VOL. 10, NO. 10, JUNE 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

APPLICATION OF THE METHOD OF DISTRIBUTION OF THE TOTAL ENERGY OF IMPACT ON THE BEARING ELEMENTS OF THE BODY OF THE BUS WHEN CALCULATING THE FAILURE LOADS

Kalmikov B. Yu., Ovchnnikov N. A., Kalmikova O. M., Guguyev I. K. and Kushnariva I. V.
The Institute of Service Sector and Entrepreneurship of Don State Technical University, Shakhty city, Russia
E-Mail: NikolaOv@yandex.ru

ABSTRACT

Article is devoted to solving practical problems in the field of passive safety of buses and in particular the definition of the uneven distribution of potential energy from the bearing elements of the body rollover bus on its side. This non-uniformity due to a significant difference axle load bus has an impact on the definition of failure loads arising from the impact of the roof of the bus on the support surface. Group of authors proposed a method of dividing the total impact energy on the bearing elements of the body of the bus and determining failure loads largest crumple bus rollover.

Keywords: bus, passive safety, the potential energy of tipping, strength, body deformation, fracture load.

INTRODUCTION

The car body is an essential element of its passive safety systems. Its level can be assessed by measuring instruments of impact-strength properties. These include the deformation of the car on which it is possible to determine the value of energy consumption, comprising a work vehicle rollover resistance forces and work for their handling in an inverted state. In addition, it is possible to determine the yield stress σ_T, ultimate strength σ_B, the intensity of deformation and ε_{iT} ε_{iB}, corresponding to the yield stress σ_T and strength σ_B, indicators hardening materials making up the damaged parts of vehicles. Finally, to determine the speed of the vehicle at the time of a collision or rollover [1].

Security construction vehicles devoted a lot of work, among them the most important are [2-8]. However, there are a variety of approaches and methods for determining the values of breaking loads bearing elements of the body. Known methods of determining the value of the failure loads for each power section of the body of the bus, with the help of the developed special software.

In this paper, we propose a method to split the total impact energy bus rollover on the main bearing elements of its body, depending on the axle load distribution, and then determine the value of failure loads for the amount of deformation of these elements.

The method involves a phased work.

Stage I: preparation, defining:

- Coefficients of axle load distribution of the bus;
- Coordinates of the center of gravity of the bus;
- The total impact energy of the bus.

Stage II: the distribution of the total energy hitting the pillar of the bus, taking into account the uneven axle load.

Stage III: the calculation of the breaking load of the material body having:

- Rigid-plastic properties;
- Ideal elastoplastic properties.

For calculations require the following inputs:

a) The distance from the reference plane of the wheel to the contact plane of the body, *h*, mm (height tipping).

b) Orientation bus with respect to the coordinate axes:

- plane (x; y) coincides with the reference plane of the wheels;
- Plane (y; z) plane parallel to the front panel of the body and passes through the central portion of the first pillar;
- Plane (x; z) perpendicular to the reference plane and passes through a junction with the sidewall of the bus body floor;
- Coordinates of each rack body side, which overturned bus, x_i, mm, where i - rack number, $x_1, x_2, \dots, x_i, \dots, x_\kappa$ - Projection of points corresponding to the central part of the pillars of the bus of the first enclosure (*1*) to the end (*k*).

VOL. 10, NO. 10, JUNE 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

- Coordinate movement pillars at z_i = 1250 mm the place of installation of seats, y_i, mm.

c) The total mass of the bus, M, kg; and the mass on the rear axle bus $M_з$, kg.

d) Additional geometric parameters of the bus: dimensions, the base, the distance from the center of the front axle to the selected origin.

e) The data obtained from the experiment, non-destructive bus bodies, whose scheme is shown in Figure-1:

- force P, kN;

- moving force F corresponding to 1-2 racks at the front and back of the bus, l_{sti}, mm.

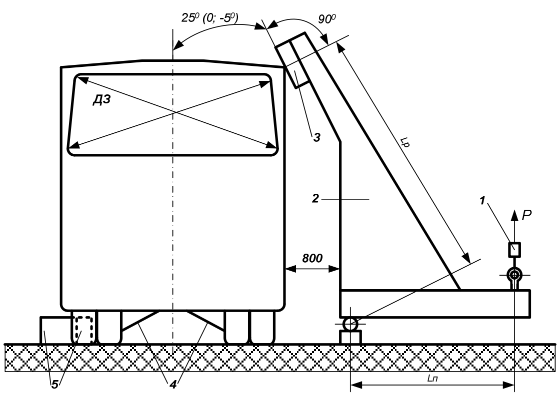


Figure-1. Scheme of loading body of the bus.

1 - force measuring device (cell); 2 - swing frame; 3 - load plate; 4 - device for preventing rotational movement of the bus; 5 - a device to prevent the translational motion of the bus; P - applied force; 800 mm - minimum height of tipping the bus; 25 ° (0, -5) - plane angle at which the force is applied; DZ - controlled during loading diagonal size of the rear window frame

At the first stage, the calculation of coefficients of axle load distribution of the bus:

$$K_{Mз} = M_з/M; K_{Mn} = 1 - M_з/M$$

where
M = the total mass of the bus, kg;
$M_з$ = the mass of the bus, attributable to the rear axle, kg;
K_{Mn}, $K_{Mз}$ = load distribution ratio to the front and rear axles of the bus.

Further determine the coordinates of the projection on the x-axis location of the center of gravity of the bus by the formula:

$$X_{цт} = S + \frac{M_з \cdot L}{M}, \quad (1)$$

Where
S = the distance from the front of the bus to the center of the front axle, mm;
L = bus base, mm.

Find the total energy of impact on the well-known bus [9] formula:

$$E = M \cdot g \cdot \Delta h, \quad (2)$$

where
Δh = the difference between the initial height of the center of gravity of the bus and its position when it touches the roof of the support surface, m. This option should rely on universal formula presented in [10].

The second step is to take into account the unequal distribution of axle loads of the bus, and, respectively, and the impact energy released during a rollover, given that:

$$M = M_п + M_з, \quad (3)$$

where
M_n = the mass of the bus, attributable to the front axle, kg;

Hence, substituting the expression (3) into (2), we obtain:

$$E = (M_n + M_з) \cdot g \cdot \Delta h,$$

or: $E_n = M_n \cdot g \cdot \Delta h$; $E_з = M_з \cdot g \cdot \Delta h$,

where
E_n, $E_з$ = impact energy attributable respectively to the front and rear axles of the bus, J..

Knowing the location of the center of gravity calculated from the formula (1), it can be assumed that the energy is distributed in the interval E_n [0; $X_{цт}$], $E_з$ - ($X_{цт}$; $X_к$], where $X_к$ - coordinate of the central part of the final stand.

The average energy E_{jcp}, of the energy per i rack front or back of the bus is determined by the formula:

$$E_{jcp} = \frac{E_j}{n}, \quad (4)$$

where
E_j = energy per front of the bus when $j = n$ or at the rear of $j = з$;
n = number of racks the body side of the bus j.

Let us consider the energy distribution attributable to the front of the bus E_n. energy distribution $E_з$ will similarly. Let $x_1, x_2, \ldots x_n$ - coordinate points on the

VOL. 10, NO. 10, JUNE 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

X axis, portions corresponding to the projections of the central struts disposed in the interval [0; $X_{цт}$]. then y_1, y_2, ...y_n - the coordinates of points on the axis Y, resulting in deformation struts bus overturns and measured at 1250 mm from the seat installation. Knowing the coordinates of two points and using the equation of the line, it is possible to calculate the values of the unknown values y_i. Далее etermine the average of $\overline{y} = \frac{1}{n}\sum_{i=1}^{n} y_i$ and the value of the absolute error $\Delta y = y_i - \overline{y}$, necessary to determine the coefficient taking into account the uneven distribution of energy pillar of the bus by the formula:

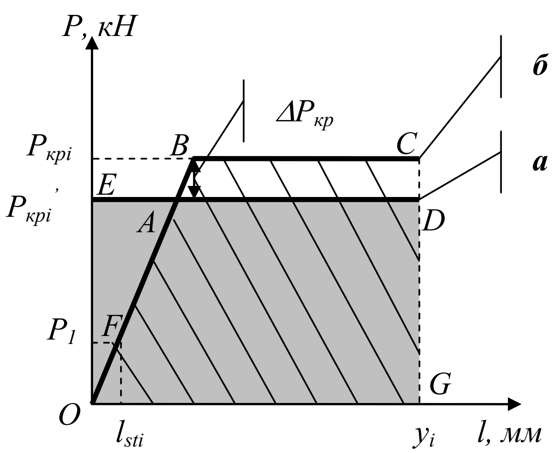
$$Y_i = \frac{\Delta y_i}{\sum_{i=1}^{n}|\Delta y_i|}, \tag{5}$$

Determine the average of E_{jcp} according to the formula (4); we can calculate the adjusted share of energy per each rack by the formula:

$$E_{ji} = E_{jcp}(1 + Y_i). \tag{6}$$

In the third step we define the value of the breaking load $P_{kpi}{}'$ for each rack, made of a rigid material (Figure-2 as a graph):

$$P_{kpi}{}' = \frac{E_{ji}}{y_i}.$$



[grey box] - area of a rectangle OEDG, corresponding strain energy E_{ji} and used to determine $P_{kpi}{}'$; [hatched box] - area of the trapezoid OBCG, corresponding strain energy E_{ji} and used to determine P_{kpi}

Figure-2. Deformation pillars.

a - for a material having a rigid properties; б - for a material with ideal elastoplastic properties

For a perfectly elastic-plastic material (Figure-2 graph-b) breaking load $P_{кр}$ defined by the formula:

$$P_{kpi} = \Delta P_{kpi} + P_{kpi}{}',$$

where

ΔP_{kpi} = the difference between the values of breaking loads $P_{кр}$ и $P_{кр}{}'$. It can be determined by equating the area of a triangle OAE and trapeze ABCD.

$S_{\Delta} = S_{трап}$.

Making simple mathematical operations, can obtain the following quadratic equation:

$$A \cdot \Delta P_{kpi}{}^2 + B \cdot \Delta P_{kpi} + C = 0, \tag{7}$$

where $\mathrm{A} = \frac{l_{sti}}{2 \cdot P_1}$; $\mathrm{B} = P_{кpi}{}' \cdot \frac{l_{sti}}{P_1} - y_i$; $\mathrm{C} = P_{кpi}{}'^2 \cdot \frac{l_{sti}}{2 \cdot P_1}$.

From equation (7) shows that the angle of slope of the line OB affects the location of the point $F(l_{sti};P_1)$. This point can be obtained by static loading of the complete bus on a special stand to force P_1, kN with the measurement of its corresponding movements racks l_{sti}.

Using the information from [11, 12], we define the numerical values of failure loads for the bus ЛиАЗ-5256 (Figure-3).

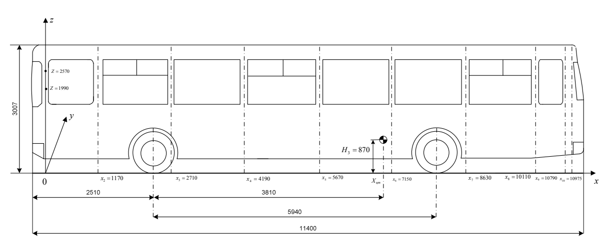


Figure-3. Orientation bus ЛиАЗ-5256 with respect to the coordinate axes.

Initial data for calculations.

a) h = 0,805 m.

Test bus ЛиАЗ-5256 place on ФГУП «НИЦИАМТ» Dmitrov city, and meet the tests regulated UNECE Regulation number 66 (Figure-4).

ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

Figure-4. Bus rollover ЛиАЗ-5256.

The data obtained was drawn up tests presented in Table-1.

Table-1. Test report bus ЛиАЗ-5256 rollover.

No. of rack	The displacement values obtained in the experiment, mm	The permissible displacement, mm	conclusion
Move the rack at 1250 mm from the floor			
2	81,2	350	complies
5	95,8	350	complies
7	151	350	complies
8	195	350	complies

b) The values needed to calculate the coordinates of the points are given in Table-2.

Table-2. Coordinates of points.

No. of rack	1	2	3	4	5	6	7	8	9	10
x_i, mm	0	1170	2710	4190	5670	7150	8630	10110	10790	10975
y_i, mm		81,2			95,8		151	195		
z_i, mm	1990	1990	1990	1990	1990	1990	1990	2570	2570	2570
l_{sti}, мм		3,6					13,6			

c) M = 17930 кг; Mз = 11500 kg.
d) H = 3007 mm; W = 2500 mm; L = 5940 mm; S_1 = 2510 mm.
e) P_1 = 33 kN; l_{st1} = 3, 6 mm, l_{st2} = 13, 6 mm.

For the raw data $P_1(l_{sti})$ an experiment was conducted associated with static loading bus body (Figure-5). При implemented this measure and record the load, displacement and stress in the stands of the body.

Figure-5. Loading bus body ЛиАЗ-5256.

Using a program for calculating the breaking load, we obtain the following values shown in Table-3.

As can be seen from the diagram shown in Figure-6, the most "weak" rack stand is №1. This is due to the fact that in contradiction included two requirements: visibility from the driver's seat and the structural strength of the body. In turn, stand №1 lowers the breaking load rack No.2.

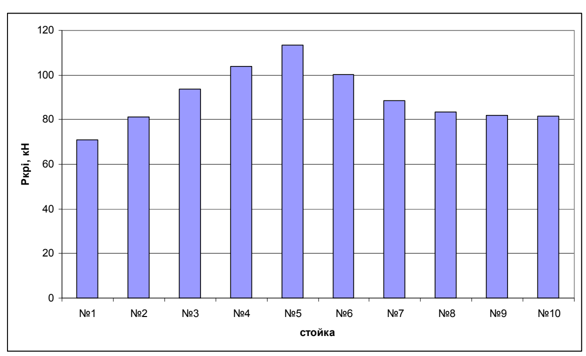


Figure-6. Distribution of failure loads on racks sidewall.

VOL. 10, NO. 10, JUNE 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

Table-3. Результаты расчетов.

No. of rack	1	2	3	4	5	6	7	8	9	10
x_i, mm	0	1170	2710	4190	5670	7150	8630	10110	10790	10975
y_i, mm	77,4	81,2	86,2	91	95,8	107	151	195	215,2	220,7
z_i, mm	1990	1990	1990	1990	1990	1990	1990	2570	2570	2570
P_1, kN	33,0									
l_{sti}, mm		3,6					13,6			
$X_{цт}$, mm	6320									
Parts of the body	anteroom					Rear				
Y_i	-0,315	-0,181	-0,004	0,165	0,335	-0,363	-0,137	0,088	0,192	0,22
ΣY_i *	0					0				
E_{ji}, J.	5219	6240	7584	8875	10167	8681	11753	14824	16235	16619
ΣE_{ji}, J.	38084					68112				
E_{jcp}, J.	7616,7					13622,4				
$P_{кpi}'$, kN	67,4	76,8	88	97,5	106,1	81,1	77,8	76	75,4	75,3
$\Delta P_{kpi\,1}$, kN	3,5	4,4	5,5	6,5	7,3	19,5	10,7	7,3	6,4	6,2
$\Delta P_{kpi\,2}$**, kN	1281	1331	1399	1467	1537	337	566	787	887	914
$P_{кpi}$, kN	71	81,3	93,5	104	113,5	100,1	88,5	83,4	81,9	81,5

* One of the conditions, confirming the validity of the assumptions is Σ = 0 of formula (5).

** The second root of the quadratic equation (7) $\Delta P_{kpi\,2}$ does not meet condition $P_{кpi}' > \Delta P_{kpi}$.

Despite the rather rigid structure of the rear, rack No.8, No.9, No.10, also show low values of breaking loads ≈ 80 kN. In this case, the weakening of the structure due to the layout diagram of the bus LiAZ 5256, in which the power plant is located in the rear overhangs. The central portion of the bus rack No.3- No.7 is stronger and, consequently, a place for passengers located therein will be safer from the point of view of the passive safety bus.

The study developed a method of distribution of the total energy of impact on the bearing elements of the body of the bus and determining failure loads largest permanent deformation of the body of the bus rollover.

The analytic dependence of failure loads and power consumption on the geometric and physical characteristics of the material body in a bus rollover. New results of research on the bearing capacity of bodies breaking load, deformability and energy.

The estimation of passive safety of the bus and the impact of design decisions on its increase.

REFERENCES

[1] Пат. 2275612(13) Российская Федерация МПК G01M 17/007 (2006.01) Способ определения скоростей движения транспортных средств при столкновении / В.П. Байков, В.Б. Киселев, К.А. Люберский. - № 2001105490/28; заявл. 01.03. 2001; опубл. 27.04.2006 г., Бюл. № 12. - 16 с.: ил.

[2] Karliński J., Ptak M., Dzialak P., Rusiński E. 2014. Strength analysis of bus superstructure according to Regulation No. 66 of UN/ECE. Archives of Civil and Mechanical Engineering. 14(3): 342-353.

[3] Gepner B., Bojanowski C., Kwasniewski L., Wekezer J. 2014. Effectiveness of ECE R66 and FMVSS 220 standards in rollover crashworthiness assessment of paratransit buses. International Journal of Automotive Technology. 15(4): 581-591.

[4] Li Z., Xiao Y., Zhu W. and Zhao H. 2013. The safety of body structure and occupant protection research of medium bus under three kinds of frontal impact forms. Volume 197 Lecture Notes in Electrical Engineering. Issue Vol. 9, pp. 279-292. Code 99825.

ARPN Journal of Engineering and Applied Sciences

[5] Jeyakumar P.D., Devaradjane G. 2012. Improvement of the frontal structure of a bus for crash accidents. ASME International Mechanical Engineering Congress and Exposition, Proceedings (IMECE). 11: 183-187. Code 100737.

[6] Wang R., Zhang X.-Y., Feng H., Chen J.-G. 2014. Simulation and improvement of bus rollover against barrier. Zhendong yu Chongji/Journal of Vibration and Shock. 33(6): 40-43.

[7] Genta G., Morello L. 2009. Automotive chassis. [Text]: Vol. 1: Components design // Springer, p. 621.

[8] Genta G., Morello L. 2009. Automotive chassis. [Text]: Vol. 2: System design // Springer, p. 825.

[9] ГОСТ Р 41.66-00 (Правила ЕЭК ООН № 66) Единообразные предписания, касающиеся официального утверждения крупногабаритных пассажирских транспортных средств в отношении прочности верхней части конструкции. – Введ. 26 мая 1999 № 184-ст. - М: ИПК Изд-во стандартов, 2000. - 19 с: ил.

[10] Калмыков Б.Ю., Высоцкий И.Ю., Овчинников Н.А. Устройство для повышения безопасности конструкции автобуса при опрокидывании. Известия высших учебных заведений. Северо-Кавказский регион. Серия: Технические науки. 2012. № 5. С. 59-65.

[11] Краткий автомобильный справочник / А.Н. Понизовкин, Ю.М. Власко, М.Б. Ляликов и др. - М: АО «ТРАНСКОСАЛТИНГ», НИИАТ, 1994. - 779 с.

[12] Иванов А.М. Прочность кузовов автобусов. Монография / А.М. Иванов, И.Н. Порватов, Б.Ю. Калмыков. - М-во образования Рос. Федерации. Юж.-Рос. гос. ун.т экономики и сервиса. Шахты, 2004. - 148 с.