APARATURA
BADAWCZA I DYDAKTYCZNA

Measure and analysis of crash vehicle deformation

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ABSTRACT
A parameter, which is commonly used to define the deformation energy loss, is the Energy Equivalent Speed (EES). The energy loss due to deformation is the most important value for accident reconstruction. The energy loss estimation method, based on measurement of residual deformation, is now being more widely used in Europe as well. The paper presents appliance and deformation measures method and results of the EES/EBS parameter determining different method analysis.

Pomiar i analiza deformacji powypadkowego pojazdu

STRESZCZENIE
Powszechnie stosowanym parametrem wielkości wytrąconej energii poprzez deformację jest energetyczny ekwiwalent prędkości (EES). Wartość wytrąconej energii jest bardzo istotną wielkością w rekonstrukcji wypadków. Metody wyznaczania wartości wytrąconej energii bazujące na pomiarach deformacji są coraz szerzej stosowane w Europie. W artykule przedstawiono urządzenie i metodę pomiaru deformacji i wyniki analizy wybranych metod wyznaczania parametrów EES/EBS.

1. INTRODUCTION

Accident reconstruction requires estimating the change of velocity (Delta-V) imparted to vehicles during collision. Estimating Delta-V commonly involves measuring or estimating the deformation of the vehicles involved in a collision. Material coefficients, which relate barrier equivalent velocity (BEV) to deformation for the two vehicles, are then interpolated or if it is sensibly possible to extrapolated from barrier crash test data.

Basis for accident reconstruction and mechanics are the Newton's theory of impact – the Newton's classical laws. Newton defined the collision into two phases: the compression and the restitution phase. In case of a full impact, at the end of the compression phase the velocities of both vehicles at the impulse point are identical.

The principle which states that the amount of energy in a closed system is constant, regardless of the changes in form of that energy. Energy can neither be created nor destroyed. Therefore the kinetic energy before the impact equals the kinetic energy after the impact plus the energy loss:

$$\sum_{i=1}^{n} \frac{1}{2} n_i v_i^2 = \sum_{j=1}^{n} m_j v_j^2 + EL \qquad (1)$$

where:
m – the total mass of the bodies
v – the body velocities before and v' after the impact
i – and j the bodies involved in the crash
EL – energy loss

Energy can be lost during the impact due to:
• Deformation of vehicles
• Rotation of vehicle
• Friction between tires and pavement
• Sound due to impact

The energy loss due to deformation is the most important value, because its amount is much greater than the other losses. The other losses are difficult to be defined, because of the unknown parameters that are depending on (e.g. duration of impact, moments of inertia of vehicle, centre of gravity of vehicle). Since they are typically one order of magnitude smaller, they are most often neglected. A parameter, which is commonly used to define the deformation energy loss, is the Energy Equivalent Speed (EES).

The energy loss estimation method, based on measurement of residual deformation, is now being more widely used in Europe as well. This trend has been facilitated by the development and diffusion of software in which energy loss can be easily calculated using this methodology. Furthermore, the stiffness coefficients database has been broadened by the addition of data on European vehicles [1].

2. EES/EBS PARAMETERS

The term Equivalent Energy Speed (EES) has been defined by Burg, Martin and Zeidler in the year 1980 and was suggested for a common use. EES is a speed measure which will be transformed into deformation energy during the collision. International Standard definition for EES (ISO/DIS 12353-1:1996(E)):

„The equivalent speed at which a particular vehicle would need to contact any fixed rigid object in order to dissipate the deformation energy corresponding to the observed vehicle residual crush"

The plastic deformation energy of the damaged car is expressed as a kinetic energy of the car with the virtual velocity value EES. For an authentic EES-estimation various crash-tests with different conditions are necessary, because the energy absorption depends on various parameters.

$$EES = \sqrt{\frac{2 \cdot W_{def}}{m}} \quad \left[\frac{m}{s}\right] \qquad (2)$$

where:
W_{def} – deformation work [J]
m – mass of the vehicle [kg]
EES – Energy Equivalent Speed [m/s]

If no immediately similar tests are available for comparison purposes, then the deformation energy can be calculated from the damage measured on the vehicle using either the speed-deformation curve generated from a number of impact results at various speeds or a force-displacement curve prepared from a single impact test. Other methods used to calculate EES are: energy grids, approximation equations or damaged based algorithms. EES can work with partial information from the crash 2 as it is only a measure of the energy dissipated by that vehicle.

The EES catalogue contains photos of damaged vehicles categorized into vehicle model and collision severity groups. This enables the user to quickly see if the EES of the calculated impact is reasonable, based on a visual comparison of the damage.

The authors in [2] presented the deceleration s, the velocity change S, and the deformation length s as a function of time. It was calculated that the rebound, visible by the negative velocity, shows that for the frontal collision accident simulation, the elastic rate is approximately 10% [2].

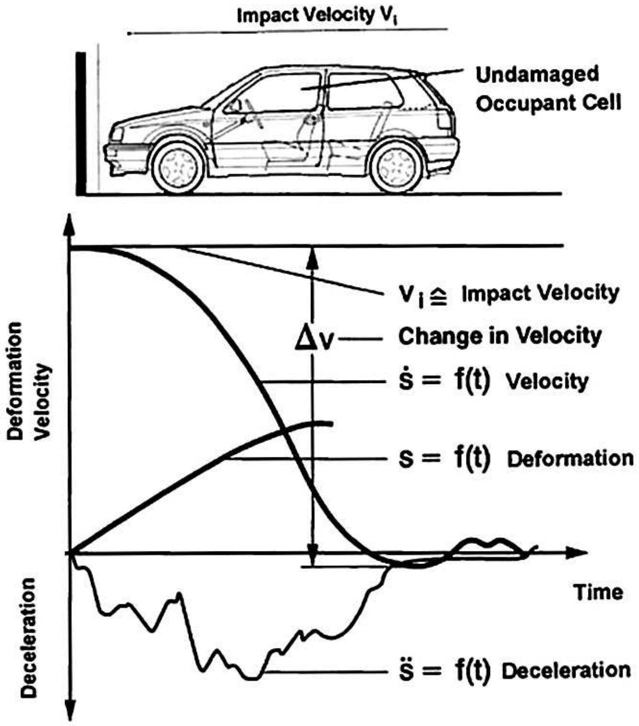

Figure 1. Deceleration, velocity and deformation as a function of time [2]

3. MEASURING INSTRUMENT

One of the ways for energy lost during the impact is due to deformation of vehicles. So the correct measurement of the deformation is very important for accident reconstruction and EES parameter determining. The measuring instrument was made by the authors of [4] for depth of deformation measure in DPD – Damage Profile Distance.

The measuring instrument is consist of aluminum beam, two stands, measuring aluminum pins and an extra precise measuring instrument. The technical drawings shows the elements of measuring instrument.

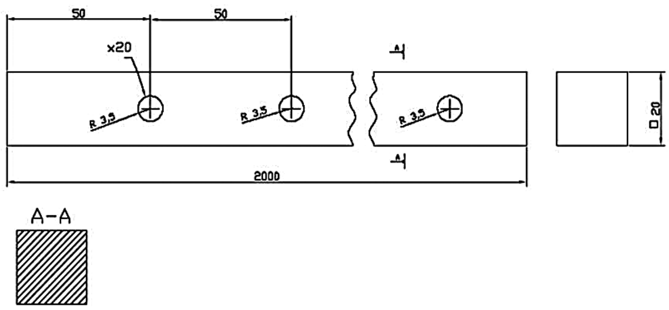

Figure 3. Technical drawing of measuring instrument beam with marked holes for pins

Mostly crumple zones are located in the front part of the vehicle. Some good estimate of how the energy absorption is distributed via the front end of a vehicle in a frontal collision is presented on Figure 2. It can be observed that sum of the forces, approximately 50% of the energy is absorbed by the longitudinal beams.

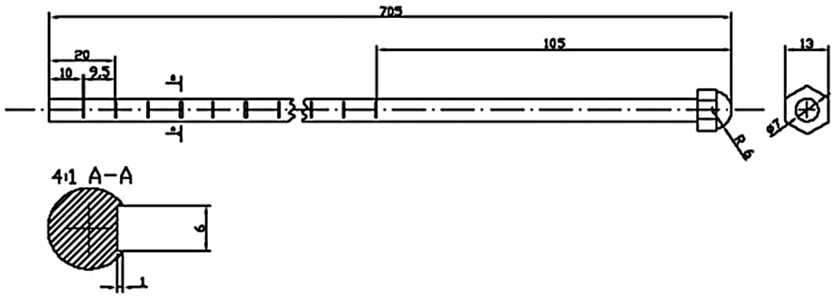

Figure 4. Technical drawing of measuring instrument pin with marked 10 millimeters division of the scale

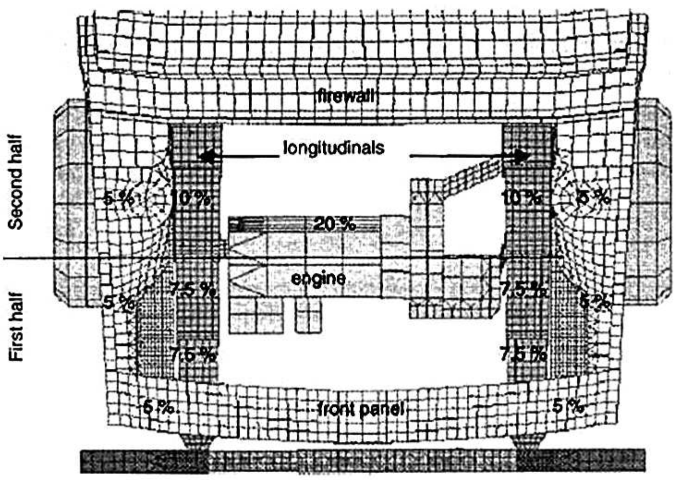

Figure 2. Schema of energy absorption of different vehicle parts [3]

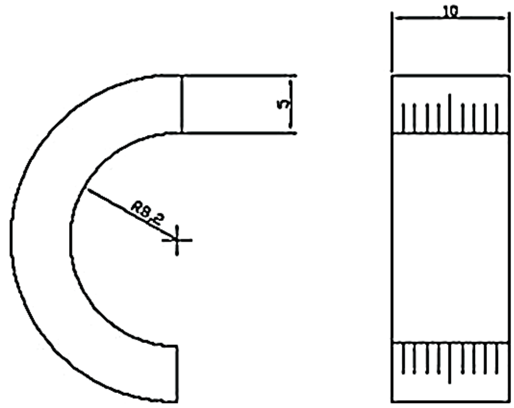

Figure 5. Technical drawing of precise measuring instrument with marked 1 millimeter division of the scale

4. DEFORMATION MEASURES

The methodology of measures presents Figures 6-8. A datum is set from the undamaged end to either the undamaged length of the vehicle or to a known length. The C1 to C6 figures can then be adjusted depending on whether the datum was longer than or shorter than the undamaged vehicle. In the pictures 7 there are two systems shown how a damage profile could

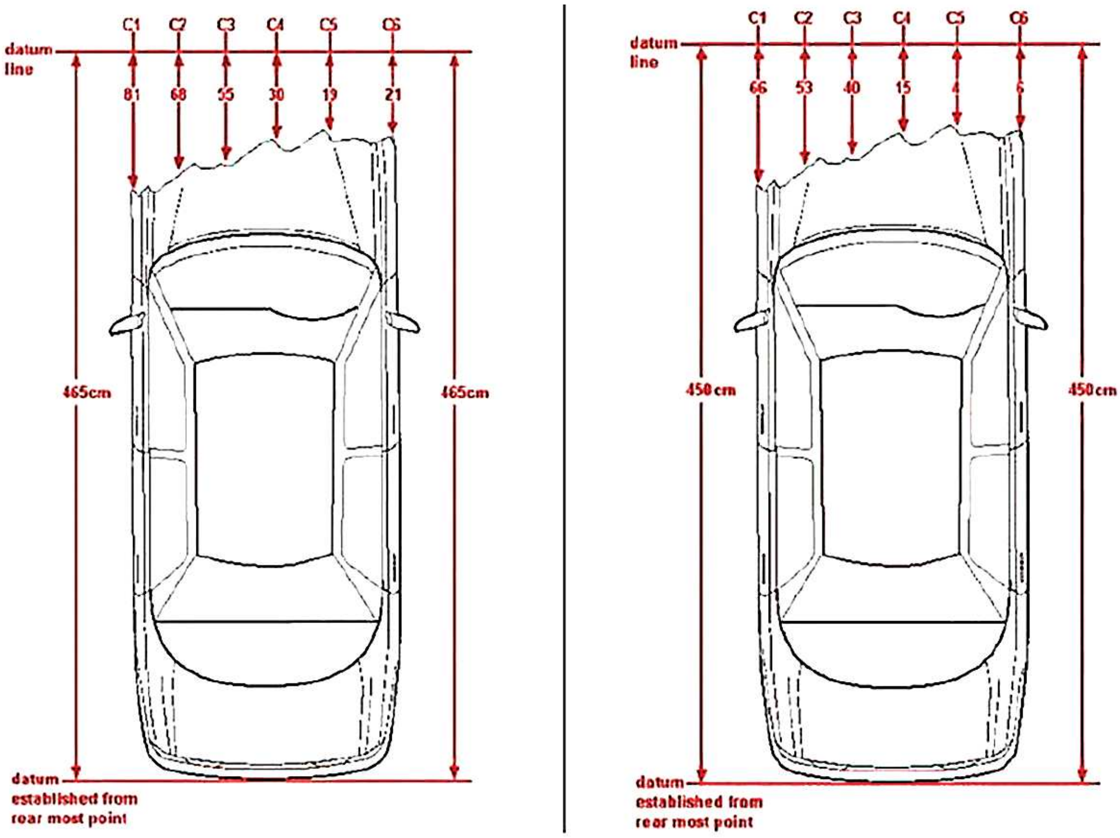

Figure 6. Setting a datum for front and rear impacts

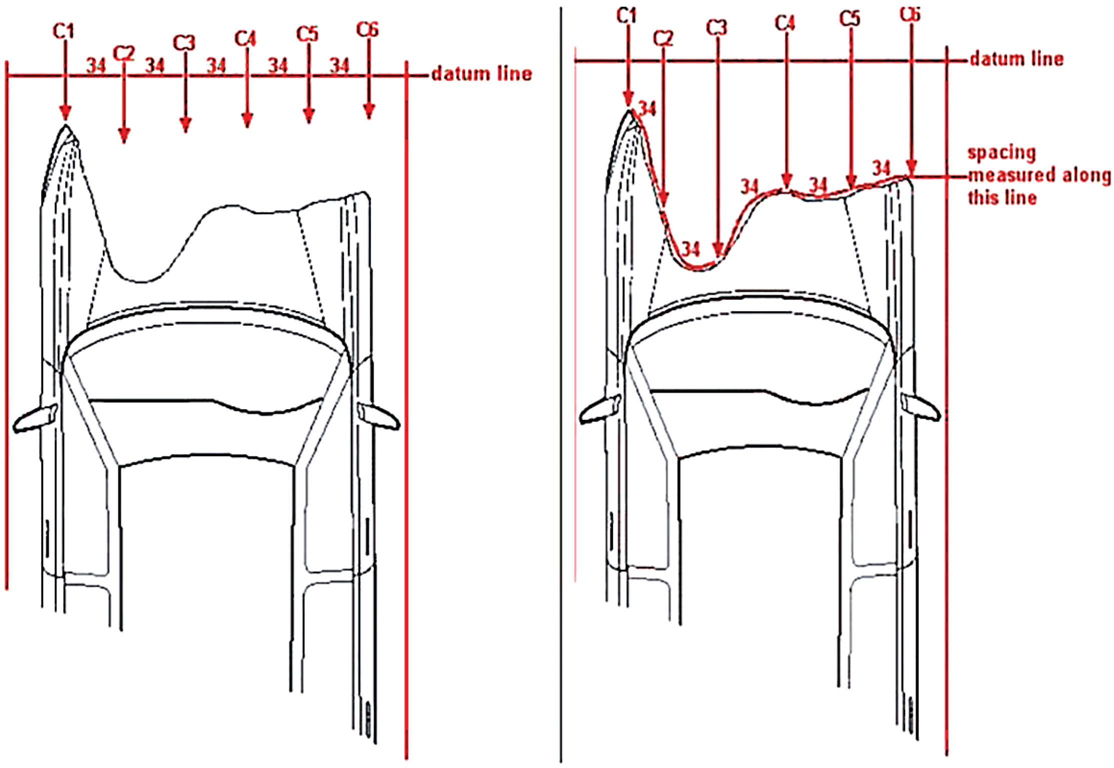

Figure 7. Spacing C1 to C6 measures

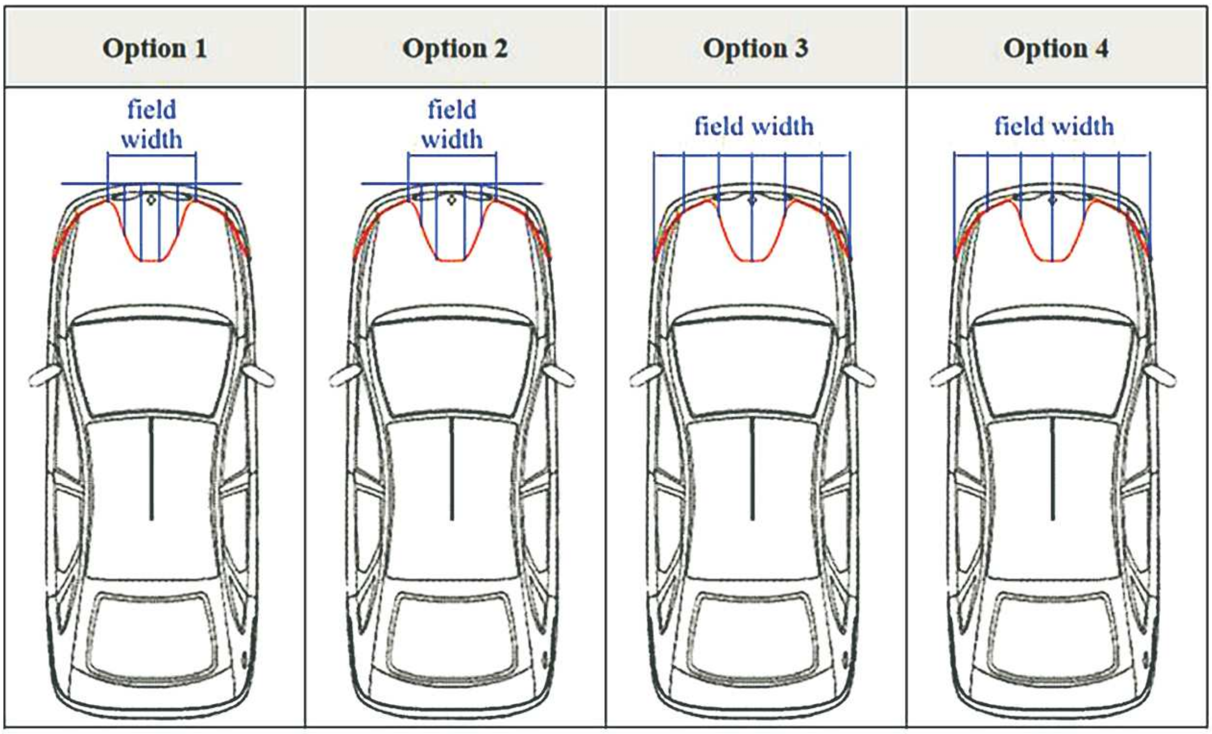

Figure 8. Spacing narrow penetrating profile

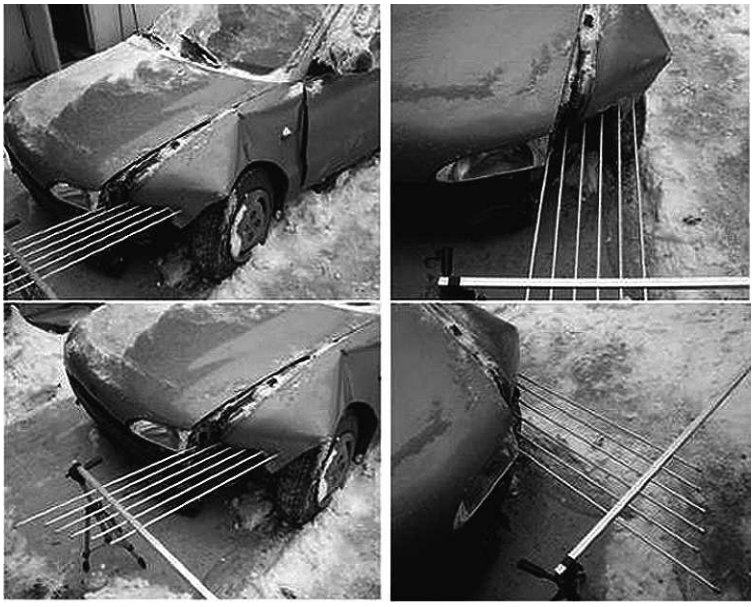

Figure 9. The damages range and measures process presents of the research object

be measured. In the first option five equal distances are within the damage field from C1 to C6 at the datum line. In the second option the measure points are taken along the damage width.

In pictures (Fig. 8) the vehicle hit a narrow object which caused the front corners of the vehicle to be dragged inwards and backwards. Now it's possible to space the damaged profile in four ways.

The paper presents example of application of the measuring instrument and results of the research of the vehicle damage during headon impacts with solid and immovable object. The damages range and measures process presents on Figure 9. The Table 1 consist vehicle technical and measures data.

5. COMPARISON OF THE EES/EBS PARAMETER DETERMINING RESULTS

For the EES/EBS parameter determining chosen method analysis was described in [5]. The comparison of the various equations was tabulated in Table 2 and Figure 10.

To illustrate distribution of determine EES/EBS values the chart was presented with marked average value.

The obtained results and deviation from average value of EES are quite according to research results presented and discussed

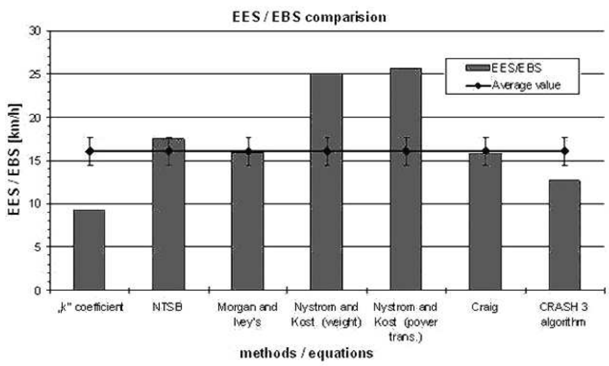

Figure 10. Distribution of determine EES/EBS

Table 1. Vehicle technical and deformation measures data

Vehicle technical and measures data		
Make/ Model	Hyundai / Accent 1.5 benz	
Weight [kg]	1024	
Length [m]	4.20	
Height [m]	1.40	
Width [m]	1.67	
Wheel base [m]	2.44	
Wheel track	front [m]	1.42
	rear [m]	1.41
Vehicle deformation		
Width of deformation [m]	0.25	
Height average of deformation [m]	0.4	
Depth of deformation [m]	C_1	0.14
	C_2	0.18
	C_3	0.20
	C_4	0.23
	C_5	0.27
	C_6	0.31
Depth average of deformation [m]	0.22	

Table 2. EES/EBS determined by chosen methods and equations

Method Equation	EES/EBS [km/h]	Deviation from average value [%]
„k" coefficient	9.21	-42.46
NTSB	17.44	8.97
Morgan and Ivey's	16	-0.03
Nystrom and Kost (by weight)	25	56.20
Nystrom and Kost (by power transmission axis localization)	25.67	59.28
Craig	15.72	-1.78
CRASH 3 algorithm	12.66	-21.20
Average value	16.06	

on X Conference of Road Accident Reconstructions Problems [6].

6. CONCLUSION

The correct and precision measurement of the deformation is very important for accident reconstruction. This is the base for EES parameter determining. The measuring method of depth of deformation measure in DPD is correlate with most often used deformation analysis tools for lost energy estimate.

Some methods and equations for determination of vehicle EES/EBS impacts with pole have been compared. More equations were compared in [7] and obtained differences of estimated speed were lower (less than 12%) but it has be said that the compared speed value wasn't averages but the measures. The vary of obtained results are caused because accident (crash) process is very complicated and using methods are only mathematical and physical simplification. There is the constant improving process of using for reconstructions tool and equations but the race to reality is very difficult because of constant improve and progress in vehicles industries by using new materials, technologies and systems for driving safety increase. These are next reasons for correct measurement and methods should be used.

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