Numerical and experimental analyses of lighting columns in terms of passive safety

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Abstract

Modern lighting columns have a very beneficial influence on road safety. Currently, the columns are being designed to keep the driver safe in the event of a car collision. The following work compares experimental results of vehicle impact on a lightning column with FEM simulations performed using the Ansys LS-DYNA program. Due to high costs of experiments and time-consuming research process, the computer software seems to be very useful utility in the development of pole structures, which are to absorb kinetic energy of the vehicle in a precisely prescribed way.

Keywords: Passive safety, crash test, EN 12767, MES, Ansys LS-DYNA

1. Introduction

Nowadays, the main objective in the design of lighting columns is to ensure maximum safety for users of roads and their surroundings. As a result of such an approach new structures of lighting columns must be tested on crash track according to European Standard EN 12767 "Passive safety of support structures for road equipment. Requirements, classification and test methods"

The paper presents the comparison of the empirical crash tests with numerical simulations. The objective of such analyses is to eliminate very expensive crash tests carried out to verify designed structures of lighting columns. The research is focused on non-energy absorption column. The next step will be to perform numerical analyses of high energy absorbing columns.

Due to the industrial character of the problem the literature addressing crash tests and numerical calculations of lighting poles is not very rich. Nonetheless, one can find papers closely related to the design of the lighting columns. The numerical analysis of the aluminum poles is presented in [1]. The paper [2] focuses on the concrete foundation with special shape connection made from aluminum alloy. Guidelines for preparation and evaluation of crash tests results and tensile tests are describe in European Standards [3-5]. The general issues of the strength of materials are described in [6].

2. Methodology of the studies

Ansys LS-DYNA is a very popular program enabling analysis of very complex problems including crash tests. In order to achieve a prescribed conformity of the numerical and experimental results, the elements affecting the results to the highest degree like vehicle crash areas and the pole together with ground were modeled with the highest accuracy. The vehicle elements, which neither are deformed nor are deformed in considerable degree, were simplified. The materials used in the production of the test columns and vehicle crumple zones were tested in the Europoles laboratory to determine their mechanical properties [5] and in consequence to achieve a greater accuracy in the numerical analysis.

Crash track consists of a specially designed buggy imitating the behavior of a conventional vehicle. During the test overloads are measured in three axes in the range of ± 600g and the rotational speed of the vehicle up to 50 rad/s. All data is stored on a computer mounted on vehicle with a sampling rate of 10000 Hz. In addition, an area of 6 m before and 12 m behind the point of the impact is recorded by two high-speed cameras (500 frames/sec and a resolution of 800 x 600 pixels). Recording of all data is triggered by two contact sensors placed on bumper of the buggy and on the surface of the column.

3. Parameters measured in the crash tests

All tests were conducted in accordance with the assumptions of the standard EN 12767 "Passive safety of support structures for road equipment. Requirements, classification and test methods". Lighting columns are categorized with respect to the absorption energy of the vehicle. In the built-up area the column must absorb kinetic energy of the vehicle while in outside of the built-up area should have sheared-off damage mechanism and absorb minimum energy (Figure 1).

Within each category the driver's safety is defined from 1 (lowest safety level) to 4 (highest safety level) depending on Acceleration Severity Index (ASI) and the Theoretical Head Impact Velocity (THIV) [2, 3].

Both indicators are calculated in accordance with EN 12767. ASI depends on the g-force accelerations in three axes, while THIV is the theoretical speed of the driver's head when hitting the steering wheel, and is calculated from the negative g-forces and vehicle impact speed [4].

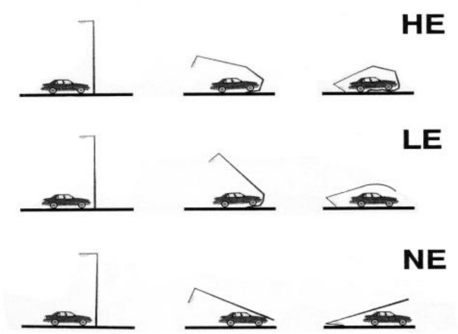

Figure 1: Non-energy-absorbing (NE), low energy-absorbing (LE) and high energy-absorbing (HE) lighting columns [3]

4. Comparison of the experimental and numerical studies

The tested lighting column is a modern structure fixed to a concrete foundation. The 1.5 m high foundation was fixed to the concentrated layer ground at 300 mm height. The column with the triangular base plate had a height of 14 m, a peak diameter of 76 mm, the convergence of 11 mm/m and was produced of S235 steel with a thickness of 4 mm. A bracket of a mass of 13 kg is mounted at the top of the column. The total weight of lighting column is 235 kg. A fastener is fitted to the foundation consisting of a standard base, 100 mm long tube and a triangular base (Figure 2).

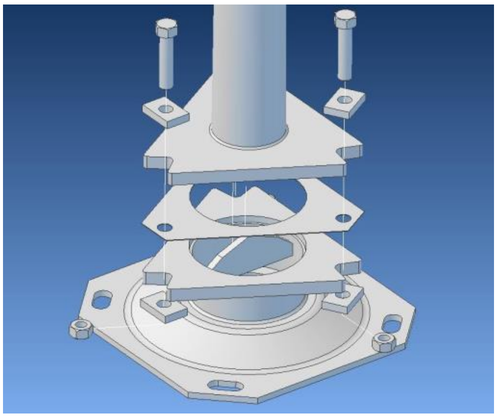

Figure 2: Slip base mounting

Such a fastening of the pole to the ground allowed to achieve high bending strength at low shear strength. The total load consists of wind pressure and the weight of the lighting column with the bracket. The maximum shear force for the examined column equals 2 kN, whereas the maximum bending moment equals 35 kNm.

The column construction was designed not to absorb kinetic energy of the vehicle, therefore, its function is to lose ground contact in the event of the vehicle impact. By breaking the connection to the ground, the column absorbs minimum energy of the vehicle, and minimizes the danger of the driver's injury. That construction of column can be used outside the built-up area.

At first, crash tests on the test track were performed. At the impact speed of 97 kph it was obtained: the exit speed of 85.8 kph, THIV 11 and ASI 0.7. The pole is assigned to category 100NE3.

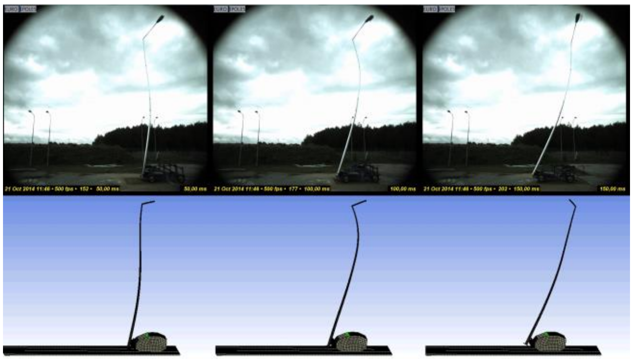

Figure 3: Pictures 50, 100 and 150 ms after the crash for the experiment and computer simulations

The numerical model has been created and modified in order to approximate the experimental results. The comparability criterion was speed reduction of the vehicle after the impact. The numerical model consists of 14213 nodes and 13783 finite elements of various types. Since the most important data for the phenomenon are recorder in the initial phase of the crash, the numerical analysis was terminated 0.15 s after the impact. Till this time the column in experiment and computer simulation was shear-off. Both the vehicle speed reduction and the column deformations in the experiment and crash test were very similar to each other (Fig. 3, 4).

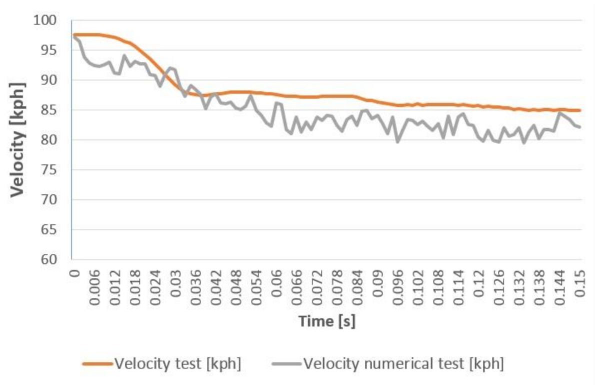

Figure 4: Comparison of the vehicle velocity reduction

5. Conclusions

The numerical result approximates the experimental one to the extent that they can be considered as reliable. Simplification of the vehicle components, which haven't been deformed during the test, has accelerated calculations without affecting the results significantly. The studies performed with lightning columns characterized by a non-absorbing energy structure encourage for further researches aimed at reliable support of the crash tests with numerical simulation especially in the phase of the structure development. This could significantly reduce the cost and deployment time of new products.

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