Laboratory studies of dampers of stand-alone system of electric drive vibration isolation of "Ferdinand" rotary drilling rig rotator

Gromadskiy V.A.

PhD in Technical Sciences
SIHE «Kryvyi Rih National University»,
Ukraine, Kryvyi Rih

Abstract
The results of laboratory studies of various kinds of longitudinal oscillations dampers (hereinafter LOD) of the rotator electric drive of the rotary drilling rig “Ferdinand” produced by “Plant of Drilling Equipment DCD” are given. The aim of research is finding the most efficient LOD of rig rotator electric drive. Laboratory tests are performed on the test bench HMS-20. The essence of the research is in increasing of the degree of compression of force to the test samples 50 kN with further measuring of deformations of elastic elements of damping device. The step of compression force increasing was 5 kN at each deformation measurement. Strain measurements were made by using calipers ShTs-1-150.0,05 GOST 166-89, at the same time, its depth gauge and jaws for internal measurements were used. LOD testing of drilling rod was carried out in accordance with the requirements of the standards: GOST 269-66; GOST 252-75; GOST 21510-76. The required number of experiments was determined by Student's t-test with relative confidence interval and relative confidence probability less than 0.90. The samples before testing were maintained indoors $t = 22 \pm 2^{0}C$ and tests were performed at the same temperature. From these results it is clear that with compression force 10-50 kN cable-rope magazines of LOD show the most stable result, stiffness coefficient deviation no more than 2%, which is within the limits of measurement accuracy and statistical significance of the experimental results with confidence probability P = 0.9. Rubber and rubber-cord washers are unstable, their deviation from mean values of rigid rate are 36% and 25%. It indicates residual deformations in elastic elements after unloading.
Key words: INVESTIGATIONS, LONGITUDINAL OSCILLATIONS DAMPING, ROTATOR ELECTRIC DRIVE, ROLLER-BIT DRILLING MACHINE “FERDINANT”

The problem and its connection with practical tasks

When operating the drilling rig in fracturing rocks in the hole by drilling bits, intense pulsed alternating drums dynamic loads are generated. The stronger rocks in the hole especially with cracks in it, the more intense are these pressures. These loads are transmitted through the drilling rod and at some rotary speeds and the efforts of its submission for slaughter are enhanced due to resonant vibrations of tubular drilling strings and subsequently destroy the structural elements of the mast, support unit and electric drive of the rig. With the development of a new system for reducing the dynamic loads of the electric drive of rotary drilling rig “Ferdinand” produced by “Plant of Drilling Equipment DCD” are protected by the patent of Ukraine No 94528 [1] the necessity for finding rational parameters of stiffness and damping standalone vibration isolation of electric drive has occured.

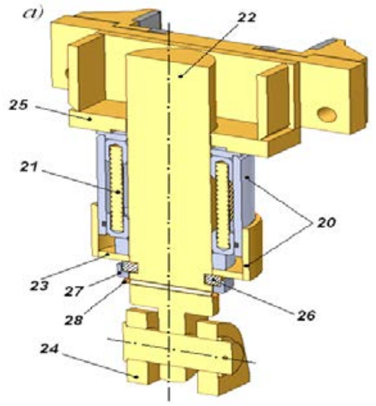
Research and publications analysis

Previously developed vibration dampers [2] of drilling rod are designed for transmitting the axial feed force up to 250 kN. In the new system of localization of vibration of upper carriage of rotator with electric drive of rotary drilling rig “Ferdinand” the dampers are on each side of the bus-gear clutch. They are loaded only by the drive with weight 27000 N.

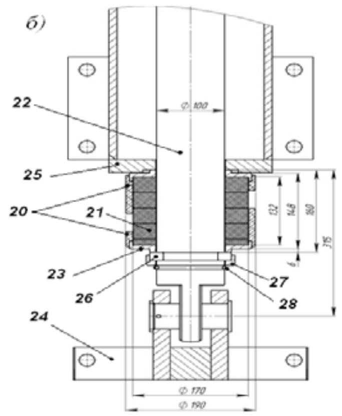
Problem statement is to conduct research of the dependence of stiffness coefficient for different kinds of dampers on the load. To select stiffness and damping parameters of new dampers so that it can ensure the effective vibration damping of vibration-isolated electric drive, support unit and the frame of the rig.

Presentation of the material and results

The samples of different kinds of dampers of the stand-alone system of electric drive vibration isolation - dynamic vibration absorber of support unit are developed while minimizing vibration of support unit by the effecting it with multidirectional force field. Technical solutions are developed in relation to the rotary drilling rig “Ferdinand” [3], which is identical to a standard size machine SBSH-250MNA-32.Fig. 1a, b shows the design scheme of LOD rotator drilling rig for three variants of elastic-damping elements - twisted wire rods bent type (cable-rope) according to patent [2], as well as rubber or rubber-cord rings. Elastic-damping elements 21 in Fig. 1a are arranged in telescoping bodies 20, which are located on stock - rods 22 of upper and lower blocks. By covers 23 shock absorbers are associated with lower traverse support unit 24, and on top of the shock body is bar of upper traverse drive 25. On stock - rods 22 shock body bump into lock 26, which are held in the radial direction by cups 27 with locking rings 28 – 27 cup clamps Fig. 2 shows photos of developed shock absorbers.



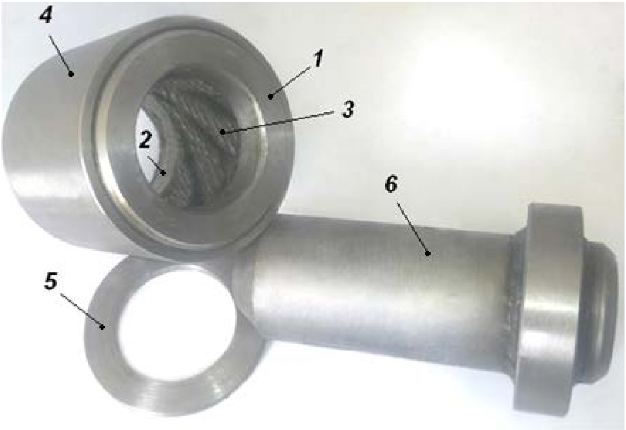
a)



b)

Figure 1. Design scheme of LOD rotator of drilling rig: a) with cable elastic-damping elements by type of rope loader of LOD b) rubber and rubber-cord rings

Dampers with rubber or rubber-cord rings, Fig. 2b, have split body 20 within package of rubber or rubber-cord rings is placed 21.



a)

b)

Figure 2. Developed and produced variants of dampers of rotary drilling rig “Ferdinand”: rope loader of LOD: 1-lower separator; 2 – upper separator; 3 – rope damping elements(rope spiral); 4 - LOD body; 5 – low cover 6 – lab equivalent of damp-stock of rotary drilling rig “Ferdinand” blocks: b) LOD with rubber rings: 1 – upper half of the body; 2 – lower half of the body; 3 – rubber rings (vibrator isolators); 4 – lab equivalent of damp-stock of rotary drilling rig “Ferdinand” blocks

The other elements of the damper mounting on damp-stock - rods 22 are similar to Fig. 1a as well. By order of LLC “Plant of Drilling Equipment DCD” there were produced different kinds of elastic-damping elements of dampers, which are tested in bench conditions to determine their stiffness and damping parameters. The design parameters of the test dampers. In the process of parametric studies a wide range of possible factors stiffness and damping parameter c3 ν3 is examined. The values of rational LOD parameters, based on the following conditions:

a) dampers are to provide the given power characteristics and load-carrying capacity;

b) stiffness coefficient of shock absorbers c3 should be minimal, however, at condition of requirements meeting;

c) damping parameter ν3 should have the maximum value for the effective damping of resonant oscillations, taking into account the minimum deterioration of the dynamic characteristics of the resonance frequency region [5].When creating the LOD for rotary drilling rig "Ferdinand" we take into account that the weight of the upper carriage spinner in this machine is 2700 kg, i.e. 27000 N together with electromechanical equipment. The geometrical dimensions of the test dapers are given in Table 1.

Table 1. Parameters of shock absorbers

№	Name of elastic elements	parameters
1	The rope with elastic elements 14,5-G-1-Zh-L-O-R-1370 GOST 7669-80	- outer diameter of the separator D, mm -150; - inner diameter of the separator d, mm - 100; - height of LOD tape assembly with cable elements after running h, mm - 140; - number of cable elements n, pc. - 7 - length of the segments of the rope to break-l, mm - 180
2	LOD rope with rubber cord GOST 20-85	- ring outer diameter, D, -165 mm; - inner diameter of the rings d, mm - 110; - ring thickness h, mm - 18; - number of rings n, pc. - 6.
3	LOD rope with elastic elements 6620 rings TR U 600 152 135 040-96	- outer diameter of the ring D, mm -165; - the inner diameter of the rings d, mm - 110; - ring thickness h, mm - 31; - number of rings n, pc. - 4.

Bench tests of different variants of dampers. Fig. 3 shows a segment of the installation cable damper of longitudinal oscillations on a universal testing machine HMS-

20 before the pre-rolling of cable elastic-damping elements.

The results of bench testing of different variants of dampers are given in the form of dependency of changing coefficients of elastic-damping elements stiffness in Fig. *4, a b, c,* where *1, 2, 3, 4* are the serial numbers of experiments. Due to the instability of results in rubber and rubber-cord dampers the number of experiments for them was increased to four. As it can be seen from Fig. 4 with a compression force of 10-50 kN the most stable results are shown by cable-rope magazine of longitudinal oscillations damper, Fig. 4, *a*.

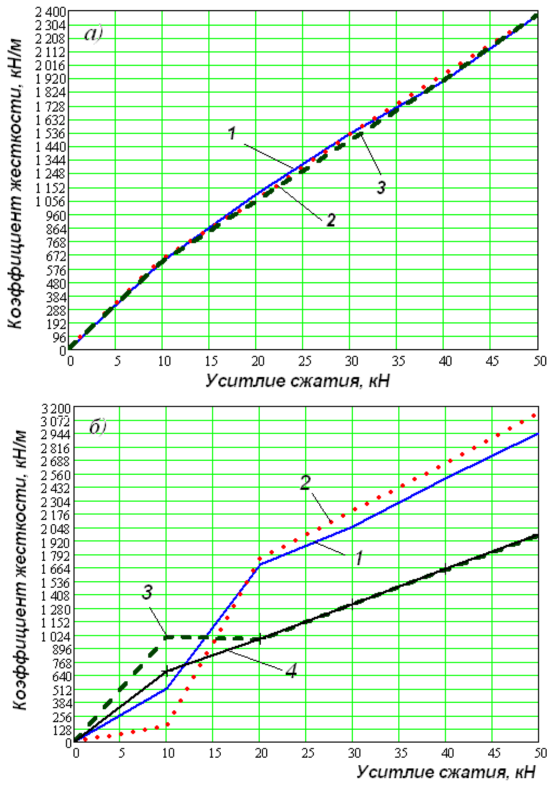
Deviation of the stiffness coefficient from the average value did not exceed 2%, which is within the limits of measurement accuracy and statistical significance of the experimental results with a confidence level of $P = 0.9$.

Rubber and rubber-cord washers act in unstable way; they have deviation from the average value of the stiffness coefficient of 36% and 25%, Fig. 4, *b, c.* This indicates residual deformations in elastic elements after unloading.

Calculations of stiffness coefficients for the three variants of longitudinal oscillations damper have shown that the smallest stiffness in the cable loaders of LOD.

As a result of regression analysis of experimental studies results of developed stiffness and damping parameters by longitudinal oscillations damper analytical dependences were obtained, Table. 2 [6]. In the second column of Table 2 the calculations of stiffness coefficients for the three variants of longitudinal oscillations damper are given, which show that the smallest stiffness is in the cable magazines of LOD. This creates prerequisites for higher efficiency localization of dynamic loads of the drive and the entire machine on the whole compared to rubber and rubber-cord washers. Dynamic stiffness coefficient of steel cable-rope elements is the same with stiffness coefficient, certain static tests, while in rubber and rubber-cord dampers dynamic stiffness coefficient is about 1.2 times greater than the static [7].

Figure 3. Segment of installation of cable LOD on universal testing machine HMS-20 before compression (break-in) of cable-elastic damping inserts: 1 – machine frame; 2 – body of cable LOD; 3 – cable inserts; 4 – upper separator; 5 – laboratory equivalent of the rod-pulling of the pulley block of rotary drilling rig “Ferdinand”; 6 – pipe – stand out for damper rod 5



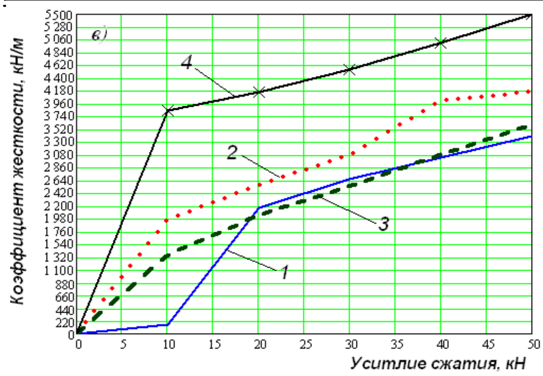


Figure 4. Diagram of dependence of stiffness coefficients change to compression force of elastic-damping elements (in the experiments № 1,2,3,4): a) – cable of LOD; b) – ring LOD of solid rubber; c) – ring LOD of the conveyor belts

Table 2. Analytical dependences and values of stiffness coefficients while testing of different variants of LOD

Kind of damper	$c = P/\delta$ with compression force 15 кН (c – stiffness coefficient, kN/mm; P – loading, kN; δ – deformation, mm)	$c = f_2(P)$ (c – stiffness coefficient; kN/mm, P – loading, kN)	Coefficient of energy adsorption s, ψ
Cable loader of LOD (loading)	c=15/17,3=0,857	c=0,58*P	0,638
Cable loader of LOD (unloading)	-	c=0,5+0,26*P	
Rubber washers (loading)	c=15/10,3=1,471	c=0,097*P	0,145
Rubber washers (unloading)	-	c=2,8=0,1*P	
Washers of rubber-cord belt (loading)	c=15/6,2=2,419	c=2,05+0,07*P	0,198
Washers of rubber-cord belt (unloading)	-	c=1,9+0,06*P	

Thus, for further calculations we take stiffness coefficients for each of pair of LOD: $c_{3\ cable.}$=857 kN/m; $c_{3\ rub.}$=1471×1,2=1765 kN/m; $c_{3\ rub.\text{-}cord}$=2419×1,2=2903 kN/m. And stiffness coefficients for each pair of LOD: $c_{3.\ cable}$=857×2=1214 kN/m; $c_{3\ rub.}$=1765×2=3538 kN/m; $c_{3\ rub.\text{-}cord}$=2903×2=5806 kN/m.

In the last column of Table 2 the energy absorption coefficients ψ for different types of LOD defined experimentally are shown.

Conclusions and tasks for further research

1. The dependence of the stiffness coefficient on the compression force for various types of damper are obtained.

2. The stiffness coefficients of LOD with cable loaders $c_{3\ cable.}$= 857 kN/m, and energy absorption ψ=0,638, ensuring effective damping of dynamic loads of the electric drive of rotary drilling rig “Ferdinand” are defined.

3. The objectives for further research are verification of obtained results by rotary drilling rigs manufactured by “Plant of Drilling Equipment DCD”, Krivoy Rog.

References

1. The patent of Ukraine for useful model No 94528, E21B 3/00, Rotary drilling rig that allows to reduce dynamic loads on rotator electric drive, mounting group and bench frame / Patent holder A.S. Gromadskiy // A.S. Gromadskiy, Yu.M. Solonychenko, V.A. Gromadskiy, Aksenov A.V. No a 2014 00101; Appl. 08.01.2014; Publ. 25.11.2014. Bul.No 22.
2. The patent of Ukraine for invention No 101870, E21B, Drilling bench / Patent holder V.A. Gromadskiy // V.A. Gromadskiy No a 201109297; Appl. 25.07.2011; Publ. 13.05.2013. Bul.No 9.
3. Drilling rig «Ferdinand». Short characteristics and complectation. Available at: http://www.siburalkom.ru/file/1i88/harakteristika_burovogo_stankaferdinand.pdf
4. Shabat B.V. Introduction to complex analysis. Moscow, Nauka, 1969. 576 p.
5. Gromadskiy A.S. Reduction of dynamic loads of open-pit excavators. Krivoy Rog,

Publishing center of Kryvoi Rog Technical University. 2008. 280 p.

6. Reduction of dynamic loads of rotary drilling rigs. Under the editorship of Anatolii Gromadskiy/ Yurii Gorbachov, Vladislav Gromadskiy, Victor Gromadskiy. Saabrucken, LAP LAMBERT Academic Publishing (Germany), 2014, 236 p.
7. Poturayev V.N., Dyrda V.I. , Nadutyi V.P. Rubber in mining. Moscow, Nedra, 1974. 152 p.