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Safety Criteria System: An Opportunity of Focussing Different Dummy Loading Values to a Single Expression

Abstract

The degrees of injury severity, as a rule injuries scaled by AIS of specific regions of the human body, investigated out of road traffic accidents correspond to the body-specific loading values, which are found out with the aid of experimental or mathematical simulation of crash tests with motor vehicles or with sled tests. The coherence between the injured human being on the one hand and the physical and the theoretical model respectively on the other hand is established by the risk function, which describes the probability of degrees of injury severity in dependence on the protection criteria. Due to the different physical characteristics in the simulation, e.g. accelerations, forces, compressions and their velocity, the compilation of these quantities, comparable to the MAIS, the maximal occurred single AIS obtained in accident analysis is much more difficult in the simulation than in the accident occurrence. Therefore it is obvious to normalize the loading values gained out of simulation and to summarise them to an entire value in a suitable manner, the safety index.

Introduction

For the processing of the safety index, results are used from accident statistics as well as from biomechanical research: the analysis on accidents provides the relevance structure which considers the significance of the loading of particular body regions due to their injury probability. The necessary risk functions with the protection criteria are derived from the biomechanical research, whereas the protection criterion level with a probability of 50 percent for reversible/non-reversible injuries is regulated by law.

After the transfer of the risk functions into the evaluation functions, all body-specific safety degrees can be summarised to a safety index. With the safety index the experimentally or mathematically determined loading values were focused to only one value, in which biomechanical phenomena and injury-statistical aspects were considered. It allows an objective assessment of the efficiency of safety systems for occupants and pedestrians and permits a reliable estimation of the inside and outside secondary (passive) safety of motor vehicles by the aggregation of current safety indices.

The Theoretical Approach

The described procedure, in which the acquired approach of a research project [1] sponsored by the BASt has been continued, includes the constraints for the safety criteria system in form of risk functions with legal regulated protection criterion levels, the evaluation functions derived from risk functions, and the relevance structure from the accident occurrence for weighting of the body-specific safety degrees. All these portions are used for the aggregation to the safety index.

The utilisation of risk functions

With the aid of a comprehensive literature research [2] currently existing and published risk functions for

Body region	Protection criterion	Protection criterion level	Legal requirements
Head	HIC	1.000	ECE R-94, ECE R-95
	a_{3ms}	80g	
	HIC	390 up to 700	FMVSS 208
Neck	N_{ij}	1,0	FMVSS 208
Thorax	a_{3ms}	50 up to 60g	FMVSS 208
	Compression	30 up to 63mm	
	a_{3ms}	60g	ECE R-94
	Compression	50mm	
	RDC	42mm	ECE R-95
	VC	1,0m/s	FMVSS 208; ECE R-94, ECE R-95
	TTI	85g or 90g	FMVSS 214
Abdomen	$F_{lateral}$	2,5kN	ECE R-95
Pelvis	$F_{pubic\ symphysis}$	6,0kN	ECE R-95
	a_{max}	130g	FMVSS 214
Femur	F_{longit}	6,8 or 10,0kN	FMVSS 208
Knee	Deflection	15mm	ECE R-94
Tibia	F_{longit}	8,0kN	ECE R-94
	TI	1,3	ECE R-94

Table 1: Legal protection criteria and protection criterion levels used in the Safety Criteria System

seven body regions and legal regulated protection criteria for frontal and side crash tests as well as for pedestrian impact tests are included (Table 1). The separation between AIS 2 and AIS 3 for the head and the extremities and between AIS 3 and AIS 4 for the other body regions allows the distinction of the probability for reversible and irreversible injuries. In order to facilitate a closed-ended mathematical formulation of the body-specific risk function, it is approximated with the aid of a lognormal distribution which can be described in each case only by two different variables.

Evaluation functions

The evaluation function is achieved by the inversion of the risk function, i.e. a reflection and a dilation, and contains a range of values for the safety degree of SG_i=1…-1. The value 1 features the maximally attainable safety level and the safety degree of SG_i=0.0 results from the standardised loading value NBW_i=1. The size offered on the abscissa is the standardised loading value, the quotient of the measured or calculated loading value and the protection criterion level, i.e. the standardised loading amounts to the value 1, if the current loading value is equal to the protection criterion level.

Relevance structure

The relevance structure is used for the weighting of the body-specific safety degrees and is determined as probability out of the accident occurrence depending on the accident type (frontal or side impact), of the seat position and of the size of the occupant (adult or child). The sum of the used weighting factors for the maximal possible seven body regions (head, neck, thorax, abdomen, pelvis as well as upper and lower extremities) is added together to 1 (according to 100%). If only a lower number of selected body regions are considered in the simulation, the relevance structure is adapted to 100%.

The compilation of the safety index out of safety degrees

In order to calculate the safety index, the safety degree of each body region (head, neck, thorax, arms, abdomen, pelvis and legs) will be multiplied by the weighting factors according the relevance structure and aggregated to the safety index SIX. Since the safety index SIX consists of the sum of all weighted safety degrees SG_i, it reaches values between SIX=1...-1 too. The safety index SIX=1 labels the highest stage of the secondary (passive) safety. If for a body region a high safety degree is reached (SG_i>0) and for an other higher loaded body region the degree of SG_j<0, the different safety degrees can be balanced and in the sum still become a positive safety index of SIX>0. However, from that comprehensive, reliable analysis of the simulation results besides the safety index SIX also the original loading values should be retained and considered in order to be able to assess deficiencies of individual safety measures and to be able to introduce corresponding improvements.

Application of the Safety Index

In the following presented application of the safety criteria system, the dummy loading values are determined of EuroNCAP crash tests for frontal and side impacts with 13 vehicles of different types [3]. On the one hand the evaluation with credit points is determined for loadings at the head, the neck, the thorax, the abdomen and the pelvis of the drivers according to the EuroNCAP conditions and on the other hand with the aid of the safety criteria system the safety index SIX is calculated. In Figure 1 the determined results are shown for the test configurations with each vehicle. Apart from two exceptions they show an outstanding agreement. The shown deviations are based on the two procedures underlying different approaches at the evaluations of the loading values and the weighting of the significance of accidents injured body regions: while with the EuroNCAP procedure

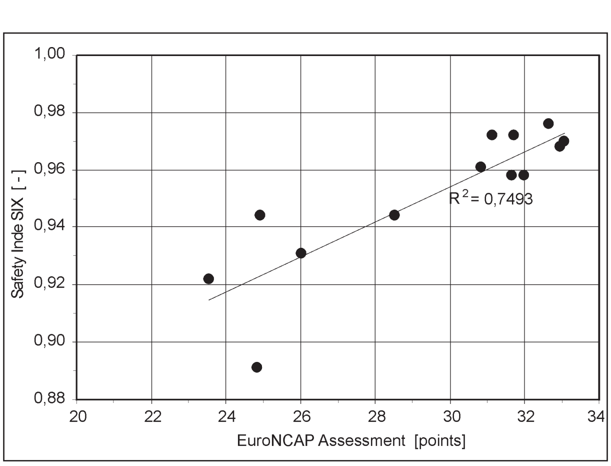

Figure 1: Comparison between the EuroNCAP assessment (points without seat-belt reminder) and the safety index based on the safety criteria system

specific points are being assigned to loading value ranges, the application of risk functions within the safety criteria system allows a continuous assignment between the body-specific loading values and the corresponding safety degrees. Furthermore, in the safety criteria system the individual body regions are weighted according to their injury probability, whereas in the EuroNCAP procedure the injury relevance remains unconsidered.

References

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