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EFFECT OF THE BUS BODYWORK ON IMPACT STRENGTH PROPERTIES IN ROLL-OVER

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ABSTRACT

According to the statistics one or two bus roll-overs monthly take place in the world. Such vehicular accidents are the most dangerous for buses shuttling to 60 people. As a rule, a bus driver is at-fault. When vehicular accident is sure, it is necessary to be supported by systems reducing the accident severity of a driver and passengers. These systems refer to passive safety of the bus design and its body is the main. The paper has analyzed the issues concerning increasing impact strength properties of the bus body in roll-over. Particularly, the paper offers to consider the degree of impact of the window sill elevation on the bus body deformation in roll-over.

Keywords: bus, safeguarding design, ruggedness, deformation, impact strength properties.

INTRODUCTION

Research studies devoted to the definition of the vehicle structural ruggedness lead to increasing impact strength properties and also reduce the accident severity of a driver and passengers in roll-over [1-3].

To increase impact strength properties there is provided:

- to apply new body materials (multicore panels) [4];
- to fill hidden cavities of the body with compositions which harden the ruggedness[5];
- to enhance the effectiveness of the existing bus passenger compartment interior (hand holds, seat frames, etc.) [6];
- to use additional systems of passive safety [7,8];
- to limit the useful life of a bus in the event of the prohibitive ruggedness reduction of structural properties of the material from which the bus body was built up [9], and so on.

The paper offers to increase the bus body ruggedness in roll-over due to changes in the design of aperture panels and to determine the optimal window sill elevation.

Let us consider the phantom cross section of an aperture panel (Figire-1).

Figure-1 has insymboled the following: P - is a force exerted on a aperture panel of the body at an angle α, H - is the bus body elevation, M_{izg1}, H_{o1}– respectively are a bending moment and the window sill elevation for the event in Figure-1, and M_{izg2}, H_{o2} - respectively are a bending moment and the window sill elevation for the event in Figure-1 b. At that the constraint Ho2 > Ho1 is kept to.

Let us equate the moments:

$$M_{izg1} = (H - H_{o1}) \cdot P \cdot \cos\alpha; \quad (1)$$

$$M_{izg2} = (H - H_{o2}) \cdot P \cdot \cos\alpha, \quad (2)$$

where H - Ho1, H - Ho2 – an arm of a force P.

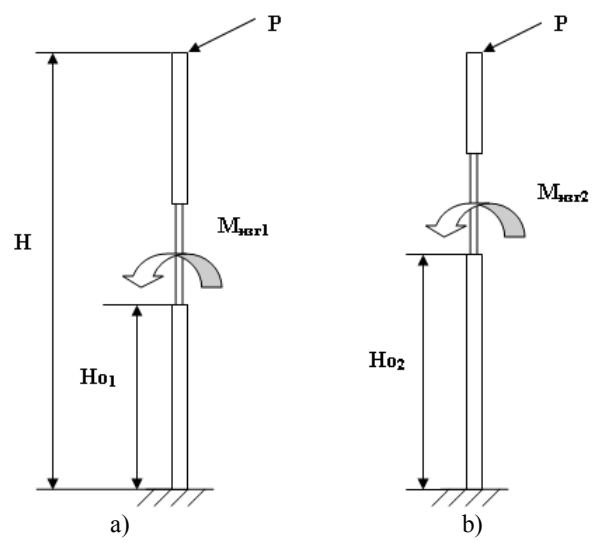

Figure-1. Cross section of an aperture panel of the bus body with the window sill elevation.

If to subtract the equation (1) from (2), we get the following equation:

$$M_{izg1} - M_{izg2} = (H_{o2} - H_{o1}) \cdot P \cdot \cos\alpha. \quad (3)$$

From this equation it is becoming apparent that the constraint Ho2 > Ho1 is kept to at $M_{izg1} > M_{izg}2$. In other words, the higher the window sill elevation the lower an arm and, therefore, smaller a bending moment.

Let us further consider the dependence of the function of the bus body ruggedness in roll-over on the window sill elevation in aperture panels.

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The UNECE–Regulations № 66 [10] characterize the bus body ruggedness as follows: "The power structure of the vehicle must be rugged enough to protect the residual space immunity when roll-over testing the complete vehicle and after this test". Figure-2 shows the bus passenger compartment residual space chart.

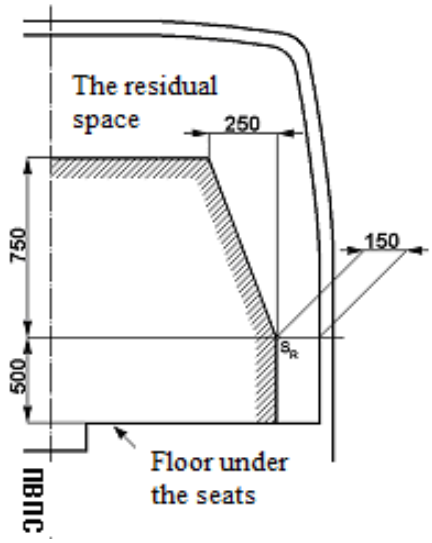

Figure-2. Residual space chart (the size range in mm).

In the Russian Federation certification tests are conducted in accordance with [10]. To determine the residual space immunity during and after the test tripods are secured to the body floor, as a rule, above the second, central window and second last window pillars of a aperture panel on which a bus will be overturned. Telescopic lines-up bumping into corresponding pillar are secured to tripods. When a bus is overturned the line-up fixes the maximal pillar motion stands at point of 1250 mm from the floor. Figure-2 presents the point 1250 mm as the sum of 500 and 750 mm.

In view of this the task consists in the determination of estimated motions of window pillars of the body lpi at point of 1250 mm from the supporting face of passenger seat anchors where i - is the number of pillars on the analyzed aperture panel. To solve this issue, let us consider the case of bus roll-over on its side when testing the complete vehicle according to the UNECE-Regulations № 66.

Let us introduce the supposition that plastic hinges are formed on aperture panels of the body at the site where a window pillar is linked up with a window sill and head.

The case when plastic hinges are additionally formed on aperture panels in the places of its linking with the underside [11] is characteristic of roll-over:

- on the right aperture panel of the body of new buses which have door apertures for passenger entry and exit;
- of new conventional buses which window pillars have a small moment of inertia due to the need for providing observability from a driver's seat [12];
- of buses which are in operation for the certain period of time and have the certain mileage [13,14].

The further studies will analyze these cases.

By using the introduced supposition, let us analyze Figure-3.

Figure-3 shows that the triangles ABC and DCF are similar. Hence a target value lpi in mm can be determined by the formula:

$$l_{pi} = \frac{h_0 \cdot (H_n + 1250 - H_o)}{H_o} \tag{4}$$

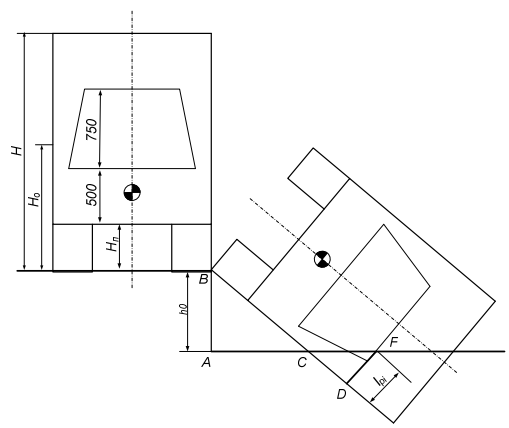

Figure 3. Bus roll-over chart (the size range in mm).

Thus, we can make conclusion that:

a) on the assumption

$$H_n < H_o < H_n + 1250 \tag{5}$$

with the increasing value Ho in roll-over value lpi decreases.

b) on the assumption

$$H_o = H_n + 1250 \tag{6}$$

the motion is according to the formula lpi=0.

Thus, buses in which design a window sill is located within the assumption (6) will be safer in roll-over by reference to the accepted assumptions. On the other hand, passengers short in height and children will feel discomfort on a trip because they will not be able to see the landscape surrounding them.

That is why the designers of manufacturing plants of buses are recommended to solve such contradiction as "security-comfort" depending on their task.

For example, on roll-over of tourist buses of various models (Figures 4-7) at a height h_0=800, we have obtained the following pillar motions (Table-1).

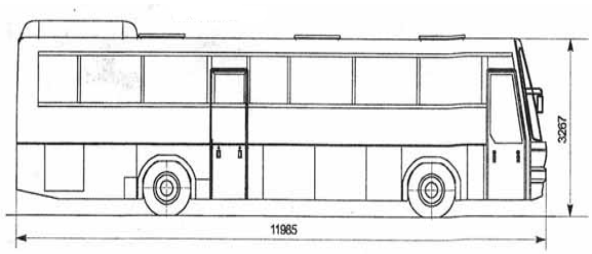

Figure-4. Belarusian bus MAN-512A.

Table-1. The size range of bus bodies, mm.

Bus model / Parameter	MAN	NEFAZ	Zhong Tong	SCANIA
H_n	1380	1420	1560	1550
H_o	2150	2200	2345	2380
l_{p3}	179	171	159	141

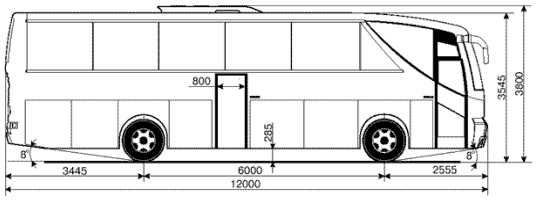

Figure-5. Russian bus NEFAZ.

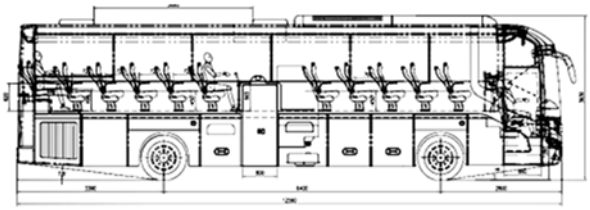

Figure-6. Chinese bus Zhong Tong ComPass LCK 6127.

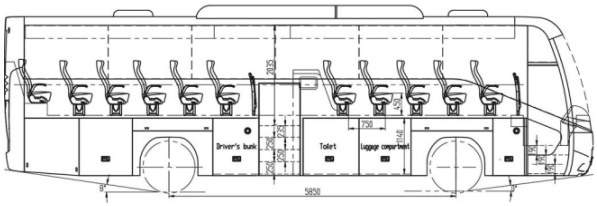

Figure 7. Swedish bus SCANIA K380IB 4X2 HIGER A80.

Table-1 shows that the first two models of buses MAN NEFAZ and also the second pair of Zhong Tong and SCANIA are quite similar in the body floor and window sill elevation. At the same time a window sill in NEFAZ and SCANIA buses in terms of design is higher by 30-50 mm than in MAN and Zhong Tong. Consequently, the calculated deformation for each third of window pillar is lower.

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