Materials Physics and Mechanics 41 (2019) 111-115 Received: January 31, 2018

INFLUENCE OF LCV BEARING STIFFNESS ON ITS STATIC AND DYNAMIC CHARACTERISTICS OF STABILITY AND STEERABILITY

Anton V. Tumasov[1*], Sergey Y. Kostin[1], Danila A. Butin[1], Aleksey A. Vasiliev[1], Pavel V. Sereda[2]

[1]Transport Systems Institute, Nizhny Novgorod R.E. Alekseev State Technical University

Minin Street 24, Nizhny Novgorod, 603950, Russian Federation

[2]Co Ltd. "Automobile plant "GAZ", Lenin Avenue 88, Nizhny Novgorod, 603004, Russian Federation

*e-mail: anton.tumasov@gmail.com

Abstract. Study of the frame stiffness influence on vehicle dynamics and stability of light commercial vehicle is done. The simulations were conducted by using ADAMS/CAR software package. The model approbation was carried by comparing the results of simulation and real tests. The objects of the studies were four different models of a vehicle having different parameters of the frame rigidity. For the needs of the research where conducted such tests as: "going into corner", "line change" and "tilt test". The results showed that a car with a rigid frame has better handling properties.

Keywords: frame stiffness, handling, stability, roll over, vehicle dynamics

I. Introduction

In order to improve drivability of a designed vehicle, manufacturers often try to increase torsional stiffness of a bearing system. Lately it has become to evolve a class of light commercial vehicles which have good handling qualities like light cars and have loading capacity comparable to trucks. While simulating the light car behavior for the purposes of stability control, the stiffness of their supporting systems is usually not accounted. This parameter can be ignored because of high stiffness together with low center of gravity and light weight. But a usual light commercial vehicle has a low stiffness of the bearing system, high center of gravity and it is heavier. Stiffness of the bearing system of a light car has an influence on the normal forces appearing in the wheels and on their dynamic reallocation while moving along an arc. Reallocation of the normal forces has an effect on vehicle handling and stability.

The study deals with the problem of calculation and experimental research of the influence of torsional stiffness of chassis frame, cab and the cargo platform on LCV dynamics in conditions of static rollover and dynamic curvilinear motion: going into corner and line changing. The objects of the research are LCVs with cargo beds (the vehicles loading capacity is up to 3.5 tons) that have a wide range of wheel base dimensions and, as a result, different torsional stiffness of the chassis frame. Thanks to the development of the simulation software, the authors had an opportunity to create a model for studying the car handling and stability properties, taking into account the stiffness of bearing systems. We assume that the study can help to determine the required stiffness of the supporting system, in order to meet the regulatory requirements on vehicle handling and stability at the design stages.

http://dx.doi.org/10.18720/MPM.4112019_18

2. Object of research

The object of research is a light commercial vehicle. The object of the study was selected according to the contract Key parameters. A GAZelle NEXT LCV was chosen, having 3500 kg total weight and a distribution between the front and rear axle of 37.4% to 62.5% respectively. The vehicle has a frame structure. The wheelbase of the model is 3145mm, track width 1750mm for a front axle and 1560mm for a rear axle. The front axle suspension has a double wishbone structure with an antiroll bar. Suspension of the rear axle has a dependent structure based on semielliptical leaf springs with additional leaf springs and antiroll bar. The torque from the engine is transferred to the rear axle. The steering system of the car has a rack and a pinion. The tires used on the vehicle have a road tread and the following dimensions: 185 / 75R16.

3. Model

Handling and stability studies were carried out, the method contained in GOST 52302-2004 being used [1]. The critical velocity of the vehicle is the main indicator of passing the tests «Skid Pad» and «Lane change». The critical angle of inclination of the supporting area is the main indicator for the static stability of the vehicle. Car model and tests were carried out using the software package ADAMS/Car. The graphic image of the model is shown in Fig. 1. The vehicle model takes into account the sprung and unsprung mass with inertia moment. The elastic model has a sprung mass distributed in total between 7 parts.

The tire model takes into account vertical, lateral and longitudinal stiffness and adequately simulates the sideslip as a consequence of lateral forces appearance. The model takes into account the kinematics of the suspension as it affects on the cross angle of the wheel, tire model takes this phenomenon into account also. The model takes into account force of air resistance because of the possible test speed can be up to 80 km/hr when the power of the air resistance becomes important.

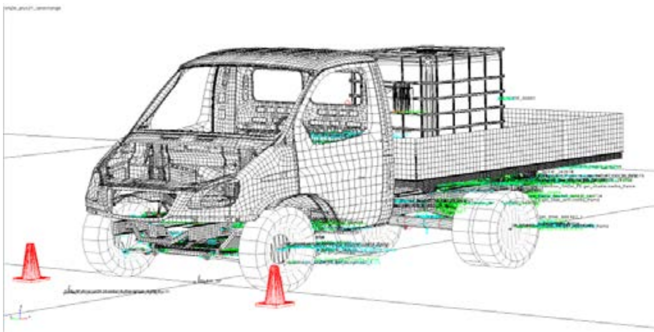

Fig. 1. View of the model with flex elements of the support system

The object of the research is a LCV with cargo platform that presented as a multi-body model with three flexible (deformable finite element models) parts: cab, frame and cargo platform. The simulation is done in MSC.ADAMS/CAR and MSC.NASTRAN software, which allows imitating the LCV dynamics with considering flexibility of chassis frame. The initial stage of this study is presented in Refs. [2,3], where the combination of experimental and simulation methods were described for estimating LCV active safety characteristics such as cornering stability. The experimental method of estimation of cornering stability is based on the regulations of the Russian Standard GOST R 52302-2004 that presuppose static and dynamic vehicle testing. The multi-body simulation method is based on MSC.ADAMS/CAR software capabilities. The approval of developed LCV multi-body model is done on a basis of good correlation between simulation results and experimental data.

Ref. [2] presents the simulation results that were obtained using the multi-body LCV model, which have a frame, a cabin and a cargo platform presented by rigid bodies. Only one modification of LCV was studied (basic modification with wheelbase 3145 mm). This study is a continuation of the research presented in Ref. [2] and pays key attention to:

- Estimation of the influence of wheel base on torsional stiffness of a chassis frame;
- Analysis of the deformation mode of a chassis frame in dependence of a type of frame

extender construction and fixation (for different wheel base magnitude);

- Estimation of the influence of subframe construction on the total torsional stiffness of chassis frame with extended wheel base;
- Estimation of the influence of torsional stiffness of a chassis frame on LCV static rollover characteristics (Fig. 2) and dynamics ones: critical speed of a curvilinear maneuver, wheels vertical reaction, roll of a vehicle (Fig. 3).

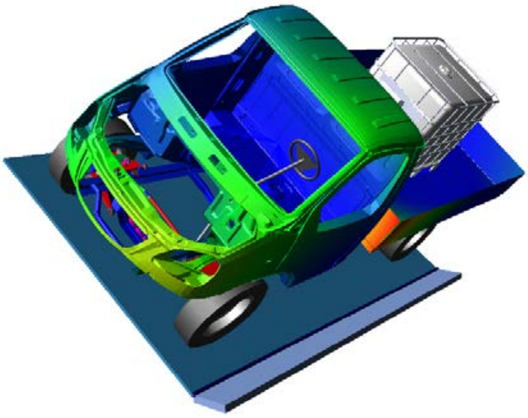

Fig. 2. Simulation of the static rollover test

Fig. 3. Simulation of "going into corner" test

Four models having different stiffness of the supporting system were studied. The different rigidity was obtained by varying the thickness of the longitudinal and transverse frames. All models and their distinctive characteristics are described in Table 1. Every model has participated in three tests (two dynamic and one static). The torsional stiffness was measured for all of the vehicle elements: frame, cabin and loading platform. The torsional stiffness can be calculated as a ratio of the rotation torque to the radial angle appearing in the supporting system as the result of this torque.

Table 1. Models and their distinctive properties

Model	**Wheel base, m**	**Type of carrier**	**Torsional stiffness of the bearing system, Nm / deg**
1	3.1	Rigid	-
2	3.1	Flex standard thickness	1780
3	3.1	Longitudinal longerons thickened by 2 mm and lateral by 1 mm	2138
4	3.1	Longitudinal longerons thinned by 2 mm and lateral by1 mm	826

4. Input control

During the dynamic tests, the vehicle has to move within a given corridor without run over a cone. To keep moving between the cones, it is necessary to turn a steering wheel. This action was provided using a steering controller. The controller compares the position of the vehicle, relative to a desired path, and turns the steering wheel to provide the motion as near as possible to the path. Fig. 4 shows the trajectory that was used in simulation tests of the «going into corner». The trajectory was obtained by the method of iterative changes for achievement a maximum speed of the vehicle. All the changes for the trajectory should be done manually by a modeling engineer.

Fig. 4 shows that the trajectory does not match the midline; it is connected with changes of the vehicle speed. At the beginning of the test, the vehicle moves at a constant speed. Because of the forces of air resistance and tire rolling resistance, its speed is not constant. That's why throttle control should be done by the speed controller, which compares the actual vehicle speed with a fixed value and changes the throttle, in order to provide constancy of the speed.

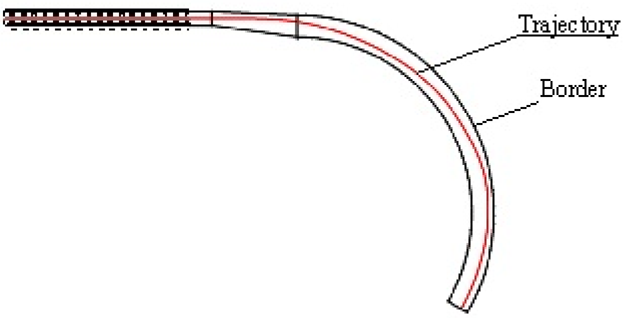

Fig. 4. Trajectory of the test «going into corner»

5. Results

The results of research allowed setting the dependence of dynamic curvilinear motion and static rollover stability on torsional stiffness of a chassis frame. The red dotted line (Fig. 5) shows the results of a study "going into corner" obtained for the vehicle rigid model. The model has a better handling and its critical speed is 63.2 km/hr. Thanks to this test, critical speeds for different car models with rigid carrier systems were established. A relationship between the rigidity of the supporting system and the critical speed was found as follows: in order to increase the critical speed by 1%, it is necessary to increase the torsional rigidity by 20%. In its turn, increasing the torsional stiffness of the frame leads to increasing the mass by 34%. Thus the increasing of the torsional rigidity is not efficient for improving the vehicle handling.

Analogous results were obtained for the study "lane change" (Fig. 6). In this case the rigid model had a better handling and its critical speed was 72.5 km/hr.

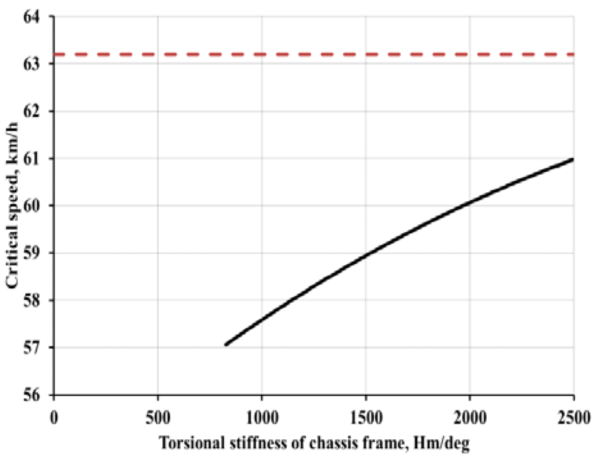

Fig. 5. Dependence of the maximum speed on the torsional stiffness for the test "going into corner": flex frame - rigid frame

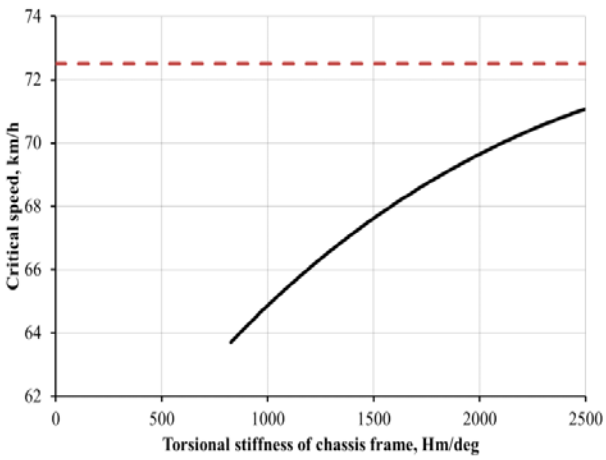

Fig. 6. Dependence of the maximum speed on the torsional stiffness for the test "lane change:" flex frame - rigid frame

Figure 7 shows the results of the study "tilt", i.e. the dependence of the critical angle of the rotary platform on the chassis frame torsional stiffness. Here, in order to increase the critical angle by 1%, it is necessary to increase the torsional rigidity by 20%. As before, increasing the torsional rigidity is not efficient for improving the vehicle static stability. The red dotted line shows the results for the rigid model, which had a better static stability and showed the critical angle of 37.2 deg.

From the study it follows that the indicators of handling and static stability have a direct connection with the torsional stiffness of the chassis frame. Even small improvements in handling and stability require significant increase of the torsional stiffness.

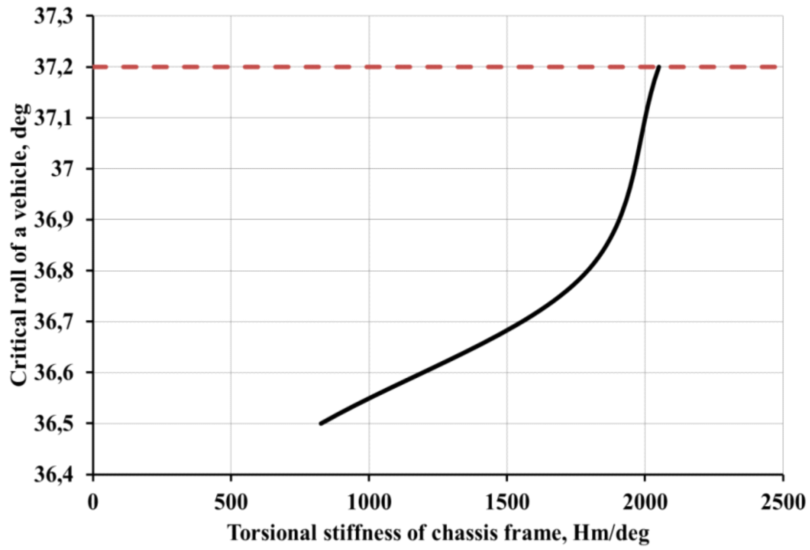

Fig. 7. Dependence of the critical angle of the supporting rotary platform on the torsional stiffness of LCV frame: flex frame - rigid frame

6. Conclusion

The study showed that the torsional stiffness of the supporting system affects the handling and stability indicators of a light commercial vehicle. Between the torsional rigidity and handling and stability properties there is a positive relation. Dynamic indicators have a negative exponential dependence on the torsional rigidity. Disregarding the stiffness of the supporting system, during the modeling of a light commercial vehicle motion, leads to an overestimation of the dynamic properties by about 5% and of the static stability by about 1%.

This study could be useful for determining the stiffness of a chassis frame for a light commercial vehicle at the design stage. Based on the test results, it is possible to make decision on optimal choice between the torsional stiffness and the weight of a bearing system.

Acknowledgements. *The research is done with the financial support of Ministry of Education and Science of the Russian Federation in the frame of the complex project "The establishment of the advanced technology production of ecological and resources-economy LCV" under the contract №02.G25.31.006 from 12.02.2013 (Governmental Regulation №218 from 09.04.2010).*

References

[1] GOST 52302-2004. *Road vehicles. Handling and stability. Technical requirements. Test methods*. Moscow: IPK Standard publ.; 2005.

[2] Tumasov A, Groshev A, Musarsky R, Konikova G, Trusov Y, Kostin S. Estimation of light commercial vehicles dynamics by results of road tests and simulation. *Journal of Communication and Computer*. 2014;11(5): 412-422. Available from: http://www.davidpublisher.org/Public/uploads/Contribute/5508e27d14800.pdf

[3] Tumasov A, Shashkina K, Konikova G, Groshev A, Bezrukov A, Trusov Y. Estimation of steerability and cornering stability of light commercial vehicle by results of road tests and simulation. In: *FISITA 2014 World Automotive Congress, the Netherlands, Maastricht, 2-6 June - F2014-IVC-048*. Available from: http://www.fisita2014.com/programme/sessions/F2014-IVC-048