Correlation between injury risk and impact severity index ASI

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Abstract

Road restraint systems should considerably reduce the severity of accidents of vehicles leaving the road. To achieve this, certain criteria have to be fulfilled.

For evaluation of road restraint systems, certain test methods and impact test acceptance criteria for safety barriers are defined in European standard EN 1317 (parts 1 and 2).

In this standard, among others, different indices are carefully set out which should be taken into account for evaluation of impact severity and injury risk for occupants. In most of the cases, the ASI (Acceleration Severity Index) describes the impact severity well.

There is an exponential correlation between ASI and HIC (Head Injury Criterion). From an ASI of 1.2, the HIC increases very quickly. For lateral impact tests (according to the standard EN 1317), the HIC limit value should be fixed at 200.

The AIS (Abbreviated Injury Scale) describes the severity of injuries and has 6 categories. AIS of 3 correlates with a HIC of 200 and an ASI of 1.2 for lateral impact tests as described in EN 1317 parts 1 and 2.

Keywords

ASI – HIC – AIS – road restraint system

1. Introduction

Despite technical advances in road construction and automobile industry, every year too many people still die in accidents and crashes into point or linearly rigid obstacles. About one third of all road fatalities are due to this kind of accidents, caused primarily by the character of adjoining side spaces of roads. As a rule, side spaces with a high potential of accident risk should be secured with road restraint systems such as safety barriers, crush cushions etc., especially if it is not possible to reshape them using constructional or other measures.

Road restraint systems are basically classified as obstacles, which ought to reduce the severity of accidents. Therefore they have to fulfil considerable requirements. For example, heavy lorries should not break them through and, at the same time, passenger cars should not be able to drive under them. In case of an impact, they basically have to work so that the resulting accelerations and decelerations are bearable for the passengers, and that the biomechanical strains are in a tolerable order of magnitude.

About 85 % of vehicles involving in accidents are passenger cars. Due to this fact, for decades now, by development and use of road restraint systems a significant number of them have been tested on their functional efficiency prior to their installation.

In future, due to European harmonisation, only those road restraint systems are permitted which have been tested according to the EN 1317 parts 1 to 4. In addition to a large number of tests and acceptance criteria, the EN 1317 demands the investigation of impact severity for every road restraint system as well. The impact severity will be described, among other criteria, by means of index ASI (Acceleration Severity Index).

2. Technical bases

2.1 Impact severity levels

EN 1317 parts 1 to 4 are the official basis for testing and acceptance criteria of road restraint systems. For evaluation of different road restraint systems, among others, determination of index ASI is required. On the basis of limit values of ASI it is possible to correlate the crash tests to severity levels A or B (table 1).

Table 1. Impact severity levels according to EN 1317 [1]

Impact severity level	Index values		
A	ASI ≤ 1,0	and	THIV ≤ 33 km/h
B	ASI ≤ 1,4		PHD ≤ 20 g

Note 1: Impact severity level A affords a greater level of safety for the occupants of an errant vehicle than level B, and is preferred when other considerations are the same.

Note 2: At specific hazardous locations where the containment of an errant vehicle (such as a heavy goods vehicle) is the prime consideration, a vehicle restraint system with no specific impact severity level may need to be adopted and installed. The index values recorded in the test of the restraint system shall however be quoted in the test report.

1.2 Acceleration Severity Index (ASI)

The Acceleration Severity Index ASI is a function of time, computed with the following equation [2]:

$$ASI\ (t) = [(\bar{a}_x / \hat{a}_x)^2 + (\bar{a}_y / \hat{a}_y)^2 + (\bar{a}_z / \hat{a}_z)^2]^{1/2}$$

$\hat{a}_x$, $\hat{a}_y$ and $\hat{a}_z$ are limit values for the components of the acceleration along the body axes x, y and z; $\bar{a}_x$, $\bar{a}_y$ and $\bar{a}_z$ are the components of the acceleration of a select point P of the vehicle, averaged over a moving time interval $\delta = 50$ ms, so that:

$$\bar{a}_x = \frac{1}{\delta}\int_t^{t+\delta} a_x\,dt; \qquad \bar{a}_y = \frac{1}{\delta}\int_t^{t+\delta} a_y\,dt; \qquad \bar{a}_z = \frac{1}{\delta}\int_t^{t+\delta} a_z\,dt$$

The index ASI is intended to give a measurement of the severity of the vehicle motion during an impact for a person seated in the proximity of point P.

The limit accelerations are interpreted as the values below which passenger risk is very small (light injures if any). For passengers wearing safety belts, the generally used limit accelerations are:

$\hat{a}_x = 12$ g $\hat{a}_y = 9$ g $\hat{a}_z = 10$ g

where g = 9.81 ms^{-2} is the acceleration of earth gravity at sea level.

ASI is a dimensionless quantity and is a scalar function of time; it has only positive values. The more ASI exceeds unity, the more the risk to the occupant. Therefore the maximum value attained by ASI in a collision is assumed as a single measure of its severity.

1.3 Abbreviated Injury Scale (AIS)

The Abbreviated Injury Scale especially describes the injuries in head and neck area of occupants involving in collisions. The categories of injury severity are subdivided into 6 levels as in table 2 [3].

Table 2: Abbreviated Injury Scale

AIS	Category	Injuries
1	minor	Light brain injuries with headache, vertigo, no loss of consciousness, light cervical injuries, whiplash, abrasion, contusion
2	moderate	Concussion with or without skull fracture, less than 15 minutes unconsciousness, corneal tiny cracks, detachment of retina, face or nose fracture without shifting
3	serious	Concussion with or without skull fracture, more than 15 minutes unconsciousness without severe neurological damages, closed and shifted or impressed skull fracture without unconsciousness or other injury indications in skull, loss of vision, shifted and/or open face bone fracture with antral or orbital implications, cervical fracture without damage of spinal cord
4	severe	Closed and shifted or impressed skull fracture with severe neurological injuries.

5	critical	Concussion with or without Skull fracture with more than 12 hours unconsciousness with hemorrhage in skull and/or critical neurological indications
6	Survival not sure	death, partly or fully damage of brainstem or upper part of cervical due to pressure or disruption, Fracture and/or wrench of upper part of cervical with injuries of spinal cord

As apparent in table 2, the injury severity does not rise linearly with the AIS categories; it rises exponentially. From an AIS equal to three, the severity of injuries rises steeply.

1.4 Head Injury Criterion (HIC)

The Head Injury Criterion (HIC) has been developed to measure the accelerations acting on the head of occupants, computed with the following equation:

$$HIC = \left(\frac{1}{t_2 - t_1}\int_{t_1}^{t_2} a_{res.} * dt\right)^{2.5} * (t_2 - t_1)$$

This index is used with head-on impacts. A HIC greater than 1000 is basically declared as the threshold value from which high occupant injuries are expected [4].

3. Results

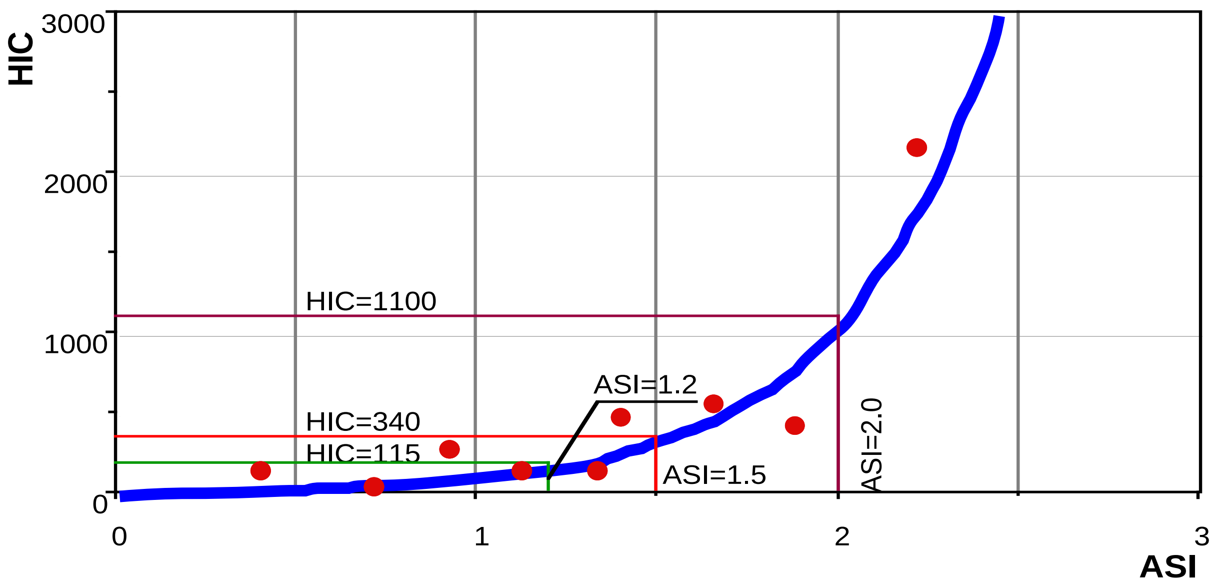
3.1 Correlation between ASI and HIC

ASI is determined on the basis of acting accelerations and decelerations in centre of gravity of vehicle. HIC describes the severity of injury on the basis of acting accelerations on vehicle occupants, provided a head strike exists.

Principally, it should be noted that vehicle occupant is not rigidly bonded with vehicle structure. Among other reasons, influences such as plasticity of vehicle seats, belt looseness, restricted belt function in lateral direction (and other factors) are responsible for different accelerations and decelerations acting in the centre of gravity of vehicle and those acting on vehicle occupants.

Measuring of HIC is relatively expensive. It is therefore advantageous to predict HIC with help of ASI. On the basis of the results provided, there exists the following correlation between ASI and HIC for lateral crush tests. Due to restricted number of tests carried out with a hybrid III dummy (9 tests), the correlation between ASI and HIC can only approximately be ascertained (figure 1).

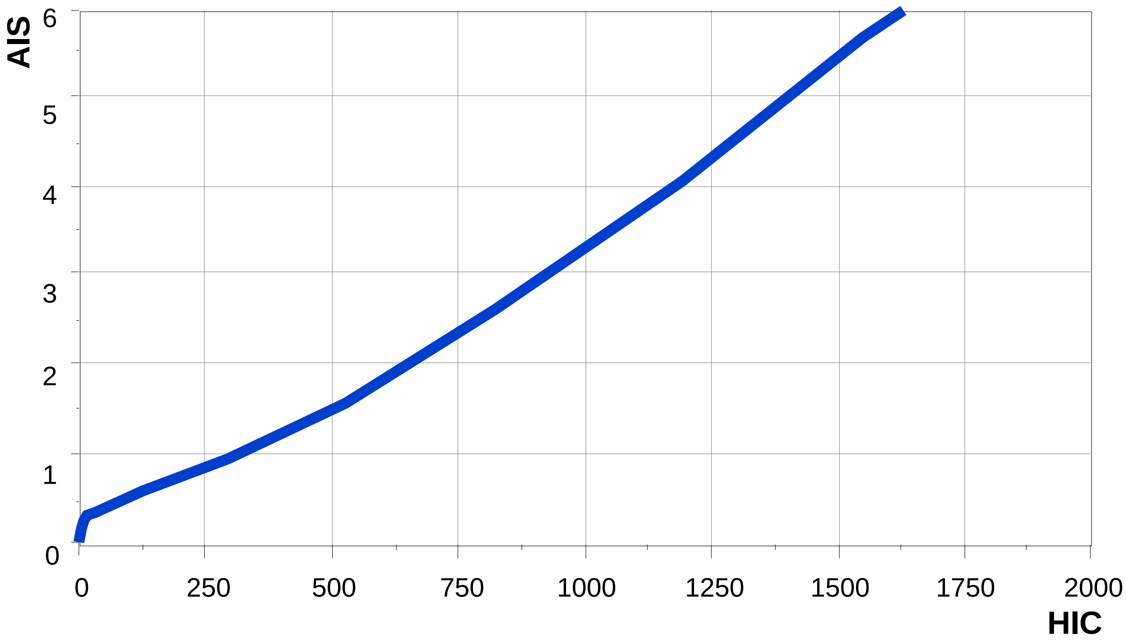
Fig. 1: Relationship between ASI and HIC [5]



3.2 Correlation between HIC and AIS

On the basis of a lot of post mortal experiments (experiments with dead bodies) [6] a correlation between HIC and AIS has been developed. It should be noted that the following correlation is based on only head-on impact tests.

Fig. 2: Correlation between HIC and AIS [6]



4. Conclusions

On the basis of evaluations and results provided, it could be shown that the correlation between ASI and HIC is an exponential function (section 3.1). From a certain value of ASI (about 1.6) the HIC rises drastically. Furthermore, from figure 1 it is apparent that up to an ASI of 1.0 HIC values are under 100. In the interval of ASI 1.0 to 1.5, HIC values increase up to about 350. A further increase of ASI from 1.5 to 2.0 results in an increase of HIC from 350 to about 1000.

From figure 2 it is apparent that for head-on accidents a HIC of 200 correlates with an AIS of less than unity. An AIS less than unity correlates with negligible injuries. But for lateral accidents the case is different. It should be emphasised that HIC was not developed to evaluate injury risk of lateral impact tests. Principally, it should be noticed that the head is not as flexible in transversal as in longitudinal direction [5]. Therefore, the limit value of HIC for a transversal loading must be much less than 1000.

With reference to section 3.1 and on the basis of available results, it can be shown that from a HIC of 200, which correlates with an ASI of 1.2, the head of the dummy penetrates the side window. Therefore, from a HIC of 200, there exists a higher injury risk for vehicle occupant. The injury risk is then of a higher significant when the head of the dummy strikes on safety barrier after penetrating the side window. It means that by lateral tests (according to EN 1317) a HIC of 200 or more associates with a high risk of severe injuries. Therefore, for evaluation of lateral impact tests (according to EN 1317), the limit value of HIC = 1000 is not appropriate and has to be set new.

To evaluate HIC representative limit values for transversal crushes, more research is needed. Furthermore, basic research is still needed to fully describe the relationship between HIC and AIS for lateral accidents. The same is the case for a possible correlation between ASI and AIS.

5. References

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