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LASER PROFILOMETER METHOD FOR MEASURING THE DEFORMATIONS OF THE CAR BODY ELEMENTS

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Abstract—In this paper is presented a new method that uses a polar coordinate system to determine the vehicles deformation magnitude. The laser profilometer method is distinguished by the small size of the equipment used, the simplicity of the measuring methodology, data acquisition and processing and high accuracy of the results.

***Keywords*—**vehicle deformations, laser telemeter, profilometer

I. INTRODUCTION

THE energy consumed during the complex process of a vehicle collision for the structure deformation, known as deformation energy, has a major importance both for passive safety and as a basis for calculating the kinematic and dynamic parameters of the vehicle, determined during the retrospective research of road events.

The deformation energy can be determined based on the deformation magnitude, taking into account the design parameters of the vehicle expressed by the stiffness coefficients.

The classical method for determining the deformation magnitude is the profilometer method, which uses a Cartesian coordinate system. In addition, methods have been developed based on photographic technique, such as the PhotoModeler method.

II. CAR DEFORMATIONS AND THE DEFORMING ENERGY

One of the main goals of reconstruction the road accidents is, in most cases, the determination of vehicles speed before the collision [1]. The main methods of approaching the reconstruction of road accidents are: impulse method, based on the laws of conservation of the linear and angular impulse and the deformation method based on the laws of conservation of the linear impulse, angular impulse and energy [2].

Using deformation method implies the existence or adoption of some models of deformation that expresses the correlation between the collision normal force per unit width of the deformed area and the deformation magnitude. The deformation models can be static or dynamic. For the dynamic deformation models the determination of the deformation energy is done based on the dynamic deformations and the static models use the magnitude of the remanent static deformations for calculating the deformation energy. While the dynamic models express the relationship between force and dynamic deformation of the vehicle body, the static models are showing the relationship between force and the plastic remanent deformation of the vehicle, assimilating this dependence as linear.

Therefore, determining the total kinetic energy consumed during the impact is done based on the deformation of the vehicle constructive elements, in particular the car body elements. The measurement of the vehicle deformations involves the determination of the magnitude of these deformations in several points of the deformed area. The energy consumed for the deformation of the vehicle constructive structure during the impact can be determined based on the remanent deformation of the car body elements, using the vehicle's stiffness coefficients specific to the deformed area.

The relation used to calculate the deformation energy in the PC Crash software is:

$$\mathbf{E_D} = \sum_{i=1}^{n\quad 1} \mathbf{w_i} \quad \begin{array}{l} \frac{\mathbf{B}}{\mathbf{6}} \;\; \frac{\mathbf{C_{i+1}^3} \quad \mathbf{C_i^3}}{\mathbf{C_{i+1}} \quad \mathbf{C_i}} + \\ + \frac{\mathbf{A}}{\mathbf{2}} \;\; (\mathbf{C_{i+1}} + \mathbf{C_i}) + \\ + \mathbf{G} \;\; (1 + \tan^2 \Theta) \end{array} \tag{1}$$

$$\mathbf{w_i} = \mathbf{L_{i+1}} \quad \mathbf{L_i} \tag{2}$$

where:

E_D - deformation energy (J);

A, B, G – stiffness coefficients;

C_i, C_{i+1} – the deformation measured at point i and point i+1 (m);

L_i, L_{i+1} – the rate of the measuring station from point i, and point i+1 (m);

w_i – the distance between two consecutive measuring stations (m);

Θ – angle between the longitudinal axis of the vehicle and the direction of the main impact force (degree).

The deformation energy thus calculated is corresponding to the remanent deformation. It is known that during compression, the car body dynamic deformation reaches the maximum value at the impulse point, then during the restitution phase, the deformation magnitude decreases to the static deformation value.

III. THE CLASSICAL METHOD FOR MEASURING THE DEFORMED PROFILE OF THE VEHICLE

The procedure of measuring the deformed profile is based on the assumption that the deformation is uniform on the vertical plane [3].

For the vehicle-to-vehicle collisions this assumption is not valid in all the cases, given the geometric and structural incompatibility of the collision partners, but it does not significantly affect the calculation of the speed variance because in these cases the total energy of deformation is used which characterize the impact as a whole [4].

The commonly used tool for measuring the deformed profile of the car is the profilometer "Fig. 1" [5].

Fig. 1. Measuring the deformed profile with the profilometer

The measurement procedure of the deformed profile using the profilometer has the following steps [6]:

- the measurement procedure is established
- the choice of the quotation base
- the width of the deformed area is determined
- the choice of the measuring stations number
- the deformation measurement at the points of measurement
- measurements are realized in the same points on an undeformed vehicle
- the deformation values $C_1 \ldots C_n$ are determined at the points of measurement, by the difference between the two sets of measurements.

When measuring the deformed profile in the frontal plane of the vehicle, the measuring base is positioned relative to the rear axle, at a distance higher than the sum between the wheelbase and the front console of the vehicle. Can be used 6 until 12 measuring stations positioned at equal or unequal distances to each other. In general 6 measuring stations are used and the measurement is done at the maximum deformation rate.

IV. THE MEASUREMENT OF THE DEFORMED PROFILE USING THE LASER PROFILOMETER

The laser profilometer method consists of measuring, in a system of Cartesian coordinates, the deformation values at several points of the deformed profile. In this paper is proposed a new measurement method of the deformed profile which uses the polar coordinate system. The measurement equipment consists in a laser telemeter mounted on a tripod "Fig. 2". The support on which the telemeter is fixed has a ball joint, so the rotation is allowed to position the light spot for the measuring points.

Fig. 2. Measuring device with the laser telemeter.

During the experimental research a Leica DISTO A2 telemeter has been used. The distance measurement using the laser telemeter is realized by fixing the light spot on the body surface, and by pressing the control buttons on the device screen, the distance between the device and the body is shown. The distance measurement with a good accuracy is up to 12 m, for favorable operating conditions. For adverse operating conditions, such as bright light, very poor reflective surfaces, large temperature variations, the measurement accuracy can be damaged. In addition, measurement errors can occur when the surface to which the distance is determined is transparent or semi-transparent. The device is available for single measurement, continuous measurement and the positioning at a desired distance to an object. The technical characteristics of the Leica DISTO A2 telemeter are presented in Table I.