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THE REDUCTION OF VERTICAL AND HORIZONTAL OSCILLATIONS OF ARTICULATED LORRY BY DEVELOPING A RATIONAL TOWING MECHANISM

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The Reduction of Vertical and Horizontal Oscillations of Articulated Lorry by Developing a Rational Towing Mechanism

General Description of Work

Topicality of Research. Increasing efficiency of lorries and towing trucks is possible: a) by improving road pavement, and b) by improving efficiency of lorry itself as well as its smooth ride. Improvement of road pavement is an expensive process and requires much time and costs, especially in such countries, which are distinguished by a challenging terrain like our country. Based on this, preference is given to the second option – improvement of smooth ride. One of the best tools for improving smooth ride of the articulated lorry is the effective change in the design of lorry and trailer, and one of these tools is the creation of a new zero-clearance design of towing mechanism and effective selection of the elastic damping elements. To achieve this, it is necessary to consider the complex loads (vertical, longitudinal, transversal and angular) acting reasoning from the road conditions. In this regard, the works of Yatsenko, Rotenburg, Khachaturov, Belenko are worthy of note. However, they are theoretical and understudied and concern the automobile itself, but the impact of trailers, in this respect, is even more understudied. In this case, the selection-test was carried out theoretically on the computer for the purpose of process accelerating, and then in laboratory conditions for data qualification purposes, and finally – experimentally in natural road conditions.

The proposed dissertation work is a follow-up to those works, which were performed at the Department of Civil Engineering and Transport of the Akaki Tsereteli State University in Kutaisi and at the proving ground in Dmitrov City (Russia).

Goal of Research. Improving running conditions of articulated passenger car, as well as protecting the driver, passengers and transported cargo from the vibrations arisen from the road conditions that is manifested in the creation and use of towing mechanism, which is aimed at reducing loads coming from trailer to the vehicle.

Research Subject. Improving running conditions of articulated passenger car, excluding incidents of accidents and increasing the average running speed.

Objectives of research:

1. To analyze and study the performed works related to the motion capacity and articulated passenger cars, as well as the impact of various types of oscillations on the human body and on its every organs.
2. To select, check and specify the dimensions and characteristics of the elastic damping elements.
3. To develop a zero-clearance coupling of a towing hitch for a new effective trailer.
3. To provide justification and efficiency of using promising trends of passenger car trailers.
4. To justify the improved running conditions reasoning from a new towing mechanism.
5. To provide efficiency of increasing road conditions safety reasoning from a new towing mechanism.

Research novelty:

1. Establishing and justifying the demand and the need for the use of coupling unit for the proposed trailer.
2. Justifying their efficiency in running conditions.
3. Developing a new towing zero-clearance coupling design and its drawings, and making of metal.
4. On the basis of theoretical study, defining the elestic-damping characteristics of the elements used, specifying them through laboratory investigations and justifying by conducting experimental trial.
5. Giving the relevant guidelines and recommendations relying on the results of research.
6. Determining and justifying theoretical, laboratory and experimental directions of research, as well as their comparing.

Practical significance of research:

- Defining the characteristics of the elestic-damping elements at the initial stage of designing coupling unit of trailer, based on the theoretical investigation, reasoning from the weight and other parameters of trailer and for the purpose of time and cost saving.
- Based on laboratory trials, selecting the best ones from the industrial elements chosen for the purpose of road test accelerating
- Justifying efficiency of their use through the road testing from an economic and ergonomic points of view.
- Determining beneficial and negative impacts of a zero-clearance coupling of hitch unit, and providing their development.
- Based on the analysis, determining the possibility of alternation of road laboratory investigations with the theoretical ones, and their efficiency with relation to time and cost.

Practical bearing of research:

The results of the proposed dissertation will be applied in the future investigations.

A new towing coupling unit was used by the author for the trailer of a single-axle and biaxial small-sized 4*2-type tractor.

They will be also used in training process at the Department of Civil Engineering and Transport of the Akaki Tsereteli State University.

Approbation of the results of research. The main provisions and results of the proposed dissertation work were presented at various scientific conferences and forums: at the annual technical seminar of the Engineering Faculty of the Akaki Tsereteli State University (Kutaisi, in the years of 2012, 2013 and 2015), at the International Scientific-Technical Conference MOTAUTO"2008 (Sofia, Bulgaria, 2008), in the monthly scientific-reviewed journal of the Georgian Academy of Sciences (N7-9,,N10-12. 2009), at the II International Conference "Non-Classial Problems of Mechanics" (Kutaisi, Akaki Tsereteli State University, 2012), in the "Messenger" N2 2013 of the Akaki Tsereteli State University and in "Georgian Engineering News (N2 2012) of Georgian technical University.

Publications. 22 scientific publications have been made on the dissertation topic, including 5 publications in reviewed editions, which are included in the list approved by the Dissertation Council.

Volume and Structure of Dissertation. Dissertation includes five chapters, general conclusions, list of references and comprises 123 pages of text and 56 drawings. The list refer ences comprises 176 sources.

Chapter 1 of dissertation refers to the review of works related to the proposed topic. There is given their analysis and made the relevant conclusions.

The road tests have shown that longitudinal loads in a less degree depend on speed fluctuation (approximately 3-5%), and they make up 60-80% of vertical oscillations, and sometimes exceed them.

The analysis of the reviewed works gives the following picture: during the movement of vehicles, there are arisen not only vertical, but longitudinal and angular oscillations, which affect the driver's working conditions and smooth ride. Due to the complexity of the experimental investigations, it is often impossible to confirm theoretical results of research through the road tests. Due to this, the use of the accessible engineering methods for developing optimal characteristic of a human vibro-protective system still remains of current interest. To this end, it is necessary to envisage the dynamic properties of human body and its sensitivity to the vibrations.

Despite all above said, longitudinal oscillations are not studied enough so far, but the impact of trailer on a vehicle, reasoning from its towing unit design and characteristics of the elastic element mounted inside it, even cannot allow us for its complete assessment. In this regard, the works are especially poor for studying the passenger car trailers. The standard provides minimum limiting sizes between the driver and control gear. However, for improving smooth ride of articulated lorry, it is not enough just to work out the recommendations. For each particular case, it is necessary to choose the optimal options of articulation of vehicle and trailer. Based on all above said, the goal of a given work is to reduce longitudinal-vertical vibro-loads and improve smooth ride by improving the trailer's towing mechanism design and characteristics of the elastic damping characteristics, where the more advanced searching method will be used and peculiarities of the oscillation process will be studied, in respect to both vertical and longitudinal directions, which affect the vehicle and trailer design in road conditions. The goal of the dissertation work is to create a towing mechanism, which will

Chapter 2 dwells on developing a rational towing mechanism of passenger car, and describes two designs of longitudinal-horizontal zero-clearance towing mechanism, from which, based on the analysis, there is chosen the best one **Fig. 1. Fig. 2**. The trailer's coupling unit consists of: vehicle's bunton (1), which by means of nut is connected with a hook (3),

which in turn, comprises a shaft (4), where a sphere (5) is located in a socket (6) placed upon its end by means of pin (7), which involves a staple (8) and a location hole (9), and is connected with a fork (10), which in turn, comprises a shaft (11), which bears the thrust-guide wheels (12) with a rubber element (13), which is secured with it and in a cylinder (14) pin-connected with it, which during operations is compressed by a screw-cylindrical thrust tube (15) and step-plate (16). The design is connected with trailer by means of U-shaped girders of a pole (17).

The trailer's coupling unit works in following way: during coupling, a fork (10) is slipped over a hook (3) and closed by means of pin (7). During operations, a sphere (5) turns inside its socket (6) in all three planes at a set up angle. But according to a sign of longitudinal load, a rubber element (13) is compressed by means of a screw-cylindrical thrust tube (15) and step-plate (16), which in turn, move with the thrust-guide wheels (12), fork (12) and a shaft (11) slipped over it.

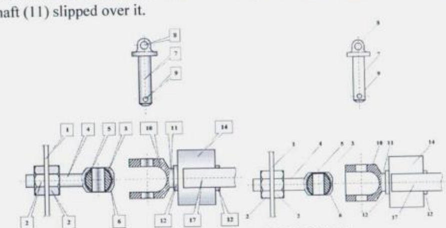


Fig. 1. A zero-clearance hooked-forked joint

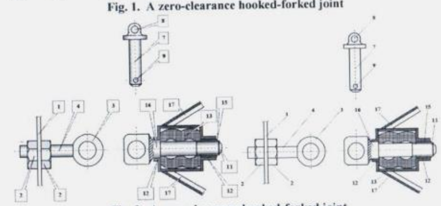


Fig. 2. A zero-clearance hooked-forked joint

There have been made the relevant conclusions for maximal reducing influence of loads coming from trailer to the vehicle and maximal exclusion of hits. There have been also developed two versions of zero-clearance spherical-articulate towing mechanisms, after their comparing and analysis, the preference was given to the second version.

1. Due to the effective elastic damping property, three types of a rubber pillow were chosen as an elastic damping element working in similar conditions;
2. In order to ensure partial damping of loads coming from trailer inside trailer itself, and in order for the load coming from it to be relatively small, it has been decided to place a damping element inside a pole that should hypothetically provide considerable reduction in longitudinal loads acting from a vehicle's trailer and transversal repulsion force that is of high importance for maintaining the vehicle stability.
3. Connecting the trailer brake with a towing mechanism allows providing the condition for making less possible jackknifing of the vehicle and trailer toward each other and reducing the impact force coming from trailer to the vehicle.

Chapter 3 describes investigation of vertical and horizontal oscillations of a passenger car trailer and a design model of vertical and horizontal oscillations of trailer.

When composing the equations, in accordance with works the assumption have been made as follows:

- articulated lorry and road are symmetrical with respect to the longitudinal-vertical plane, which passes through its gravity center;

- oscillations of the vehicle and trailer towards each other are insignificant;

- the road wheel contact is a point one;

- mathematical expectation of articulated lorry velocity is constant and equals to its driving speed.

- The first assumption allows us for composing a plane mathematical model for articulated lorry.

- The second assumption excludes the members, which have a small effect of the second order on the main coordinates and speed, and besides, this enables us to replace the body till describing trigonometric functions by small angles themselves.

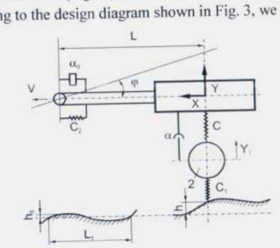
- The tird assumption allows us for excluding the leveling (straightening, smoothing) nature of a tire, which envisages the action of the road.

- The fourth assumption allows us for ignoring speed fluctuation and speed inequalities caused by spinning masses, as well as longitudinal-vertical oscillations occurring between trailer and vehicle, with regard to equilibrium position.

The general mathematical design diagram for articulated lorry is composed in accordance with the appropriate assumptions.

In passenger cars, there are mostly used trailers with a single axle, and its mathematical model is (Fig. 3.), but the equations of motion are.

According to the design diagram shown in Fig. 3, we will obtain:



$$h=h_0[1-\cos(2\pi x/L_1)]$$

(Fig. 3.)

$$\begin{aligned}
&I_o\ddot{\varphi}+\alpha l^2\dot{\varphi}+cl^2\varphi+cly-cly_1+\alpha l\dot{y}-\alpha l\dot{y}_1=0\\
&m_1\ddot{y}_1+\alpha\dot{y}_1+(c+c_1)y_1-cy-cl\varphi-\alpha\dot{y}-\alpha l\dot{\varphi}=c_1h\\
&m\ddot{x}+\alpha_o\dot{x}+c_2x=c_2x_{CT}\\
&m\ddot{y}+\alpha\dot{y}+cy+\alpha_1\dot{\varphi}-\alpha\dot{y}_1+cl\varphi-cy_1=0
\end{aligned} \tag{1}$$

As a result of a number of transformations, there is presented the equation system in a vector-matrix form:

$$\dot{Z}+AZ=B \tag{2}$$

where, $Z=(Z_1,Z_2,Z_3,Z_4,Z_5,Z_6,Z_7,Z_8)^T$

$$\begin{aligned}
&\varphi=z_1,\ \dot{\varphi}=z_2,\ \dot{y}_1=z_3,\ \dot{\bar{y}}_1=z_4,\\
&\bar{x}=z_5,\ \bar{x}=z_6,\ \bar{y}=z_7,\ \dot{\bar{y}}=z_8
\end{aligned} \tag{3}$$

$$A=\begin{pmatrix} 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0\\ \frac{P_{0}^{2}}{P_{10}^{2}} & \frac{2n}{P_{10}} & -\frac{P_{0}^{2}}{P_{10}^{2}} & -\frac{2n}{P_{10}} & 0 & 0 & \frac{P_{0}^{2}}{P_{10}^{2}} & \frac{2n}{P_{10}}\\ 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0\\ 1 & -\frac{2n_{1}}{P_{10}} & \frac{P_{10}^{2}+P_{20}^{2}}{P_{10}^{2}} & \frac{2n_{1}}{P_{10}} & 0 & 0 & -1 & -\frac{2n_{1}}{P_{10}}\\ 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0\\ 0 & 0 & 0 & 0 & \frac{P_{2}^{2}}{P_{10}^{2}} & \frac{2n_{0}}{P_{10}} & 0 & 0\\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1\\ \frac{P^{2}}{P_{10}^{2}} & \frac{2n_{00}}{P_{10}} & -\frac{P^{2}}{P_{10}^{2}} & -\frac{2n_{00}}{P_{10}} & 0 & 0 & \frac{P^{2}}{P_{10}^{2}} & \frac{2n_{00}}{P_{10}} \end{pmatrix} \quad (3) \qquad B=\begin{pmatrix} 0\\ 0\\ 0\\ \frac{P_{20}^{2}}{P_{10}^{2}}\bar{h}\\ 0\\ \frac{P_{2}^{2}}{P_{10}^{2}}\bar{x}_{CT}\\ 0\\ 0 \end{pmatrix} \quad (4)$$

The initial condition is: $Z(0)=(0;0;0;0;0;\bar{v};0;0)^{T}$ (5)

The system of (2) equations with the initial conditions is solving by Runge-Kutta method in a Matchad system, there are given the appropriate diagrams.

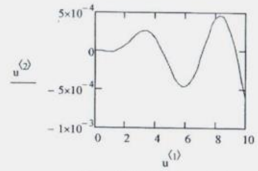


Fig. 4. Pole-till angle variation

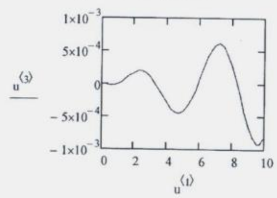


Fig. 5. Pole-till angle center variation

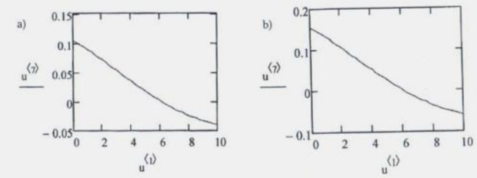


Fig. 6. Variation of longitudinal displacement speed of trailer gravity center:
a) v= 10 km/h; b) v=30 km/h

The same problem was examined by computer-based simulation method with the following conditions, when V=30km/h and unit disturbance is 0,01m.

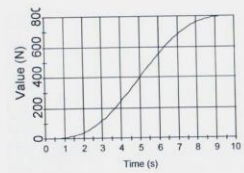


Fig. 7. Load characteristics for Fig. 8. and Fig. 9.

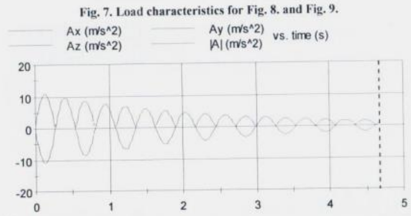


Fig.8. Longitudinal acceleration of the connecting rod eye of the experimental trailer. Trailer has the rubber element (single-piece resistance 0,1m C=0.6*10^5 K=0,4*10^3)V=30km/h

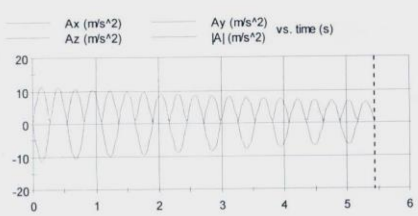


Fig. 9. Longitudinal acceleration of the pole ring of the experimental trailer. Trailer has no the rubber damper (single-piece resistance 0,1m C=0.6*10^5 K=0,1*10^3)V=30km/h

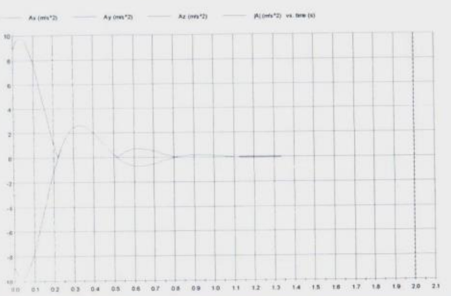


Fig. 10. Longitudinal acceleration of the connecting rod eye of the experimental trailer. Trailer has the rubber element (forced sinusoidal excitation C=0.6*10^5 K=0,4*10^3). Longitudinal axle of trailer near the longitudinal axle of the vehicle creates an angle of 15 degrees. V=90km/h

As follows from the analysis, the following conclusions have been made:

1. Clearance increase in a trailer's coupling unit causes increasing longitudinal loads.
2. Variation of the characteristic of the elastic damping element in a coupling unit causes a non-uniform effect on a trailer displacement amplitude, in particular: the higher is a mechanical compliance, i.e the lower is rigidity, the lower are the impacts, but displacement time of trailer goes up. In other words, the dynamics of speed development deteriorates. Thus, it is not recommended to reduce it below the limit of rigidity (C=0,32.10^5 n/m, α_0=2,83.10^3 sec/m).
3. The excessive hardening causes increasing impact values during braking and displacement (i.e. increases the dynamic loads in a coupling unit).
4. An increase of speed of hauling plant causes increasing longitudinal speed of trailer gravity center at an initial moment, but at the end of the 10th second their values are almost identical for all speeds of hauling plant.

Chapter 4 dwells on studying the elastic-damping elements of a passenger car coupling unit. To this end, it is necessary to:

- determine the elastic static characteristic of the elastic element;
- determine the dynamic elastic-damping characteristic;
- determine the vibro-protective characteristic, and reasoning from them, there is determined the transition factor for a given coupling unit.

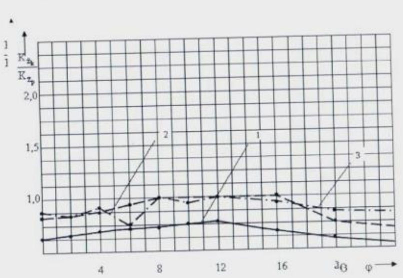


Fig.11. The transition factors of a new version of coupling unit 4
1. The rubber element of a carriage spring motion catch device of KAZ-4540. 2. The rubber element of a carriage spring motion catch device of KAZ-608. 3. Two barrel-contoured elements.

As follows from the analysis, it has been established that:

1. Reasoning from the load conditions similar to our case, there have been selected three versions the elastic damping elements of towing mechanism. These elements are the rubber element of KAZ-60, which is used in a cushioning catch device, a carriage spring motion catch device of KAZ-4540 and two barrel-contoured rubber elements, which in addition to fact that they work in almost similar conditions like in our case, satisfy all those conditions, which they are expected to meet, and one of them regards their overall dimensions as well.

2. Laboratory investigations have shown that from the selected elements, the best result is produced by the rubber element of KAZ-4540, as well as in case with two barrel-contoured elements, when the air-gap distance corresponds with the amount of air-clearance d=1,5 mm. However, the test has also shown that it must not be treated that the air-gap distance of a constant amount corresponding with d=1,5 mm cannot be optimal for all conditions. Also, it should be noted that in case of a constant clearance, the rubber element rigidity, damping and other characteristics are almost constant, since its variation is provided by the air-gap distance variation in accordance with loads. It appeared that it is desirable that the amount of clearance should vary within the limits corresponding with the air-gap distance d=0,5...2,5 mm. Variation below or above it does not produce the anticipating results.

3. Laboratory trials carried out at the proving ground in Dmitrov City have shown that the characteristic of the transition factor of the rubber element of a carriage spring motion catch device of KAZ-4540 is considerably better than with other two elements that is explained by the advantage of its interior volume, and due to which its better damping characteristic is conditioned.

4. If we compare theoretical investigations reviewed in the previous chapter with laboratory trials, we should note that the elastic-damping characteristics of the mentioned three elements match each other with high enough accuracy, in other words there is confirmed again expedience of their use. In other words, we can replace laboratory trials by theoretical investigations.

The following conclusions have been made as a result of research and analysis the fourth chapter:

1. Reasoning from variability of the rubber element and air-gap distance, the

created design has a good capacity to reduce the impacts coming from trailer to the vehicle, which are arisen due to variability of the appropriate road loads.
2. The bench-test methodology allows for determining the elastic-damping and vibro-protective characteristics for the elastic-damping element of towing mechanism in accordance with the air-gap distance;
3. The bench-tests carried out enabled us to confirm that the elastic-damping characteristics of the element vary in accordance with the amount of air-gap distance. In particular: a) its reducing to d=2,5-0,5 mm increases its rigidity and damping rate 2-4,5 times, in accordance with a type of the rubber element; b) the rubber elements with air-dampers have the best characteristic, when their clearance corresponds with d=1,5 mm, however, the better result is produced if it is possible to change it in accordance with its load;
4. From various testing versions, the best result is produced towing mechanism with two barrel-contoured elements and the rubber element of a carriage spring motion catch device of KAZ-4540. But the laboratory trials carried out at the proving ground in Dmitrov City have shown that the characteristic of the transition factor of a carriage spring motion catch device of KAZ-4540 is considerably better than in case with other two ones.

Chapter 5 describes the road experimental trail of articulated passenger car and the methodology of road experimental trial.

The road experimental trials were carried out at the proving ground in Dmitrov City and in Kutaisi surrounding territory. The tests were carried out on a passenger car (with the engine size 1,5 l) with trailer and without it. Full weight of trailer was 450 kg. Test was carried out in different road conditions, in vertical, longitudinal and transversal directions, in accordance with loads recommended by the production plant. The vehicle and trailer were prepared before testing by observing all required conditions. In particular, the vehicle and trailer have been checked before testing and undergone the break-in.

The data recording and transmitting instruments were installed in full compliance with the rules.

For the road experimental trial, the following roads will be selected:

- asphalt (dynamometric) road with a length of 2000 m;

- normal paving road with a length of 1000 m;
- special-profile paving road with a length of 500 m;
- earth road with a normal profile with a length of 1000 m;
- mountain road with a length of 1000 m.

During recording, the attention was paid to breakaway-braking and transient rating. The values of speeds have been selected in accordance with the appropriate roads.

During the road experimental trial of trailer, the records were made on the acceleration dispersion and mean square value of acceleration at the following points:

1. At the gravity center of trailer in both vertical z and longitudinal x directions;
2. Under the car's rear seat on the floor (with and without trailer) in all directions (x, y, z);
3. Under the car's driver seat on the floor in all directions as well.

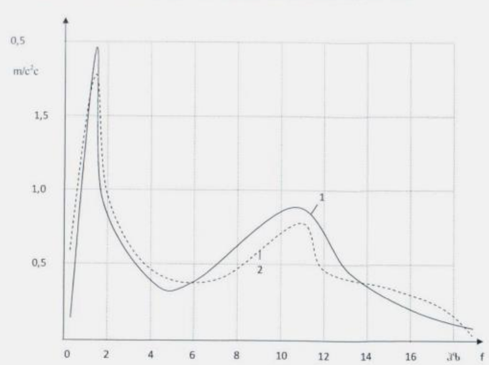


Fig.12. Acceleration spectral density of asphalt road V=90 km/h, Commercial trailer:
1-trailer gravity center (vertical);
2- trailer gravity center (longitudinal);

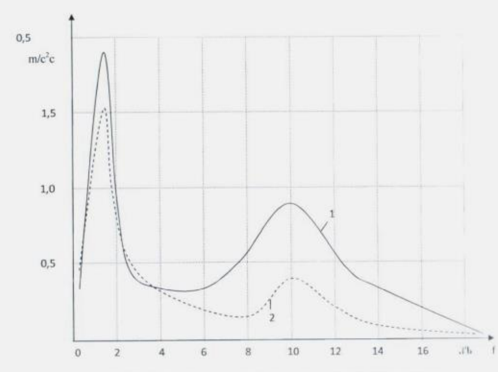


Fig. 13 Acceleration spectral density on the asphalt road V=90 km/h, Experimental trailer, with the rubber element of KAZ-45-40 :
1- trailer gravity center (vertical);
2- trailer gravity center (longitudinal).

Fig.14 illustrates the transition factor diagrams in a longitudinal direction from trailer to the vehicle for both commercial and experimental trailer with the rubber element of KAZ-4540. The transition factor is one of the most obvious good tools of evaluation. Within the low-frequency range 0-1,4 hertz, the best, or in other words, a little lower transition factor has the commercial design, but within the range of 1,4-16 hertz – the experimental design is better within all ranges that is clearly seen and as was expected. It should be noted that within the range of 4,5-8 hertz, the experimental towing mechanism design with the rubber element of KAZ-4540 reduces loads almost by 50-65% that confirms validity of the results obtained at previous graphs 12,13 as well as proves the view mentioned in the above noted works.

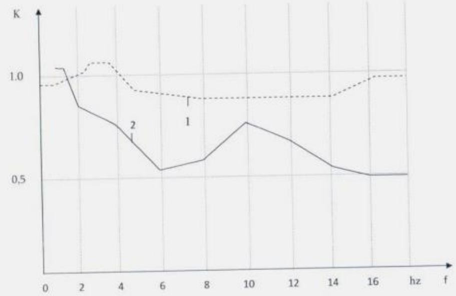


Fig.14. The transition factors acting from the commercial and experimental trailer to the vehicle
1. with commercial trailer;
2. with experimental trailer

Conclusions followed from Chapter 5

1. The road experimental trial has shown that longitudinal oscillations constitute 50-60% of vertical ones, and sometimes exceed them.
2. The road experimental trial has shown that a new design of trailer's coupling unit is effective on longitudinal loads and reduces them by 30-50%.
3. A new design leads to reducing vertical loads in the pole by 2-6% that with zero-clearance connection and in the pole of the elastic damping element is caused by the transition.
4. It reduces repulsion transversal force acting on the vehicle and excludes jackknifing of trailer and vehicle.
5. The transition factor in longitudinal direction within all ranges is better except for low frequencies (0-1,6 hz.

The main conclusions.

1. In respect to longitudinal oscillations, there have been found and reviewed the different papers of scientists on articulated lorries. There have been established their topicality, effect on a human organism as well as the necessity of their further studying.
2. There has been developed a new design of a coupling unit for r educing longitudinal loads acting from trailer to the vehicle by using the elastic damping rubber elements and efficient braking system of trailer, which excludes jackknifing of trailer and vehicle.
3. Through laboratory tests, here have been established the elastic damping characteristics of the elastic elements as well as the transition factors for the different cases with the air gap. Also, there has been selected the elastic-damping commercial element.
4. There have been developed a mathematical model of trailer corresponding with longitudinal-vertical loads. Also, there have been determined the values and parameters of this mathematical model. Theoretical investigations have been carried out and solved in Mathcad system in dimensionless coordinates. Also, there has been carried out theoretical computer-based investigation by simulation method.
5. It has been established through theoretical and experimental investigations that reducing the values of longitudinal loads acting on the vehicle from traiuler by using a new towing mechanism is possible within the low-frequency range by 18-23%, where a peak was displaced to the left into the 1,4-hz zone, but within the high-frequency range of 4-6 hz the effect is relatively lower and constitutes 8-15%.
6. The road experimental trial has shown that a new design of trailer's coupling unit is effective not only on longitudinal loads, but it also reduces vertical ones by 2-6% that is explained by a zero-clearance joint and transition of the eleastic damping element into the pole. Also it reduces repulsion transversal force acting on the vehicle and excludes jackknifing of trailer and vehicle.
7. Comparison of theoretical and experimental investigations has shown that the difference between them within the low-frequency range is 10-15% that allows us for concluding that for the purpose of reducing testing time and cost, it is expedient to use the above mentioned both methods of theoretical research.

8. The experimental trias carried out in real road conditions have shown:
   - the transition factors from trailer to the vehicle within the range of 6-14 hz is by 40-50% lower comparing with the commercial version within the high-frequency range, where the vehicle moves on the asphalt road at speed of 90 km/h
   - but for the same conditions, within the frequency range of 4-6 hz, it is better to use the experimental one is better and the difference is 30-38%.
   - for the low-frequency range, the ratio is as follows: within the range of 0-1,6 hz, the commercial one has the characteristic better by 2-9%;
   - but over the 1,6 hz, the experimental one is better by 11-27%.

The main results and recommendations

1. Longitudinal and angular loads affect seriously the vehicle and smooth ride, stability of vehicle and safety of articulated lorry. Thus, they cannot be ignored and must be taken into account when calculating the elastic-damping element of its towing mechanism.
2. Transition of the elastic-damping element into the pole is effective with a view to fact that longitudinal and transversal oscillations are damping in trailer itself, that results in increasing longevity and comfort of vehicle.
3. Transition of the elastic-damping element into the pole excludes partially jackknifing of trailer and vehicle.
4. Connecting the elastic-damping elements with a braking system of trailer causes braking of trailer in such extent that prevents their jackknifing.
5. The computer-based theoretical investigations agree so closely with the road ones that it is recommended to be used that reduces 10-12 times the required time and cost.
6. A new design allows for increasing the average running speed of articulated lorry that increases cargo turnover, reduces time of transportation and results in significant cost saving.