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PROPOSALS FOR DETERMINING THE IMPACT ENERGY AT BUS ROLLOVER FOR CONDITIONS OF UNECE №66

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ABSTRACT

Reducing the total impact energy bus is possible due to reduction of the mass of the bus, the acceleration of free fall or drop height of center of gravity. The most promising at the moment is to reduce the height of the fall of the center of gravity of the bus. To reduce the height of the fall is possible to use the author's device to prevent a rollover accident. This paper proposes a method for determining the total impact energy bus rollover bus. The method is applicable to conditions determined by the UNECE Regulation № 66, intended for the certification of passenger motor vehicles of category M3, taking into account the possible application of the device to prevent tipping.

Keywords: bus, construction safety, strength, deformation, center mass, energy.

INTRODUCTION

To assess the quality of manufacturing and design safety of vehicles in the Russian technical regulations "On the safety of wheeled vehicles" [1]. Technical regulation establishes requirements for the safety of wheeled vehicles when they are issued into circulation in the territory of the Russian Federation and the operation regardless of their place of manufacture in order to protect human life and health, environmental protection, protection of property of individuals and legal entities, state or municipal property and warnings actions misleading purchasers wheeled vehicles.

The objects of technical regulations, which are subject to these technical regulations include:

- wheeled vehicles of categories L, M, N and O are designed for use on public roads, as well as the chassis of the vehicle;
- vehicle components that affect the safety of vehicles.

According to the regulations the design of the vehicle with its category and destination must provide:

a) effective braking system;
b) effective action of steering, handling and stability;
c) minimize the traumatic effects on inside the vehicle and the ability of people to evacuate them after traffic accident;
d) minimize the physical impact on other road users;
e) fire safety;
f) visibility of outer space for the driver;
g) measuring, registering and limiting the speed of the vehicle;
h) electrical safety;
i) Protection of vehicles against unauthorized use;
j) minimization of emissions of harmful substances (pollutants), as well as energy efficiency, which is expressed in minimizing fuel consumption of vehicles with internal combustion engines and electric cars electricity consumption;
k) minimization of external and internal noise;
l) resistance to external sources of electromagnetic radiation and electromagnetic compatibility;
m) safe for the health status of the microclimate in the cab driver and the passenger area and the minimization of harmful substances in the air cab and passenger compartment of a vehicle;
n) necessary and sufficient quantity, location, characteristics and effects of lighting and sound signaling devices;
o) desired location and identification of controls and controls of the vehicle;
p) compliance with dimensional and weight restrictions, defines the features of the national road network.
q) Having considered the requirements 3) Regulations "Combat traumatic effects on the occupants by means of people and the possibility of evacuation after a traffic accident" [2, 3, 8] in respect of buses (Table-1).

Table-1. Requirements for the design of the bus.

No.	Elements of objects of technical regulation, in respect of which the security requirements	Description and origin of a document confirming compliance
1	Seat belt anchor	UNECE Regulation N 14-06, including the addition of 1
2	Requirements for safety belts and restraint systems equipment	UNECE Regulations № 16-04, including amendments 1-7 (up to 31 December 2011)
3	Seat buses strength of seats and their anchorages	UNECE Regulation N 80-01, including the addition of 2
4	Strength of superstructure passenger vehicles	UNECE Regulation N 66-00, including a review of 1
5	safety glazings	UNECE Regulation N 43-00, including the addition of 8

After analyzing these requirements, they can be ranked in terms of the importance of performance in terms of the internal passive safety:

Level I: Strength of superstructure passenger vehicles;

Level II: The seats of buses, the strength of seats and their anchorages;

Level III: Seat belt anchor; Requirements for safety belts and restraint systems equipment;

Level IV: Safety glasses.

As is well known by severity of injury involved in road accidents are divided into 5 categories:

- Fatal accidents;
- Accident with severe injuries;
- Accidents less serious degree of injury;
- Accidents with mild injuries;
- Accident without injury to participants in road accidents.

It can be assumed that, I level of significance - the indicator "Strength of superstructure passenger vehicles" to minimize fatal accidents, II level - to minimize accidents with severe injuries, III level - an accident with less serious degree of injury, IV level - accidents mild injury.

Consequently, the most significant impact on the internal passive safety bus has "Strength of superstructure passenger vehicles." The assessment of this parameter by ECE Regulation №66-00 [4, 5, 6].

According to the Regulation №66 bus shall be approved if the body has sufficient strength to ensure that during and after the tests or by calculation the following conditions are met:

- none of the elements of the body has shifted did not come into the residual space;
- no part of the residual space protrudes from the body.

The calculations are based on the definition of the potential impact energy bus rollover E^* J. The formula for its calculation is given in Annex 5 of the Regulations of the UNECE № 66. It uses the following assumptions:

- quadrangular cross-section of the body;
- suspension system is rigidly fixed;
- movement of the body is a pure rotation about the axis of tilting.

If the height of the fall of the center of gravity h, m, is determined by the graphical method, the impact energy E^* J, is calculated by the following formula:

$$E^* = 0,75\,M \cdot g \cdot h, \tag{1}$$

where M = gross vehicle weight, kg;
g = 9,81 m/s^2 – acceleration of gravity;
0,75 – coefficient taking into account the mass of the bus, which affects the impact energy.

Moreover, the collision energy can be defined by the formula:

$$E^* = 0,75 \cdot M \cdot g \cdot \left(\sqrt{\left(\frac{W}{2}\right)^2 + H_3^2} - \frac{W}{2H}\sqrt{H^2 - 0,8^2} + 0,8\frac{H_3}{H} \right), \tag{2}$$

where

W = the overall width of the vehicle, m;
H_3 = height of the center of gravity of the vehicle, m;
H = vehicle height, m;
0,8 = minimum height of tipping platform, m.

Using Figure 1, we can determine the height of fall of the center of gravity of the vehicle from the equation:

$$r + h_0 = h + x \tag{3}$$

where

r = distance from the common center of gravity to the outside wheel, segment BG, m;
h_0 = height tipping platform for the case when h_0 > 0,8, Figure 1 - a segment GF, m;
x = distance from the center of gravity of the moment of impact to the surface, segment BC, m.

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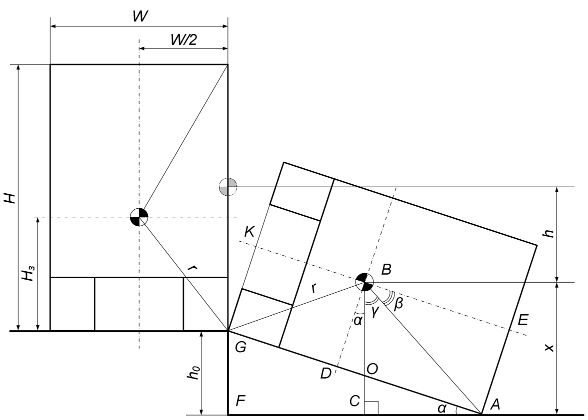

Figure-1. Schematic for determining the height of the fall of the center of gravity.

From equation (3) define the desired value *h*:

$$h = r + h_0 - x \tag{4}$$

The components of r and x and substituting them into equation (4) we obtain the sought value *h*:

$$h = \sqrt{\left(\frac{W}{2}\right)^2 + H_з^2} + h_0 - \sqrt{\left(\frac{W}{2}\right)^2 + \left(H - H_3\right)^2} \times \times sin\left[arcsin\left(\frac{h_0}{H}\right) + arcsin\left(\frac{W}{2\cdot\sqrt{\left(W/2\right)^2 + \left(H - H_3\right)^2}}\right)\right] \tag{5}$$

After determining the height of the fall of the center of gravity of the formula (5) Substituting this value of *h* in the formula (1) and to determine the total impact energy bus rollover:

$$E^* = 0{,}75 \cdot M \cdot g \cdot \left[\sqrt{\left(\frac{W}{2}\right)^2 + H_з^2} + h_0 - \sqrt{\left(\frac{W}{2}\right)^2 + \left(H - H_з\right)^2} \times \times sin\left\{arcsin\left(\frac{h_0}{H}\right) + arcsin\left(\frac{W}{2\cdot\sqrt{\left(W/2\right)^2 + \left(H - H_3\right)^2}}\right)\right\}\right] \tag{6}$$

As can be seen from (1) to reduce the impact energy E^* is possible by reducing the weight of the bus, the acceleration of free fall or drop height of center of gravity. The most promising at the moment is to reduce the height of the fall of the center of gravity of the bus.

To reduce the height of the fall of the center of gravity of the bus will use a device to prevent a rollover accident. [7] The principle of the device is as follows. In the operation of the bus 1 (Figure-2) the current value of the roll angle of the body is determined by the angular position sensor (roll). In the event that the current value of the roll angle of the body becomes equal to or greater than a small amount of critical values of the angle of the slope, the control unit, connect the power supply to the pyrotechnical gas generator. Squib activated, ignites the combustible substance contained in the gasifier.

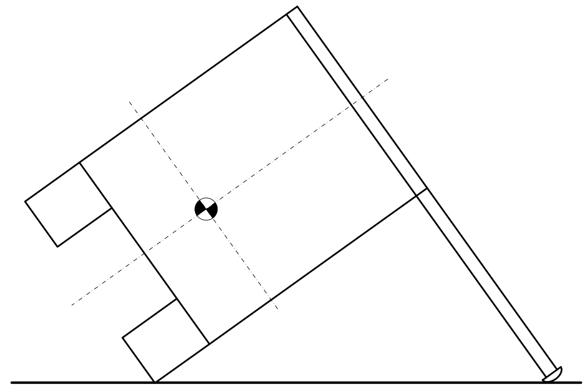

Figure-2. A device to prevent vehicle rollovers.

The resulting gas enters the pneumatic cylinder acts on a piston fixed to the rod 2, and pushes it along with the other attached to its end stop 3. When the piston reaches the end position it is fixedly locked by means of spring retainers.

The bus continues to change its position relative to the longitudinal axis until it touches the stop 3 with the bearing surface of the wheels 4.

Consider the scheme of bus rollover on Rules №66 (Figure-1) and compare it with rollover bus equipped anti-tipping node (Figure-2). Unlike in the presented schemes will be available on the vehicle design elements - 2 rod with a focus 3, change the height of the fall of the center of gravity. In view of the proposed changes, the circuit tipping ECE Regulation №66 for the bus, equipped and unequipped anti-tipping node will be as follows (Figure 3).

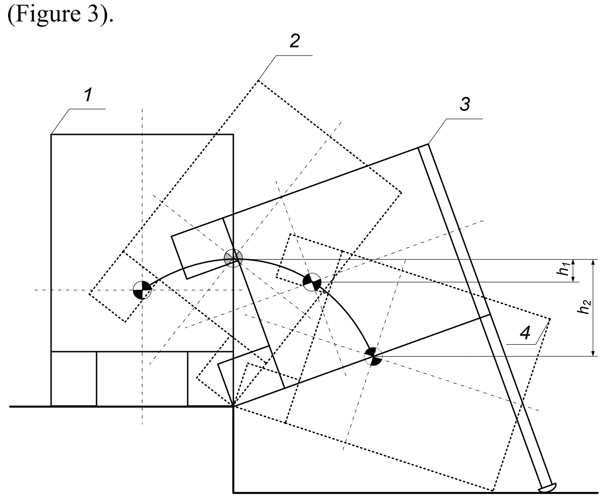

Figure-3. Determination of the height of the fall of the center of gravity of the bus for the calculation of the impact energy on the Rules №66.

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1 – bus in the initial position; **2 –** the center of gravity of the bus maximum distance from the bearing surface of the wheel; **3 –** position of the bus, equipped with anti overturning node in the moment of contact surface; **4 –** position of the bus, unframed anti overturning node in the moment of contact surface; $\boldsymbol{h_1}$ **–** height of fall of the center of gravity of the bus, equipped with anti overturning node; $\boldsymbol{h_2}$ **–** height of fall of the center of gravity of the bus, unframed anti tilting unit.

When you change the initial position of the bus to change the formula for calculating the drop height of its center of gravity. Omitting the derivation of this formula, we give it only in the final version. Fig. 4 is a diagram for explaining a process for determining the drop height *h*, fitted with a center of gravity of the bus device to prevent overturning.

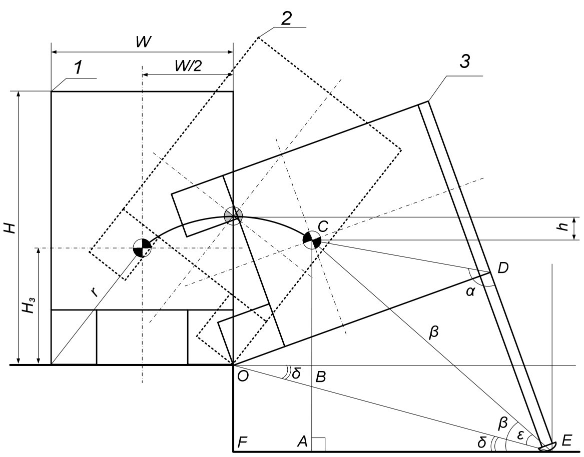

Figure-4. Diagram for determining the height of the fall of the center of gravity of the bus and the angle *β*.

Thus, the drop height of center of gravity of the bus is determined by the formula:

$$h = h_0 + \sqrt{\left(\frac{W}{2}\right)^2 + H_з^2} - \sqrt{a^2 + l_{um}^2 + 2a \cdot l_{um} \cdot cos(arctg\frac{2(H - H_з^{'})}{W})} \times$$

$$\times sin\left[arcsin\frac{h_0}{\sqrt{\left(\frac{W}{2}\right)^2 + H^2}} + arccos\frac{a^2 + l_{um}^2 + 2a \cdot l_{um} \cdot cos(arctg\frac{2(H - H_з^{'})}{W}) + H^2 - H_з^{'2}}{2\sqrt{a^2 + l_{um}^2 + 2a \cdot l_{um} \cdot cos(arctg\frac{2(H - H_з^{'})}{W})} \cdot \sqrt{\left(\frac{W}{2}\right)^2 + H^2}}\right]$$

This formula can be used to calculate the impact energy by the formulas (1), (2) and (6). In the calculations, it should be noted that in the absence of anti-tilting site in the design of the bus length of the rod $l_{um} = 0$.

The study was established:

a) In Russia, the technical regulations laying down requirements for the safety of wheeled vehicles when they are issued into circulation in the territory of the Russian Federation and their subsequent operation. In this case, to the ATS category M3 (buses) passive safety requirements for their design formulated in five UNECE Regulations №№ 14, 16, 43, 66, 80. However, none of these Regulations do not mention the term "Traumatic people", which contradicts third requirements of technical regulations "Minimizing traumatic effects on the occupants by means of people ...” Thus, in respect of buses, with an average capacity of 50 people. In the main document of the Russian Federation - TR "On the safety of wheeled vehicles", there are no requirements governing minimize the traumatic impact on the occupants by means of people.
b) The most significant indicator - "Strength of superstructure passenger vehicles," directly affects the severity of the accident, is regulated by the UNECE Regulation number 66, which contain some inaccuracies.
c) The formula for calculating the height of the fall of the center of gravity does not account for other than rectangular cross-sectional design of bus bodies, in particular the formula provided in the UNECE №66 ignores protrusions anti tipping site.

It is therefore necessary to revise the formula for calculating the drop height of its center of gravity, one embodiment of which is shown in the main part of the work.

d) To reduce the value of the total impact energy is most advisable to begin work on reducing the height of the fall of the center of gravity of the bus.
e) To reduce the height of the fall of the center of gravity of the bus should be offered the use of anti-tipping devices.

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