication					

fig. 5 - range of the estimated impact speed/results of the teams

Another statement of the accident analysis is the maximum intrusion into the side panel of the struck car . fig. 6 .



$\bar{X}$ (mean value) (cm)	24,5	23,0
s (stand.deviation)	12,7	11,8
cases	HUK	BMW

fig. 6 static intrusion of 90° - side impacts

The impact energy analysed by the investigation team is calculated from the mass ratio and the estimated speed and is plotted against the intrusion depth. fig. 7 .

A wide tolerance range reveals the flaws of the accident analysis and the difficulty of determining the influence of the moving struck car. In (1, 2, 4) the impact speed of the occupant on the intruding panel of the compartment is indicated as a reason for the severity of the occupants` injuries.

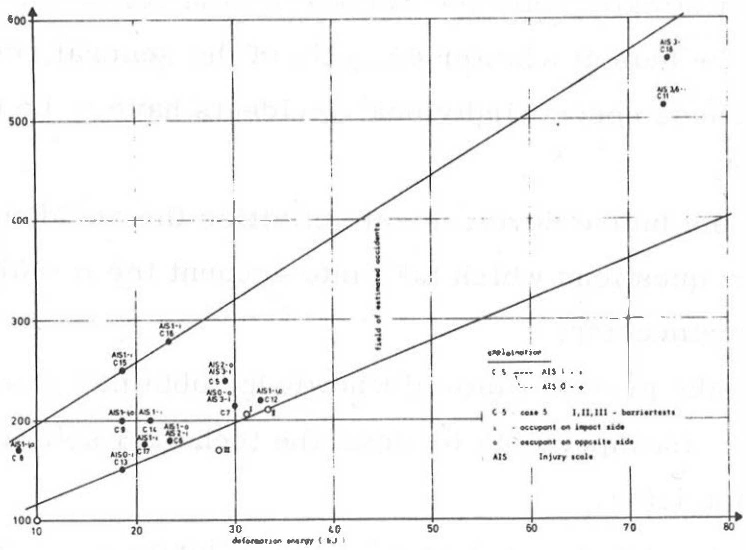


fig. 7 - classification of bmw-accidents and crashtests

The injury risk for individual parts of the human body is described almost concurrently. From fig. 8 , 9 an injury risk can be determined in the sequence head , chest , pelvis , upper and lower extremities. In (1, 2) only few details are given in the description of the injuries. These indications allow concrete development work only to a limited degree.

driver / front passanger HUK / BMW		injured body area of the occupants (%)						
		AIS	Head	Chest	abdomen	upper extremities	lower extremities	spine
impact side (826 / 40 occupants)	injury severety	1	43,6/27,5	17,5/17,5	8,3 / 10	45,8/55	29,5/22,5	17,7/20
		2	5,7/5,0	2,9/2,5	o,1/ -	4,6/ -	1,2 / -	2,o/ -
		3 - 5	2,0/2,5	1,8/12,5	2,6/2,5	o,8/ -	1,0 / -	o,3/ -
		6	1,1/2,5	o,7/ -	o,7/ -	- / -	- / -	o,1/ -
	injury-frequency		52,4/37,5	22,9/ 32,5	11,7/12,5	51,2/55	31,7/22,5	20,1/20
opposite side (608/29 occupants)	injury severity	1	36,4/37,9	15,2/1o,3	5,3/3,4	39,3/34	37,6/41	14,0/3,4
		2	7,3/6,8	2,2/ -	o,4/ -	3,0/ -	2,6/ -	1,5/3,4
		3 - 5	1,5/6,8	o,7/ -	o,7/ -	1,1/ -	o,2/ -	o,4/ -
		6	o,6/ -	- / -	- / -	- / -	- / -	-/ -
	injury-frequency		45,8/51,7	18,1/1o,3	6,4/3,4	43,4/3,4	40,4/41	15,9/6,8

fig.8 injuries on the humon-body frequent to AIS

Conclusion of the results of accident analysis :

A statistically relevant number of side collisions must be selected with the help of a better analysis of the general accident characteristics. These special individual accidents have to be thoroughly evaluated.

For the future development activities the accident analysis has to answer questions which take into account the possibilities of testing engineering.

With the present state of knowledge obtained from the accident analysis it is impossible to describe technical solutions by the investigation team.

The description of the occupants` injuries must be improved. The injury mechanism of side impacts has to be elaborated in a biomechanical research program and compared to the results of the accident analysis.

Only by a fleet test of standard vehicles - modified by new technical solutions - a future accident analysis can determine whether there is any improvement of damage pattern in comparison to a benefit/cost - investigation.

Injury severity / type of lesion		AIS 1		AIS 2		AIS 3		AIS 3		total
		Imp. side	Opp. side	Imp. side	Opp. side	Imp. side	Opp. side	Imp. side	Opp. side	
HEAD	skull dislocation	o				o				
	extensive laceration	o		16	8	o				45
	eye injury	o			1	o				1
	face fracture			4	4	o 5				16
	skull fracture			1				7	2	10
	celebral injury	o	o	23	19	8	6	3	1	60
	face dislocation	o	o							
SPINE	severe whiplash injury			13	7					20
	nerve root damage			2						2
	cervical spine fracture								1	1
	thoracal spine fracture			1				1		2
	lumbar spine dislocation	o		1			1			2
	lumbar spine fracture			1			1			2
THORAX	chest dislocation	o	o							
	effusion of blood in the chest area	o								
	fracture 1/2 ribs			18	8					26
	fracture 3/4 ribs					1	3			4
	fracture more than 4 ribs					o 13	3			16
	sternum fracture				1					1
	intra thoracic injury					2	2	2		4
ABDOMEN/PELVIS	pelvis dislocation		o							
	effusion of blood in the pelvis area	o								
	pelvis fracture					16	1			17
	sacro-illac fracture					o 2				2
	hip-joint fracture					4	2			6
	intro-duminal injury			1	1			1	1	4
UPPER EXTREMITIES	extensive laceration	o		2						2
	shoulder dislocation	o		3	3	1				7
	shoulder fracture			4	2	1				7
	clavicle fracture			14		1	2			17
	humerus fracture			1	1	2	1			5
	forearm fracture			5	2		1			8
	hand fracture			2	1		2			5
	forearm dislocation	o								
LOWER EXTREMITIES	extensive laceration	o			5					5
	dislocations	o	o	5	4	o				9
	femoral fracture			1	1	4				6
	patella fracture				1					1
	fibula/tibia fracture			1	1	2	1			5
	foot fracture			1	1	1				3
	knee dislocation	o				o				

fig. 9 - injuries of the head, chest and abdomen (HUK - data , o - BMW cases)

Test results on side impact protection

BMW-tests and tests according to (3) served for evaluation purposes. The testing conditions comply with the requirements according to the US-standard FMVSS 208 and the safety-standard ECE/w/Trans/WP29/463. The tests were run as barrier/car and car/car test and are compiled in fig . 13 . The speed variations are indicated for the striking vehicles. The two vehicles involved in the tests have a mass ratio approximately M = 1,0 ..The speed range of the impacting vehicles is between v = 9,2 and 23,4 m/s . The barriers comply with the requirements according to SAE 972 a , ISO/TC22/SC10/N105 and ECE/W/Trans/WP29/463 .(v = impact velocity)

In the head , chest and pelvis the dummy readings are tridimensionally recorded. The dummy chest-acceleration of a 90^{o}- barrier crashtest on a conventional BMW-vehicle are indicated in fig. 10 . In fig. 11 , 12 a comparable 90^{o} - side impact on BMW - vehicles is shown as car/car test at v = 12 m/s and 18 m/s . The measuring values and statements obtained in various side impact tests indicated under (3) have been added and listed up in fig. 13 . In the BMW-tests with a barrier mass of 1100 and 1800 kg typical acceleration curves have been determined in the 90^{o} side impact for the dummys` head, chest and pelvis. The mean value of accelerations for a characteristic period of time and the peak value of accelerations have a limited level. Compared to the barrier impact a reduced acceleration has been measured in the car/car test at v = 11 m/s . Only in a car/car test at v = 18 m/s the dummy acceleration becomes critical.

(reference : a critical level is related to the injury criteria according to FMVVSS 208 and scientific statements)

In the test program of Calspan (3) vehicles of conventional design, vehicles with modified structure and laminated glass on the side and

vehicles with modified structure, glass and interior have been thoroughly checked. The vehicles have been impacted at 90° and 60°. The struck vehicle was both stationary and in moving condition.
From the summary of all test results - including tests on details - mentioned under fig. 13 the following conclusions can be made :

1. in several tests with mobile barrier a scattering range is given for the acceleration values of the dummies,
2. with similar vehicle deformation the standardized barrier-side impact shows higher acceleration values on the dummy than a car/car-90° side impact at "v" less than 11 m/s ,
3. the 90° car/car side impact at v = 18 m/s shows critical values at the dummys` head , chest and pelvis,
4. the car/car test (according to 3) at v = 13 m/s and 18 m/s shows that critical accelerations can only be determined on the the dummy at v = 18 m/s,
5. the critical level of accelerations is a function of the impact history of the dummy on rigid parts of the compartment,
6. the values in fig. 12 are comparable, consequently , in fig. 13 the resultant chest accelerations of BMW and Calspan tests are compared with each other,
7. the test series in the car/car test (3) at v = 18 m/s shows that better dummy values can be obtained by means of a modified structure, laminated glass and modified interior,
8. with v = 23, 4 m/s these side protection measures become insufficient and the dummy accelerations critical,
9. in a car/car test at 60° and v = 13 m/s , the dummy accelerations are lower than in the 90° test,
10. the 60 ° barrier impact , especially of the moving, struck vehicle leads to high acceleration values on the dummy,
11. fig. 14 shows construtive modifications on vehicles as an effect

on the chest acceleration of the dummy in the individual test stages of the Calspan program :

a. in the 90^{o} car/car test improvements are obtained by means of a modified structure and a modified interior despite a test-speed increase to v = 17 m/s ,

b. only with a structure modification and at an impact speed of v = 17 m/s improvements on the dummy cannot be achieved in the 90^{o} car/car test,

c. in the 60^{o} barrier test with v = 13 m/s better dummy acceleration values can only be achieved by means of a modified structure,

d. as expected,in the 60^{o} barrier test with v = 13 m/s substantially improved dummy accelerations can be measured provided that interior and structure are modified.

		Test 1-6	Test 7	Test 8	Col.-1	Col.-2	Col.-5	Col.-8	Col.-9	Col.-12	Col.-3	Col.-10	Col.-6	Col.-11	Col.-4	Col.-7
head	HIC	56-240	75	242	28	50	130	306	70	170	65	46	215	101	78	86
	occ,y-dir.(60ms)	18-32 g	7,1 g	18,3 g												
	occ.resvlt.(3ms)	30-57 g	22g	65 g	15g	35 g	39g	56g	25g	40 g	30g	30g	55g	36g	34g	30g
	contact	dummies	dummies	dummies												
chest	SI	130-335	70	910	-	-	-	-	-	-	-	-	-	-	-	-
	occ.y-dir.(33ms)	19-30 g	12g	28 g	26,8g		27g	29g	20,4g	-	21,7g	18,7g	30g	25g	-	-
	occ.result.(3ms)	48-83 g	46g	88 g	35 g	20g	45g	73g	31g	75g	44g	31g	64g	44g	2og	61g
	contact	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	interior convent.	x	x	x	x	x	x	x	-	-	x	x	x	-	x	x
	interior modified							-	x	x	-	-	-	x	-	-
pelvis	SI	160-350	100	800-1000	-	-	-	-	-	-	-	-	-	-	-	-
	occ.y-dir.(42ms)	15-23 g	11 g	41 g				-	-	-	-	-	-	-	-	-
	occ.result.(3ms)	36-60 g	42 g	114 g	30 g	29 g	86 g	66g	50g	108g	30g	30g	56g	50g	32g	37g
car	angle of impact	90°	90 0	90°	90°	90°	90°	90°	90°	90°	90°	60°	60°	60°	60°	60°
	ratio of mass	1,o5	1,o	1,o	1,o5	1,o5	1,o5	1,o5	1,o5	1,o5	1,o5	1,o5	1,o5	1,o5	1,o5	1,o5
	impactvelocity	up to 11	9,2 m/s	18 m/s	13,1m/s	13,4m/s	17,8m/s	17,4	17,4	22,5 m/s	13,4m/s	13,3 m/s	13,4m/s	13,4m/s	13,4m/s	13,4m/s
	impacting car	barrier	car	car	car	car	car	car	car	car	car	car	barrier	barrier	car	barrier
car	struck car	standing	standing	standing	standing	driving	standing	stand.	standing	standing	standing	standing	standing	standing	driving	driving
	convent.struct.	BMW	BMW	BMW	FORD	FORD	FORD	FORD	FORD	FORD	FORD	FORD	FORD	FORD	FORD	FORD
	modified structure	-	-	-	-	-	-	x	x	x	-	x	x	x	-	-
	modified glass	-	-	-	-	-	-	x	x	x	-	x	-	x	-	-
	max.static int-intrusion(mm)	220	220	390	240	172	375	220	203	314	508	165	287	187	363	226

fig. 13 - list of crashtests and dummy-data (BMW , Calspan)

Attachment:

page 12 - fig. 10 , 11 , 12 - crash diagrams
page 13 - fig. 14 , 15 - chest acceleration in crashtests

General Summary :

The accident analysis should be revised in order to give a better description of the typical side impact. The biomechanical research should elaborate fundamental statements for the injuries determined by the accident analysis.

As far as the angular impact is concerned improvements of the side structure should be investigated by the constructive elaboration of the problem of side impact protection. In order to reduce the dummys' acceleration levels constructive solutions for glazing and padding should be examined. The efficiency of the solutions achieved can only be estimated by the acceleration level of test dummies.

The benefit of a side protection system in future vehicles can only be tested in actual road traffic conditions.

The standardized side impact procedure according to the safety standards of NHTSA and ECE at test speeds up to 11 m/s seems to simulate the road accident (side impacts) in a sufficient way.

As a matter of fact, research work requires test speeds from 11 m/s up to 18 m/s. For a scientific research work within the scope of European activities it is surely useful to take into account the experiences of the Calspan test program (3) .

References:

(1) Occupant protection in lateral impact - ESV-Conference , 10/76
F. Hartemann , C. Thomas , J. Y. Foret-Bruno , C. Henry , A. Fayon , C. Tarriere (Lab. Renault-Peugeot)

(2) Car/car side impacts - a study of accident characteristics and occupant injuries - ESV-Conference , 10/76
M. Danner , K. Langwieder (HUK - Germany)

(3) Occupant survivability in lateral collisions (Vol. 1)PB 250 410, 1/76 , Calspan Corporation (prepared for NHTSA)
J. E. Greene

(4) Internal data of BMW

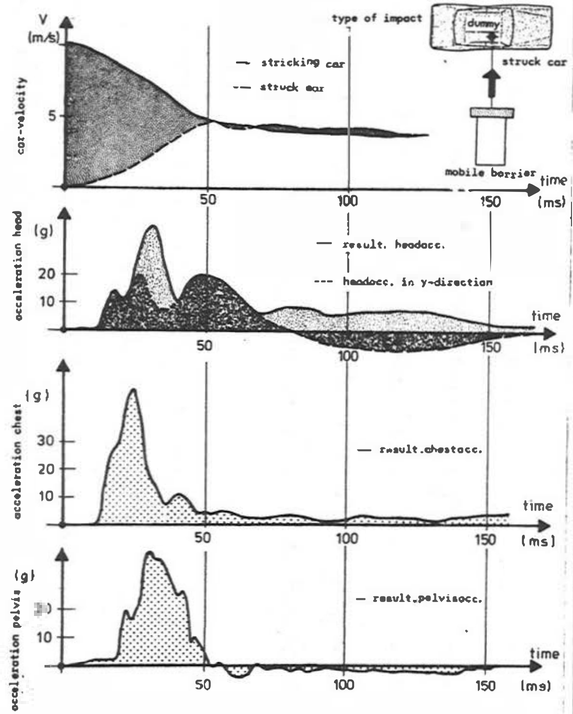


fig. 10 - barrier-test , v=10,2m/s conventional BMW

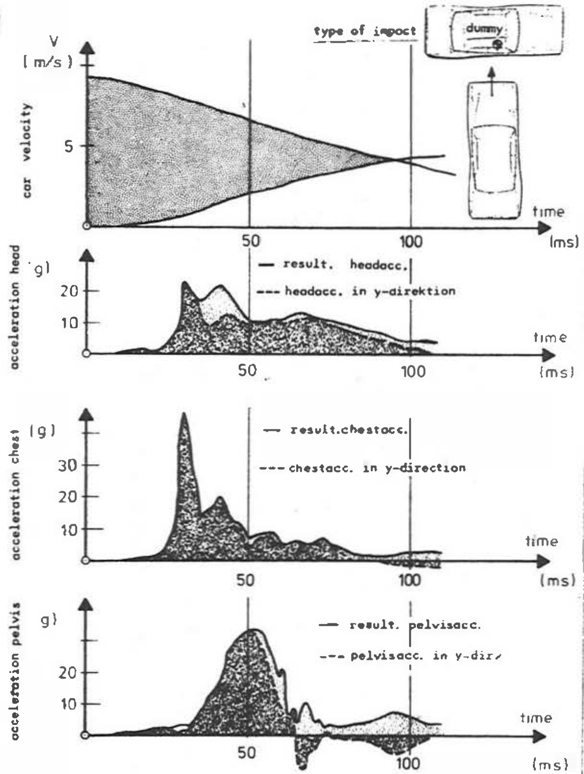


fig. 11- car/car , v = 9,25 m/s conventional BMWs`

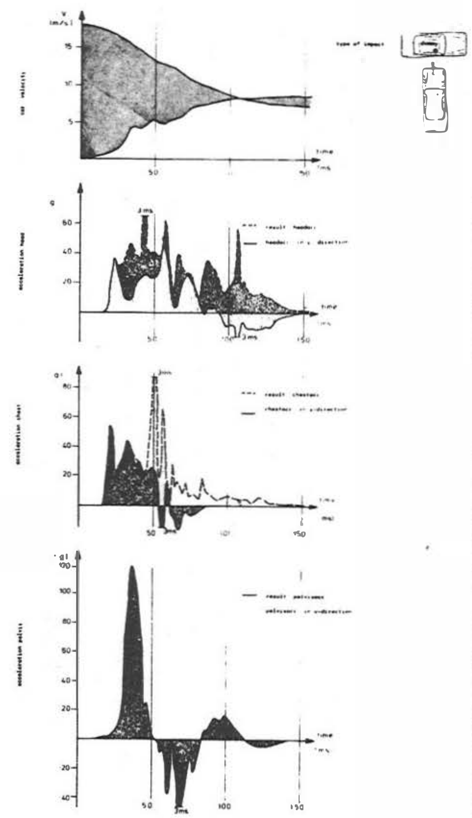


fig. 12- car/car , v= 18 m/s conventional BMWs`

fig. 10, 11, 12 - crash diagram of selected crashtests / side impact , impact angle = 90°

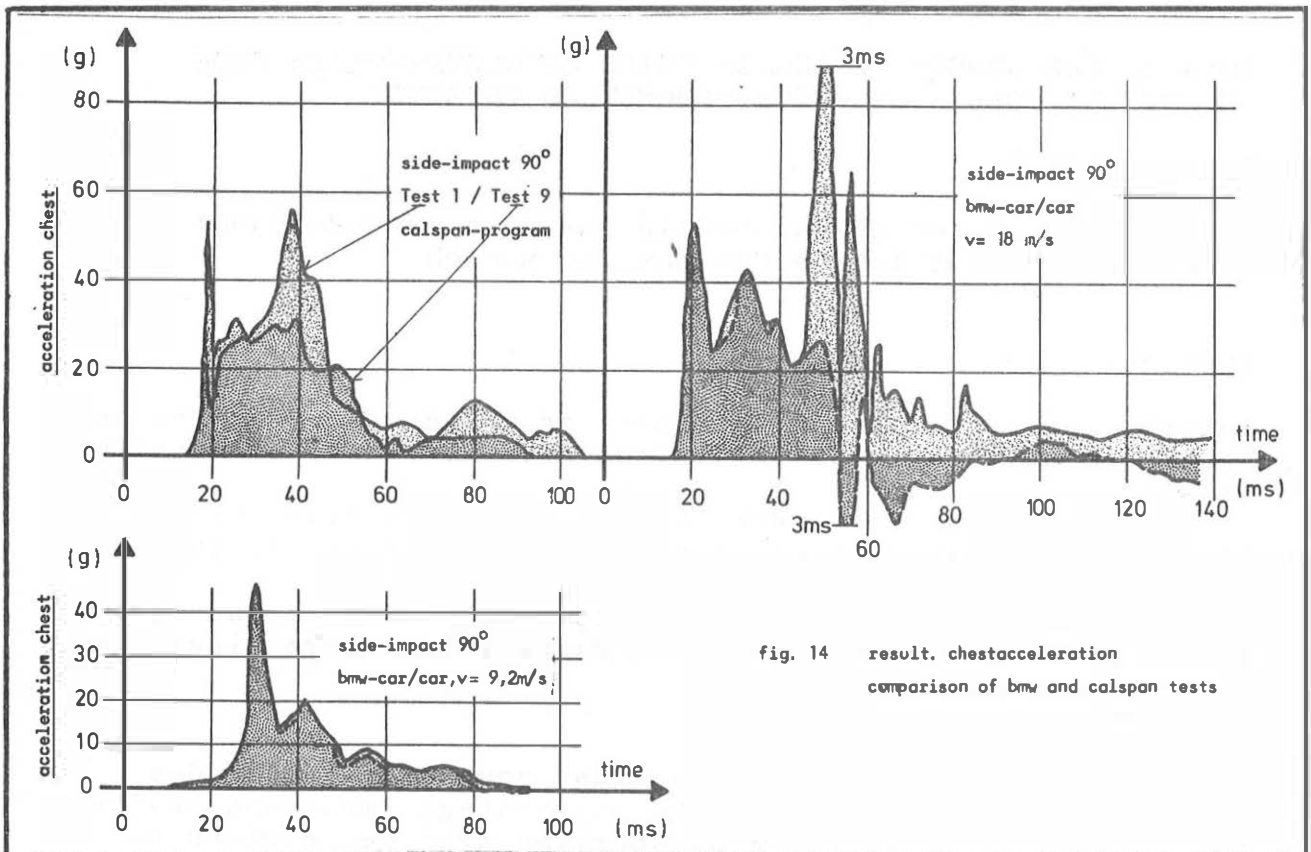


fig. 14 result. chestacceleration
comparison of bmw and calspan tests

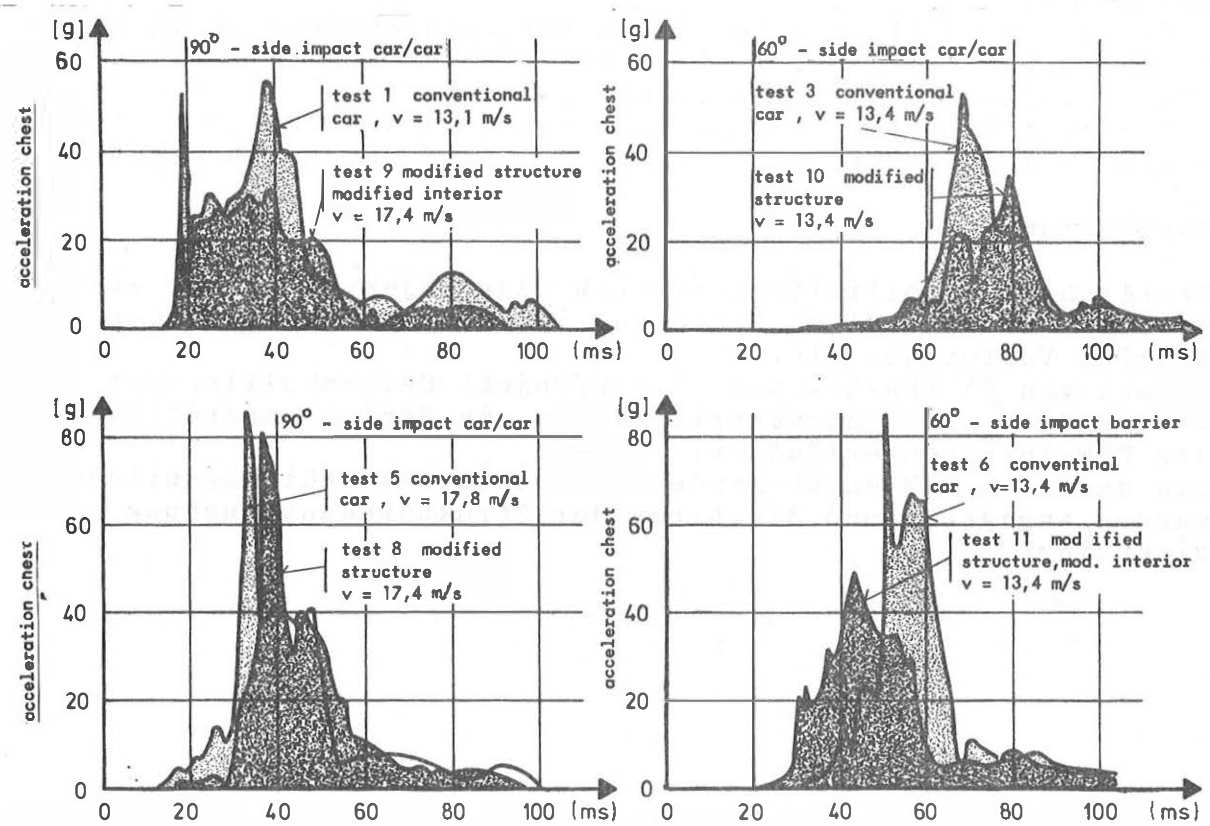


fig. 15 result. chestacceleration in the calspan - research program
variations: type of crash, structure , interior of struck cars