REDUCTION OF MUTUALLY DEPENDENT RISK OF INJURIES IN MULTIPLY OCCUPATED PASSENGER CARS BY DESIGN RELATED MODIFICATIONS OF THE COMPARTMENT

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INTRODUCTION

Today an increase in the average occupation rate of passenger cars, a.g. > 1.8 persons per car, can be noted. This development originated with increased fuel costs for motor vehicles and also from the government-encouraged "car-pooling". As about 15 % of all passengers are sitting on the rear seats, most of them seem to have a modest acceptance of safety belts. In new cars, for which rear belt fitting is compulsary in Germany (since May 1979), the rate of belted rear seat passengers is roughly estimated at about 20 %. One of the reasons for the different rates established for the front and rear seats can be seen in the safety of seat backs, that is supposed to be sufficient. This however cannot be confirmed in this respect.

From single in-depth analysis data of accidents and some scarce literature sources the existance of a risk of severe additional injuries for belted and unbelted passengers is generally known [1,2,3]. The interaction-related additional loads to testdummies are specified up to about 100 % [4].

The increasing figures of occupants, which are also involved in the real-life accident scene, require that interaction-related injuries, always combined with basic injury scatters, must be in our view in future und have to be investigated in detail.

As it will be demonstrated by the results of this study, the use of safety belts can no longer be considered as an individual risk taking of each of the passengers on the different seating positions. Moreover , it could be proved that by means of certain modifications interaction effects and loads can be restrained, even if the present rear safety belt is neglected.

METHODS

The first step of this investigation was to evaluate the kinematic and kinetic phenomena between two 50 % male (Hybrid II) testdummies one sitting behind the other. The aim was to obtain an up-to-date standard of interaction in representative car types.

Therefore a number of at least three up to five sled tests for each test configuration with completely fitted passenger compartments was conducted in the crash test facilities of TÜV Rheinland. With the belted frontal and unbelted rear seat passengers the directions of impact were longitudinal and 15° angled frontally and rearside. According to results from fullscale crash tests by the Federal Highway Research Institute (BASt), Cologne [5], the equivalent test velocities for the sled tests were fixed at 5,8; 8,9; 11,6; 12,6 m/s for the frontal and 5,8; 11,5 m/s for the rearside impacts. So the comparability of results from fullscale and sled tests could be studied.

The second aim was to modify certain interior components of the restraint system where failure and interaction-intensifying behaviour had been observed before. In repetition of the complete test series under the same condition, the influence of the modifications was to be evaluated. Under this study the efficiency of these modifications had to be assessed by means of a cost/benefit-quotient, oriented to the scale of human injuries (AIS) and projected to the real-life accident scene.

RESULTS

To evaluate to day's standard of interaction-related additional dummy loads, a total of 40 sled tests in this series was carried out . The kinematic phenomena of dummy movement can be characterized generally by reverse directed motions of adjoined body parts i.e. the skulls of both dummies, the femurs of the rear passenger and the back of the belted front seat passenger. In the lower limit range at a test velocity of 5,8 m/s equivalent to 30 km/h interaction starts with purely single contacts without any additional loads and extends to multiple mutually dependent body impacts with additional loads comparable to the basic stress, although those impacts can be more or less damped by the structures of the seat back and the head rest.

The main interaction-intensifying effects of failure of interior components were as follows:

- Impact of knees to the back of the front seat passenger, damped only by the upholstery of the seat back

- Break of the front seat adjusting device and the joint of the seat back frame

- Vertical dislocation of the head restraint and direct facial/dorsal impact of skulls.

In the measurement data curves mutually dependent dummy loads are characterized by coincident but reverse directed peaks of load measured in adjoined body parts of both dummies at distinct points of time. Fig. 1 serves as an example. Moreover, in belt forces interaction produces a typical isolated second peak value of force that intensifies the first with increasing test velocity and that stands for additional compressive thoracic loads of the front occupant.

Based on the results obtained from comparative tests with hindered interaction by belting the rear occupant, to day's standard of interaction-related dummy loads can be summarized as follows:

+ 85 % additional head load (HIC = 416 ± 70)

+ 65 % additional chest load (SI = 257 ± 93)

for the belted front occupant in frontal impacts at a test velocity of 11,6 m/s equivalent to 60 km/h.

Disregarding the rear safety belts under the same test conditions the rear passenger is exposed to

+ 150 % additional head load (HIC= 694 ± 88)

+ 100 % additional chest load (SI= 249 ± 42), Fig. 2.

From evaluation of the different kinds of failure certain modifications of the interior restraint components were derived.

The most effective method to uncouple the movements of the rear and front seat dummies and so to hinder interaction, was to block the longitudinal seat adjuster and to stiffen the joint of the seat back for experimental purposes by means of a special deceleration device, joined to the upper seat back frame and braced to the body of the compartment. In the knee impact zone between the two shafts of the seat back frame a deformable perforated sheet has been installed, and the head restraint has been broadened laterally. Moreover, in the potential zone of head impacts another deformation device from perforated sheet was fixed surrounding the b-pillar and the rear seat has been fitted with a head restraint.

With additional upholsteries in these impact zones a series of another 45 sled tests under identical test conditions but with modified restraint components of the compartment was conducted. The mean values and standard deviations of the measured dummy loads are plotted in the tables - on the one hand for the standard model - and on the other hand for the modified compartment.

From the figures it can be seen that the relief of dummy loads for the frontal occupants by means of reduced or hindered interaction is considerable while for the unbelted rear occupants an additional overload still has to be accepted , see Fig. 3.

Some additional tests with advanced modifications allow to draw the conclusion that the standard level of the rear seat dummy loads is actually within reach with some further investigation work.

Nevertheless, the efficiency of the rear seat safety belt is far from being replaced by the modified components.

The third aim of this investigation was to assess the efficiency of the tested modifications by means of a cost/benefit-quotient.

The costs for one modification set, essentially the reinforced front seat, were determined at 30,-- DM per life period of a car. The costs for the 21.6 million passenger cars in Germany that would have to be fitted with the modification packs, were calculated at an annually total of 104 million DM, including the additional fuel consumption costs.

The benefit to the economy was established on the basis of the frontal collisions with those real-life accidents being considered in which unrestrained occupants are sitting on the rear seats and cause additional injuries to belted front seat passengers.

By applying a correlation model of dummy loads and the severity scale of human injuries [6,7] and considering frequencies of impact velocities [8] from an average injury grade of $\overline{OAIS}$ = 3,2 a reduction by $\Delta\overline{OAIS}$ = 1,4 by means of the modification model seems [9] to be in reach. By this, the interpolated potential cost of about 42.000,-- DM for each person severly injured in this types of accident can be exploited, Fig. 4.

Projected to 3300 severly injured frontal occupants per year in such a configuration that at least one unrestrained passenger is sitting in the rear, the reduction of costs to the benefit of the economy can be calculated at 140 million DM.

As the benefit of the modifications for the other types of collisions has not yet been proved, but can be supposed, the cost/benefit-quotient Q = 0,7 calculated as described above seems to be the higher threshold value.

CONCLUSION

As long as seat belt wearing is not compulsary for each seating position, interaction-related additional loads and increased severity of injuries have to be considered. As the different kinds of injuries are superimposed, the distinct scatters of interaction-caused injuries in real-life accidents are difficult to analyze.

By means of crash tests with dummies it could be demonstrated that through straightforward modifications, especially at the front seat, an improved safety standard for the occupants can be realized.

The next step will be to test the influence of these modifications also in other types of collisions. Moreover, it has to be made sure, that the favourable cost/benefit-quotient will foster the further development of integrated restraint systems and their testing procedures.

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equiv. test velocity / passenger compartment / Dummy seating position		frontal collision				rear collision			
		head load (HIC)		chest load (SI)		head load (HIC)		chest load (SI)	
		front	rear	front	rear	front	rear	front	rear
5,8 m/s	standard-model	61 ± 18	148 ± 162	72 ± 19	15 ± 9	24 ± 9	40 ± 5	28 ± 8	25 ± 5
	modified model	52 ± 12	214 ± 38	66 ± 11	31 ± 11	35 ± 12	36 ± 11	23 ± 4	22 ± 3
8,9 m/s	standard-model	238 ± 59	348 ± 143	164 ± 22	72 ± 14				
	modified model	187 ± 64	461 ± 149	138 ± 17	225 ± 57				
11,6 (11,5) m/s	standard-model	416 ± 70	694 ± 88	257 ± 93	249 ± 42	189 ± 113	243 ± 134	188 ± 62	98 ± 36
	modified model	300 ± 111	949 ± 196	171 ± 20	590 ± 53	133 ± 35	102 ± 12	98 ± 13	81 ± 8
12,6 m/s	standard model	540 ± 74	878 ± 433	260 ± 85	428 ± 170				
	modified model	291 ± 73	1034 ± 133	165 ± 20	874 ± 211				

Mean values and standard deviations of the most important dummy loads in the standard model and modified passenger compartment in oblique frontal and rear collisions.

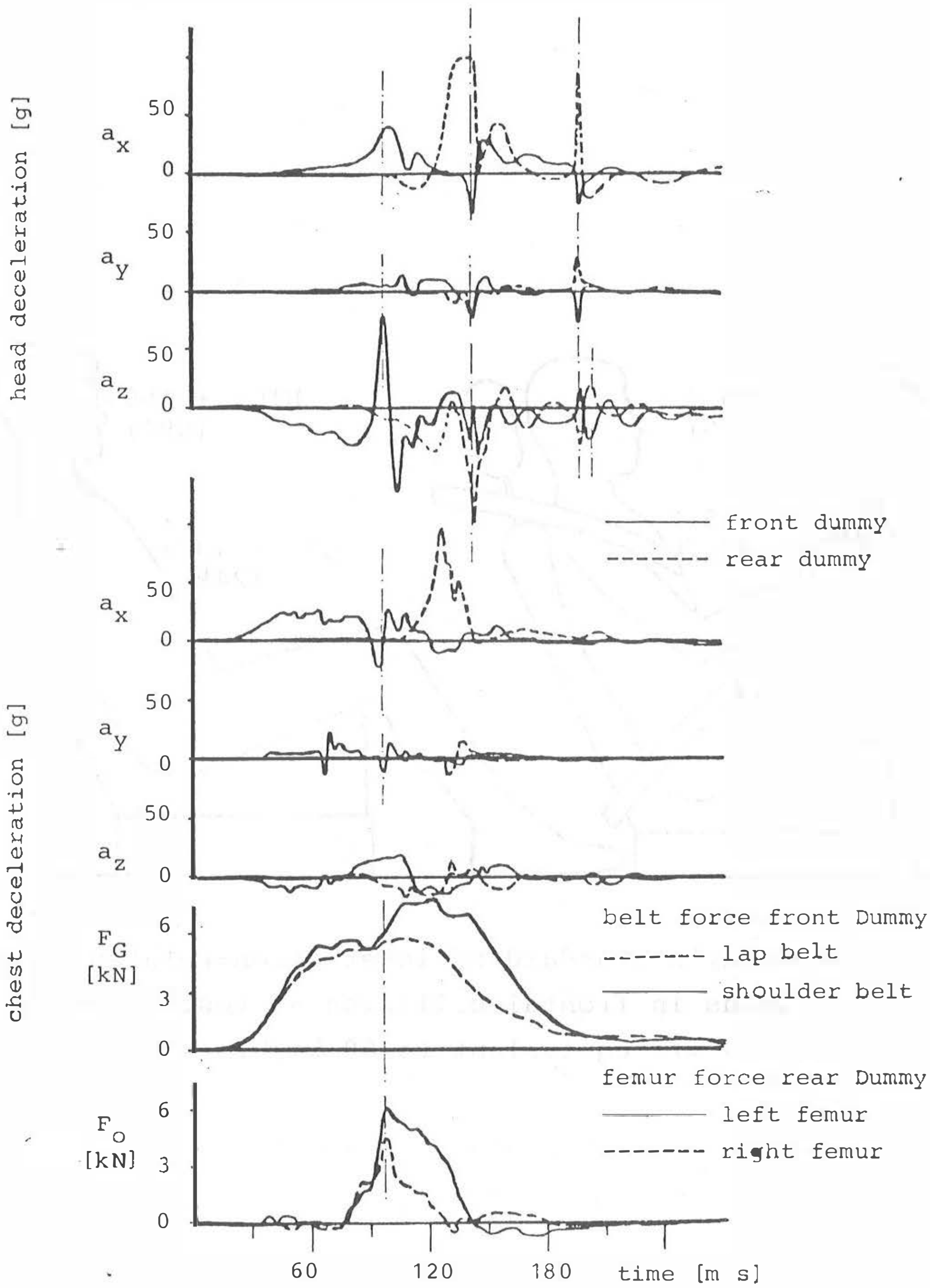

Fig. 1: Interactions between belted frontal and unbelted rear passenger dummies in deceleration curves of head and chest and in belt and femur forces, frontal collision at test velocity 12.6 m/s equivalent to 70 km/h.

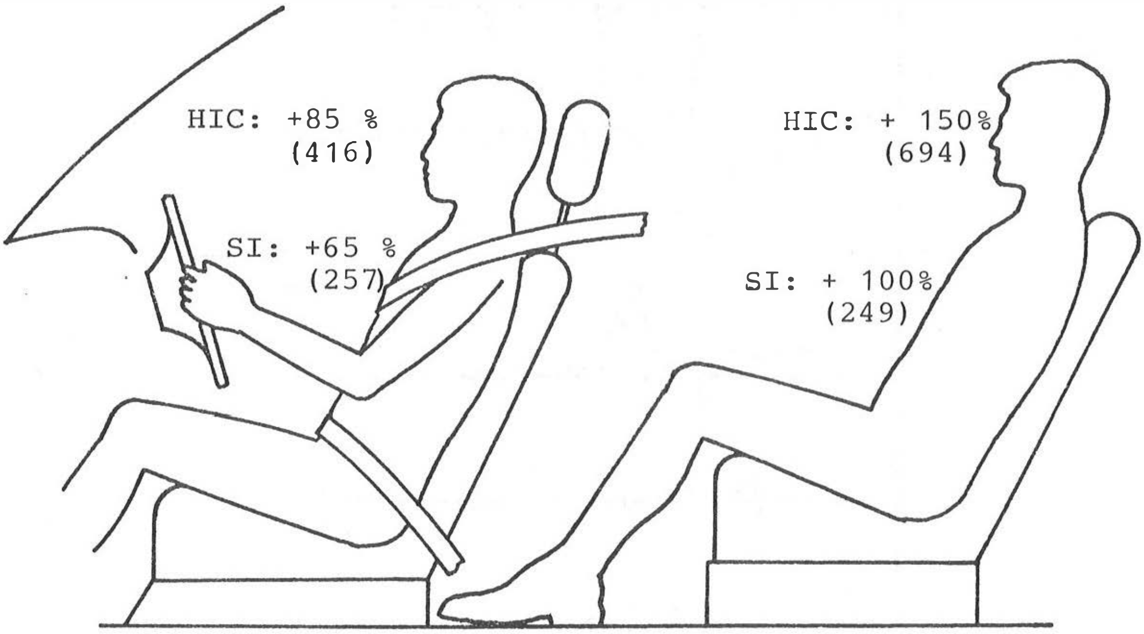

Fig. 2: Today's standard of interaction-related dummy loads in frontal collision at test velocity 11.6 m/s equivalent to 60 km/h.

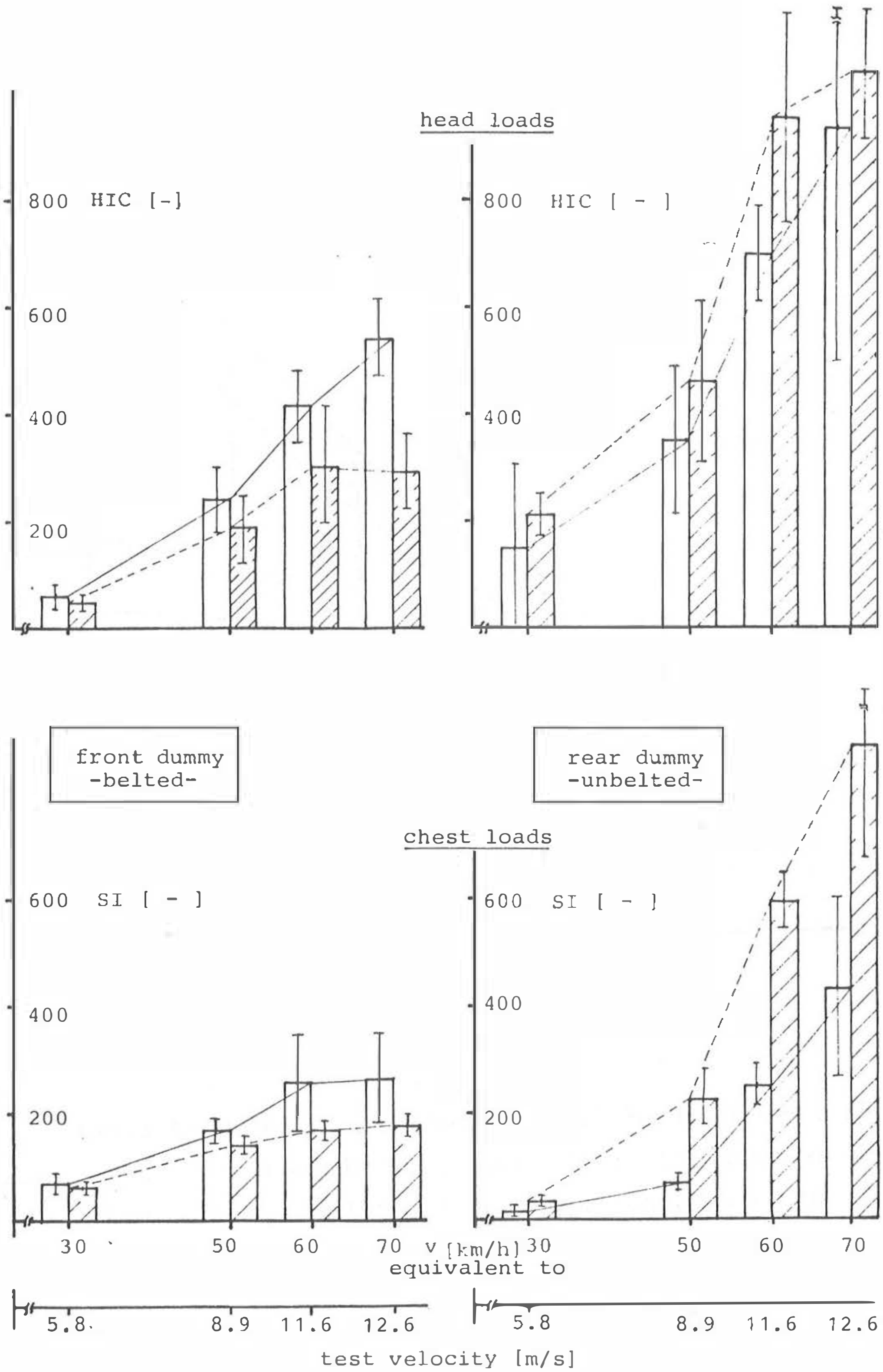

Fig. 3: Mean values and standard deviations of dummy loads in head (HIC) and chest (SI) in the standard model [ ] and modified [hatched] passenger compartment in oblique frontal (0,15°) collisions.

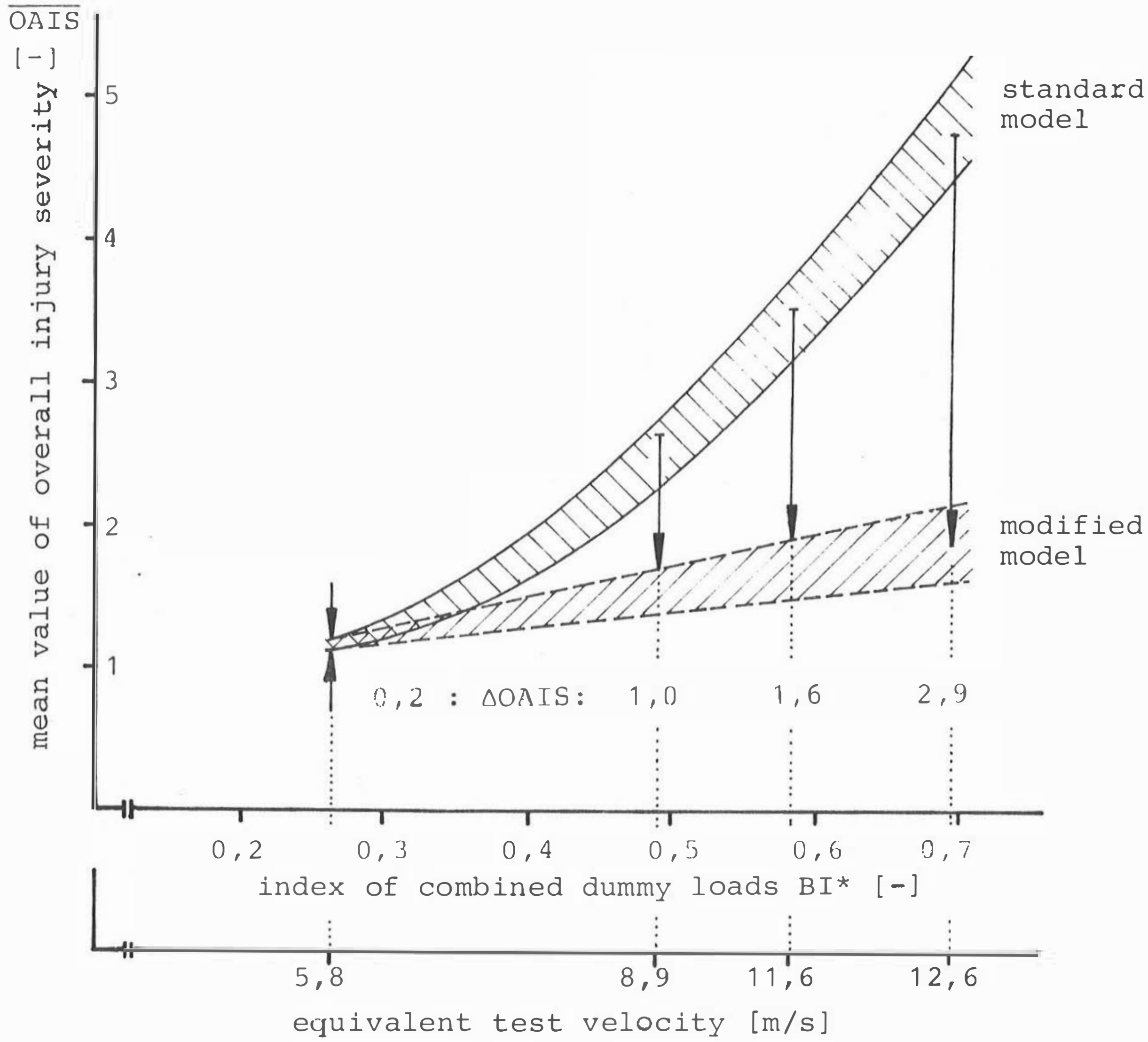

Fig. 4: Potential of injury reduction of belted front passengers in frontal collisions by modifications of the compartment as a function of the index of combined dummy loads.