UDC 629.4.015

Ways of improving the units construction of hydraulic shock absorbers of passenger cars on the bogie of KVZ-CNII type

Vadim Ishchenko

Ph.D.
Associate Professor of the
State University of Economics and Technology

Yuri Shcherbina

master
senior lecturer of the
State Economic and Technological University

Abstract
Long-term operational experience, numerous theoretical and experimental studies show that the dynamic qualities of a passenger car are significantly influenced by the technical condition of hydraulic shock absorbers. When malfunctions or changes in the working parameters of the absorbers occur, the accelerations of the car body oscillations increase, the smoothness of the movement deteriorates and the level of the stressed state of the load-bearing elements of the structure increases. The article describes the results of the work on the search for rational design schemes and technical solutions to improve the operation of hydraulic shock absorbers in operating conditions.
The side forces transmitted to the rod of the shock absorber in the dynamics are investigated based on the computer model of passenger car dynamics for high-speed movement in the "Universal Mechanism" software package. In SolidWorks CAD, the calculation of the rod-guide system stresses was carried out. The project for upgrading the units of the hydraulic shock absorber NTs-1100 was proposed.
Keywords: HYDRAULIC SHOCK ABSORBER, COMPUTER MODEL OF THE ABSORBER, TECHNICAL CONDITION, UNITS MODERNIZATION, SIDE FORCES

Introduction

Long-term operational experience, numerous theoretical and experimental studies show that the dynamic qualities of a passenger car are significantly influenced by the technical condition of hydraulic shock absorbers. When malfunctions or changes in the working parameters of the absorbers occur, the accelerations of the car body oscillations increase, the smoothness of the movement deteriorates and the level of the stressed state of the load-bearing elements of the structure increases. The purpose of this article is to analyze the problems in the operation of hydraulic absorbers of domestic production on the basis of the analogue – NTs-1100 type, which occur when operating passenger cars and searching for technical solutions aimed at improving the design of these absorbers.

Materials and methods

Analysis of the technical condition of hydraulic shock absorbers in operation shows that the most common faults are as follows:

- Loss of working fluid due to reduced density of the hydraulic system;

- Increase of gaps in the “rod-guide” system which causes the resistance parameter decreasing from the maximum to -25% of the nominal value;

- Loosening of the threaded connection of the rod to the upper head of the hydraulic shock absorber as a result of repeated bending loads (when skewing) and stretching-compression;

- The rod thread stripping at frequent disassembly due to the replacement of rubber sealing cups;

- Wear and destruction of the guide and “overtempering” of metal in the working area of the rod due to temperature overheating caused by the structural features of the absorber mounting units from the effect of significant side forces when skewing, which lead to wedging in operation.

To solve the problems associated with the occurrence of malfunctions of NTs-1100 type hydraulic shock absorbers, it is suggested to carry out complex modernization of the units. The main activities that are envisaged by the modernization project include:

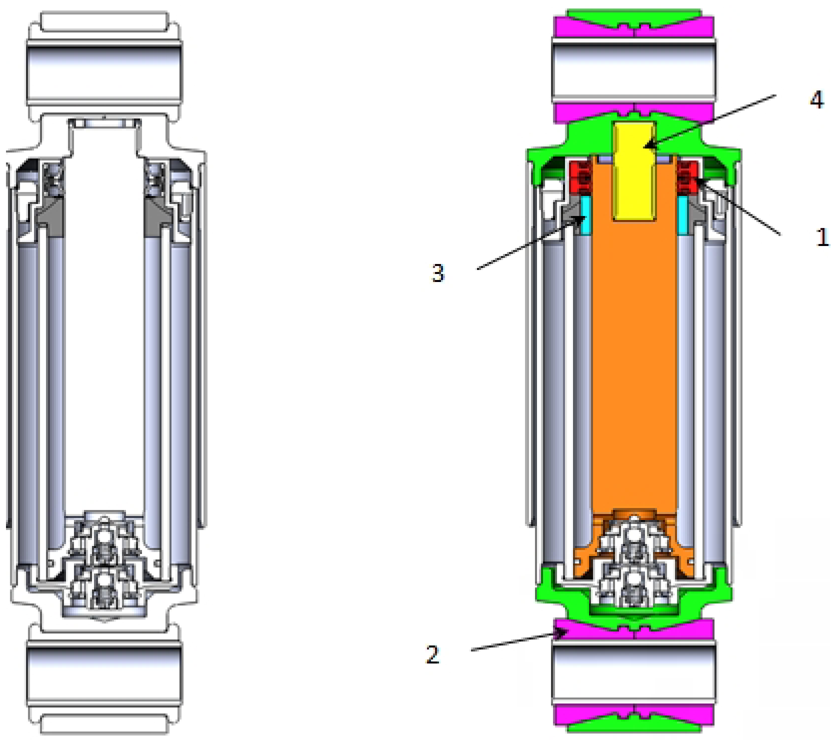
- Replacement of sealing rubber cups (Fig.1, pos. 1)

- Changing the pin joint of the shock absorber mountings (Fig. 1, pos.2)

- Changing the design of the guide (Fig.1, pos.3)

- Changing the rod attachment to the upper head of the absorber (Fig. 1, pos.4).

The design of the project is shown in Figure 1.



a) b)

Figure 1. The hydraulic shock absorber

a) before modernization; b) after modernization

In order to determine the values of the side forces acting on the units of the hydraulic shock absorber in “Universal Mechanism” software package, a computer model of the dynamics of the passenger car on the bogies of KVZ-CNII type [1, 2] was examined under conditions close to operational ones.

The calculation conditions were chosen according to which the object was investigated. They include high-speed mode of the car motion, V = 20-140 km / h; rectilinear and curved sections of the rail track; state of the rail track– the absence and presence of horizontal and vertical unevenness; stiffness parameters of the bogie driving dog $C_{d.d.}$ = 2500 - 4700 kgf/cm; before the start of integration, the system is in a state of static equilibrium; the integration time is 12 seconds.

Results

The results of calculating side forces transmitted to the hydraulic shock absorber were obtained according to the accepted conditions of numerical integration (Fig. 2).

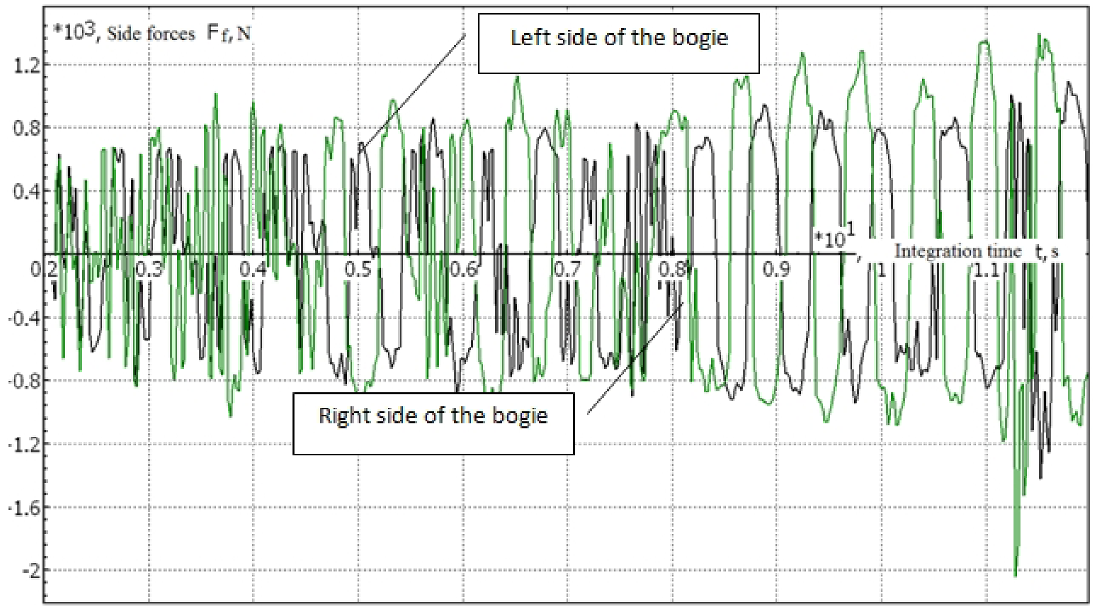


Figure 2. Oscillogram of side forces transmitted to the rod of shock absorber when moving in the straight section of the track at V = 80 km/h obtained by computer simulation in the “Universal Mechanism” software package

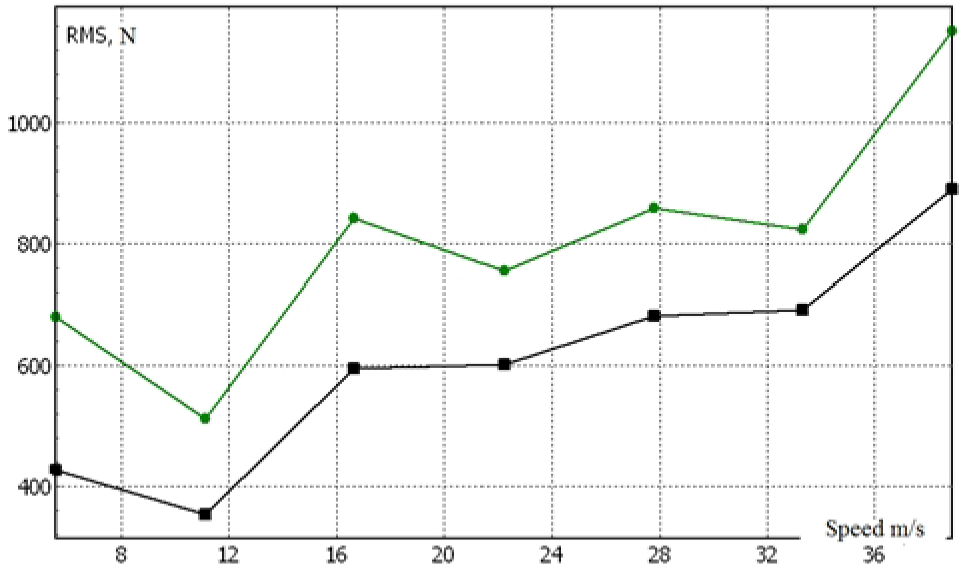


Figure 3. Dependence of the RMS side forces, which are transmitted to mounting units of the hydraulic shock absorber at the stiffness of the driving dog of $C_{d.d.}$ = 2500 kgf / cm in the route speed range up to 140 km / h on the straight section

To determine the dependence of longitudinal loads changes on the conditions of high-speed motion, an imitation study has been carried out in the dynamics of the passenger car model taking into account the stiffness parameters of the bogie driving dog as an element that perceives longitudinal forces acting on the central spring suspension and limits the relative rotation angles of the bogie frame relative to the bolster and rail track. The variation in the side force when speed increasing is shown in Figures 3-6.

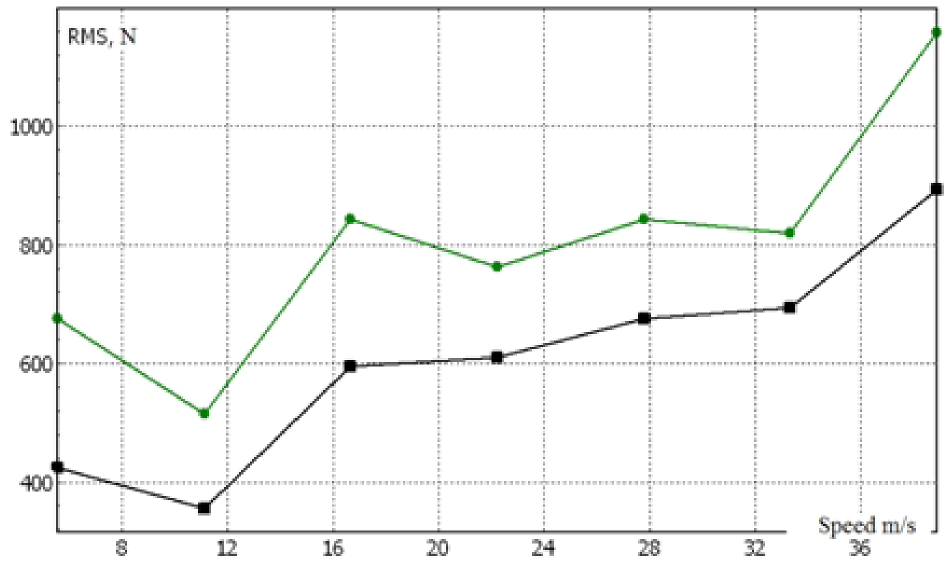


Figure 4. Dependence of RMS side forces, which are transmitted to mounting units of the hydraulic shock absorber at the stiffness of the driving dog $C_{d.d.}$ = 4700 kgf / cm in the route speed range up to 140 km / h on the straight section

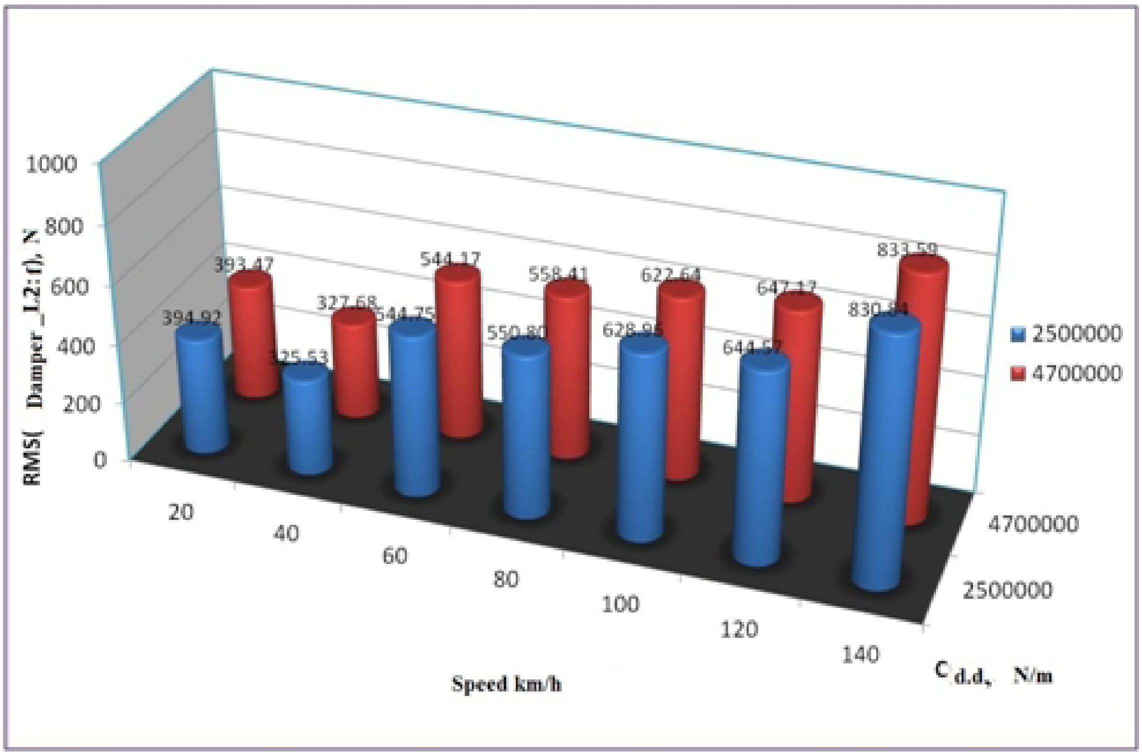


Figure 5. Dependence of RMS side forces, which are transmitted to mounting units of the hydraulic shock absorber (left side of the bogie) at the stiffness of the driving dog $C_{d.d.}$ = 2500 - 4700 kgf / cm in the route speed range up to 140 km / h on the straight section of the track

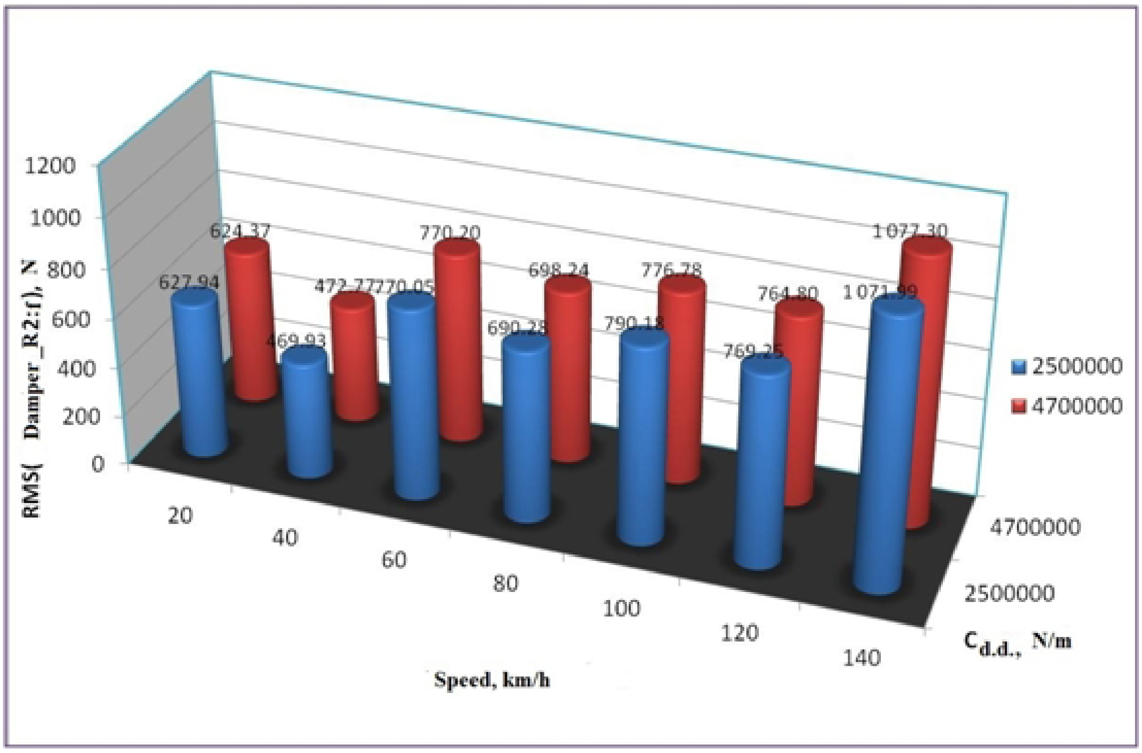


Figure 6. Dependence RMS side forces, which are transmitted to mounting units of the hydraulic shock absorber (right side of the bogie) with the stiffness of the driving dog $C_{d.d.}$ = 2500 - 4700 kgf /cm in the route speed range up to 140 km / h on the straight section of the track

According to the results of the model calculation, the table 1 of the initial data was formed.

Table 1

Motion speed, km / h	Rail track section	Horizontal and vertical rail track unevenness	Driving dog stiffness, $C_{d.d.}$, kgf /cm	RMS of side forces, N
140	straight	Absent	2500	460.37
140	straight	Absent	4700	455.02
140	straight	Present	2500	1151.52
140	straight	Present	4700	1157.96
120	curve, R = 600 m	Absent	2500	475.21
120	curve, R = 600 m	Absent	4700	469.47
140	curve, R = 600 m	Present	2500	1089.66
140	curve, R = 600 m	Present	4700	1091.95
140	curve, R = 1000 m	Absent	2500	477.02
120	curve, R = 1000 m	Absent	4700	476.51
140	curve, R = 1000 m	Present	2500	1257.29
140	curve, R = 1000 m	Present	4700	1251.51

According to the results of analysis, it is established that:

- with the growth of the passenger car speed, the level of side forces transmitted to the hydraulic shock absorber is gradually increased;

- the value of the stiffness parameter of the driving dog, which is within the limits of $C_{d.d.}$ = 2500-4700 kgf /cm does not significantly affect the obtained values of side forces. They are almost on the same level;

- when taking into account the unevenness of the rail track more than 2.5 times, the horizontal forces value transmitted to the shock absorber mounting units increases;

- root-mean-square deviations of the side forces can reach more than 1000 N at the motion speeds (V = 110-130 km/h).

The obtained results determining the horizontal side forces that are transmitted to the shock absorber indicate a real possibility of a situation when with the increase in the level of side forces, there will be a "wedging action" in the absorber operation, which will lead to a partial or complete loss of the shock absorber performance.

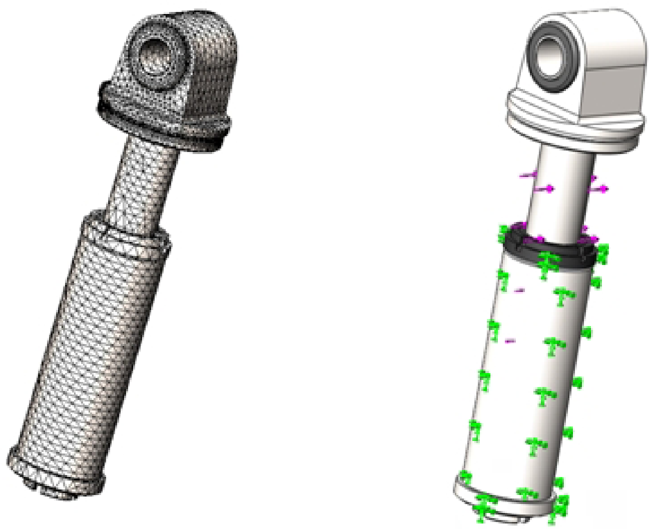
An imitation study of the created computer model of shock absorber was carried out in order to find the distribution of stresses from the action of side horizontal forces when "wedging action" in the "rod-guide system" using the SolidWorks software package. When performing the calculation, the properties of the materials of the consti- tuent units were taken into account, and the accuracy of the geometry of the elements was maintained in accordance with the drawings of the design documentation for the hydraulic shock absorber Nts-1100.

Before the beginning of stress determination by the finite element method, a grid of high quality was created on the solid body of the absorber model with a total number of elements – 86802 and units – 142680 without distorted elements by Jacobian.

The calculation procedure assumes a complete fixation of the guide and working cylinder with the restriction of all degrees of freedom and the application of side horizontal forces determined by "Universal Mechanism" software package to the elements of the upper part of the shock absorber (head with the rod) (Fig. 7).

The distribution of stresses in the guide will have the following form taking into account peak side loads (Fig. 8).

The obtained values of the maximum stresses arising in the guide of the shock absorber with applied side horizontal forces up to 2500 N are shown in Fig. 9.



a) b)

Figure 7. Creation of a grid (a) and a scheme for applying external loads to the elements of the shock absorber (b)

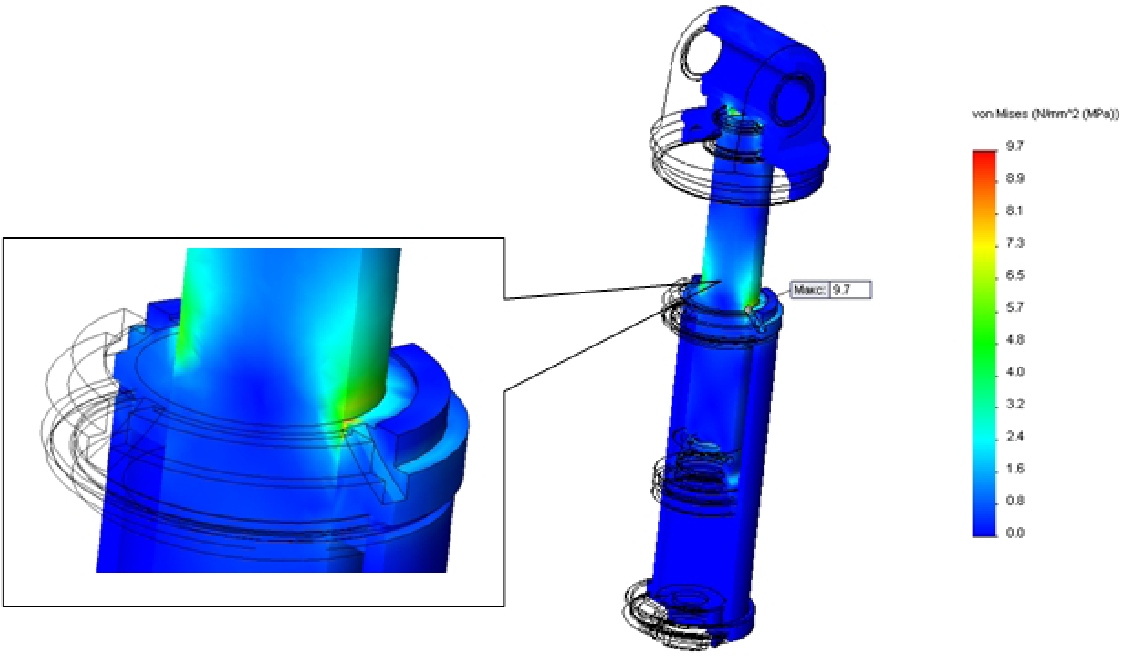


Figure 8. Graphical representation of the stress distribution when the longitudinal side force is applied to the hydraulic shock absorber F_f = 2000 N

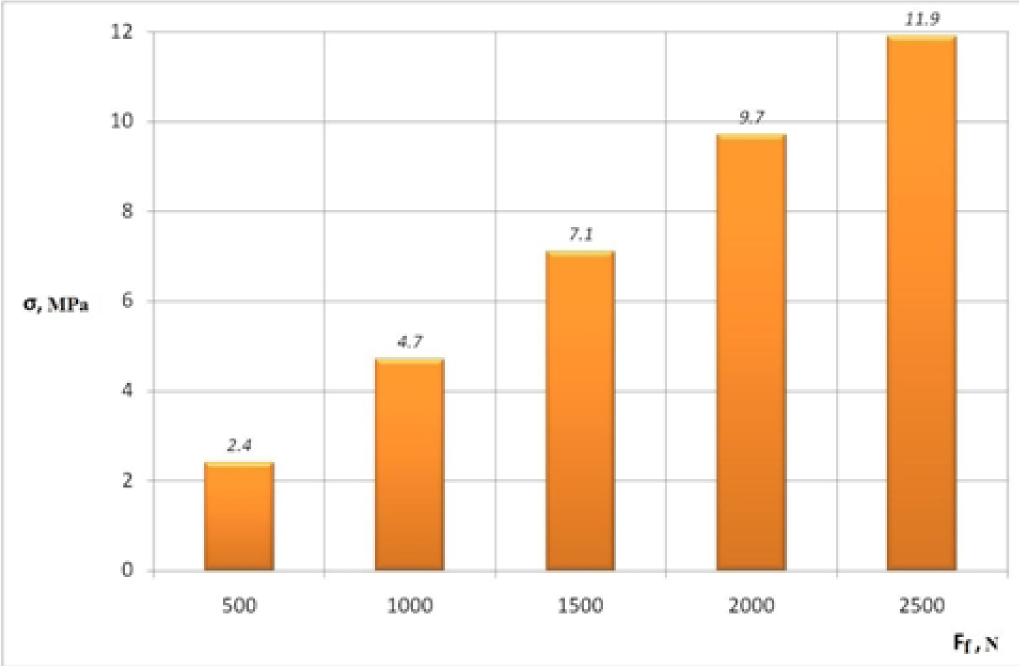


Figure 9. The nature of the change in the values of the stresses in the guide of the shock absorber from the action of side forces

Considering the constant cyclicity of the longitudinal loads action during the movement of the car, which are transmitted to the mounting units of the absorber, their negative influence on the elements of the shock absorber can be argued. The carried out researches explain the reason for the "wedging action" of the shock absorber, the occurrence of wear and failure of the guide, the "overtempering" of the rod metal, the deformation of the working cylinder surface. In general, with the increase in side horizontal forces, the operating conditions of the shock absorber are deteriorated, the heating temperature of the "rod-guide" friction pair increases, which in turn can lead to the loss of the properties of the working fluid when critical values are reached.

Conclusions

1. The proposed technical solution for the complex modernization of the hydraulic shock absorber will improve the quality of its operation, reduce the risk of loss of serviceability as a result of "wedging" from the action of the side forces, increase the service life.

2. By means of computer simulation, the character of the change in longitudinal side forces, which are transmitted to the shock absorber mounting units and their influence on the stress state of the absorber elements, was investigated. The range of values of root-mean-square deviations of longitudinal forces in the framework of high-speed motion V = 20÷140 km/h was determined.

Acknowledgements

The authors express their gratitude to G.Yu. Chernyak for active participation in the work on creating a computer model of the dynamics of a passenger car on bogies of KVZ-TsNII type. The work was carried out in the framework of scientific and research work to determine the effect of hydraulic shock absorbers on the dynamic performance of cars by means of simulation.

References

1. Chernyak G. Yu., Shcherbyna Yu. V. (2007) Rozrobka modeli pasazhyrskoho vahona dlia doslidzhen dynamiky v prohramnomu kompleksi «Unyversalny mekhanyzm» [Developing a model for the passenger car for the research of dynamics in software package "Universal Mechanism"]. *Zbirnyk naukovykh prats DETUT. Seriia «Transportni systemy i tekhnolohii»* [Proceedings of DETUT. The series "Transport systems and technologies."]. Kyiv: DETUT, No 12, p.p. 75-82.
2. Chernyak G. Yu, Shcherbyna Yu. V. (2008) Rozrobka matematychnoi modeli dynamiky pasazhyrskoho vahona v prohramnomu kompleksi «Unyversalny mekhanyzm» [Developing the mathematical model of dynamics of the passenger car in software package "Universal Mechanism"]. *Problemy ta perspektyvy rozvytku transportnykh system v umovakh reformuvannia zaliznychnoho transportu: upravlinnia, ekonomika i tekhnolohii: Materialy IV mizhna-*

rodnoi naukovo-praktychnoi konferentsii. Seriia «Tekhnika, tekhnolohiia» [Problems and prospects of development of transport systems in conditios of railway reform: management, economics and technology: Proceedings of IV international scientific conference. Series "Technic, technology"]. Kyiv: DETUT, p.p. 112.

3. Pogorelov D.Yu. (2005) Simulation of Rail Vehicle Dynamics with Universal Mechanism Software. Rail vehicle dynamics and associated problems. Gliwice: *Silesian University of Technology*, p.p. 13-58.
4. Paul Tran (2016) SOLIDWORKS, *Advanced Techniques*. 728p.
5. Paul Kurowski (2016) Engineering Analysis with SOLIDWORKS Simulation. 500p.