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# Х А Б А Р Ш Ы С Ы

# ВЕСТНИК

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН

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**D. K. Kushaliyev[1], A. N. Vinogradov[2] T. A. Baltayev[3], B. A. Ermanova[3]**

[1]Zhangir khan West Kazakhstan Agrarian Technical university, Uralsk, Kazakhstan;
[2]Saratov State Technical University named after Gagarin Yu. A., Saratov, Russia;
[3]Kazakhstan University of Innovation and Telecommunication Systems, Uralsk, Kazakhstan.
E-mail: zkaty777@mail.ru, van56@mail.ru, statmail_87@mail.ru, ermanova.b@mail.ru

# DEVELOPMENT OF REPAIR KITS FOR KNOTS OF TRANSPORT EQUIPMENT AND TECHNOLOGICAL EQUIPMENT

**Abstract.** Sliding and rolling bearings are applied in transportation and production equipment, these bearings operate under high loads in reciprocating/rotary mode. They are used in railroad, road, and agricultural transport for suspensions, dampers, steering, shaft drives, in garment equipment, mining, oil and gas production and processing, as well as some other industries. However, their operation lifetime is insufficient and recovery of such couplings by conventional methods comprised of replacement with repair kits of similar design does not solve this problem.

As assumed in this article, the operation lifetime of couplings operating under heavy loading in reciprocating/rotary mode can be increased by improved recovery of their operability using repair kits based on new operation principles of tribocouplings, that is, sliding bearings with movable spring bearing boxes.

The design of repair kit design of rubber bushing in the form of sliding bearing with movable conical spring boxes has been theoretically substantiated. Mathematical models of size variations of movable conical spring box of sliding bearing of damper rubber bushing have been developed.

Theoretical importance of the work is comprised of the expanded proven concepts of recovery of damper rubber bushings using repair kits with movable spring boxes. Practical significance is that the developed repair kits of damper rubber bushing are characterized by operation lifetime higher by 1.5…2 times in comparison with regular kits.

The obtained results can be applied for development of new engineering solutions, for improvement of recovery of transportation and production equipment with couplings operating under high loads in reciprocating/rotary mode.

**Key words:** repair kit, spring boxes, vehicle suspension, dampers.

**Introduction.** Transportation and production equipment operates with sliding and rolling bearings under high loads in reciprocating/rotary mode. Such bearings are used in railroad, road and agricultural transport in suspensions, dampers, steering, shaft drives, in garment equipment, mining, oil and gas production and processing, as well as some other industries. Manufacturing companies of the equipment are requested to increase operation lifetime retaining reliability of parts, units, assemblies and systems. However, at the design and manufacturing stages, these problems are solved insufficiently, and during operation it is required to carry out functional tuning in order to improve operation quality [1]. Functional tuning, besides all, assumes application of repair kits in units and assemblies in order to recover their working state and even for improvement of their operation lifetime.

Numerous works are devoted to provision of operability of transportation equipment in the course of operation lifetime: Avdon'kin, Apsin, Grebennikov, Grigor'ev, Gurvich, Denisov, Dyumin, Zvyagin,

Kanarchuk, Kramarenko, Kuznetsov, Novikov, Savel'ev, Sheinin, N. Gkikas, J. Little, D. Cormick, S. Bennett, I.A. Norman, and others [2,10,11,13,14].

Analysis of operation reliability of passenger cars evidences that suspension elements are not characterized by equal lifetime during overall operation period [3]. Dampers are the most expensive suspension elements. The frequency of their failures is about 17%, specific labor consumption required for recovery is about 12%. Operation lifetime of dampers depends on operation conditions of cars and does not exceed 70 thous. km. The most popular and typical couplings operating under high loads in reciprocating/rotary mode are rubber bushings of car dampers. Rubber bushings fail due to wear and fatigue breakages. Conventional recovery of such couplings by replacement with repair kits of similar design is not efficient because operation lifetime is not increased. Therefore, it is important to search for new engineering approaches aiming at improvement of lifetime of couplings of transportation and production equipment operating under high loads in reciprocating/rotary mode, as well as at improvement of their operability recovery using repair kits.

This work substantiates theoretically the design of repair kit of rubber bushing containing tribocoupling based on new operational principle: sliding bearing with movable conical spring boxes.

**Methods.** Operation lifetime of tribocouplings, in particular: sliding bearings operating under high loads in reciprocating/rotary mode, can be improved by using concepts of Prof. Zhukovsky about motion without friction leading to its decrease in working body [4].

The first concept was comprised of friction compensation by auxiliary countermotion of intermediate support driven by external energy source. The second concept differs by application of supplemental lateral motion (instead of countermotion) of platform, its speed should exceed significantly the sliding speed of a body over platform. The second concept can be implemented by various designs, including those without external energy source, for instance, due to remaining disequilibrium of rotating body. Implementation of these concepts using forced rotation or vibration of intermediate support confirmed possibility to decrease friction in working body. These concepts were embodied in gyroscopes on the basis of specialized reverse rotary support: ball bearings with two rows of balls and intermediate rings which rotated in opposite directions by means of toothed gearing. In internal combustion engines with undermounted camshafts and motion transfer to valves via plungers and rods, the cam wear is insignificant, which can be attributed to the second concept by Zhukovsky: existence of auxiliary lateral motion (plunger rotation) and conversion of sliding friction to rolling friction achieved by cam displacement relatively to plunger rotation axis.

The repair kit with cylindrical spring box was developed for crossarms of various vehicles [5].

However, cylindrical spring box is characterized by certain disadvantages: difficulties in manufacturing and assembling due to necessity to apply selective method.

**Theoretical substantiation of conical spring box for damper rubber bushing in comparison with cylindrical box.** In conical spring box the required coupling conditions are provided automatically by the box design. The conical box in sliding bearing for reciprocating/rotary motion is characterized by peculiar positioning. In rest state the conical spring box at half of its length (on the side of lower diameter) is positioned rightly reaching zero in the middle of the box on shaft and having the same positioning on the bushing on the side of higher diameter of the spring box. Such positions provide guaranteed allowance on both working surfaces, thus meeting the requirements of bearing operability: plastic deformation on working surfaces [6].

The mathematical model of conical spring box of sliding bearing of damper rubber bushing is based on the mathematical model for cylindrical spring box.

The conical spring box differs from the cylindrical one, hence, the following assumptions have been made for predictions:

- absolute linear deformation of spring box $f_x$ equals to 1 mm due to negligible deformation of spring box in rubber bushing;
- the length of spring box in loaded state $H_x$ equals to $H_0$ because the spring is unloaded;
- the pitch angle of coils of spring box in unloaded (free) state is $\alpha = 1.83°$
- the initial pitch angle of screw beam axis of unloaded spring box is $\alpha = \alpha_0$.

The sliding bearing for reciprocating/rotary motion is proposed [5,6] with partial implementation of the Zhukovsky's concepts about motion without friction (by rotation of intermediate support) without application of external energy source.

Tribocoupling (figure 1) is comprised of the shaft 1, the external ring 2 and the spiral box 3 in the form of coiled spring positioned between them. The spiral box is movable, conical with the cone angle from 1° to 5°, herewith, the spring wire diameter d equals to one half of the gap between the shaft diameter D and the diameter of box opening D+2d. Herewith, it is installed with allowance at edges as well as with allowance at internal and external surfaces for constant ratchet effect [7,12].

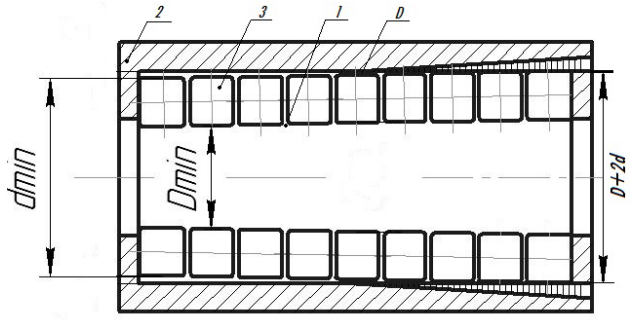


Figure 1 – Sliding bearing for reciprocating/rotary motion

The identifying feature of the bearing design is that it is equipped with movable box in the form of conical coiled spring (intermediate element) which in oscillating mode is forced only in one direction, thus providing uniform wear and lubrication distribution due to decrease in adhesive constituent of friction and occurrence of ratchet effect [9].

Tribological principles are executed in the bearing: activation of working surface by plastic deformation and suppression of oxidation.

Activation of working surfaces by plastic oxidation is provided by installation of elastic spring box between external and internal bushings so that to achieve certain allowance on working surfaces of the box. Herewith, during operation (rotation to one direction) the allowance increases on one working surface and decreases on the other working surface up to formation of gap and sliding. When rotating to another direction, the gap is replaced with allowance and vice versa.

Suppression (restriction) of oxidation on working surfaces of bearings is supported by design, because sealing glands are used preventing access of oxygen and other oxidants to working surfaces, or by addition of inhibitors to lubricants.

The developed bearing is the main element of innovative repair kit of damper rubber bushing (figure 2).

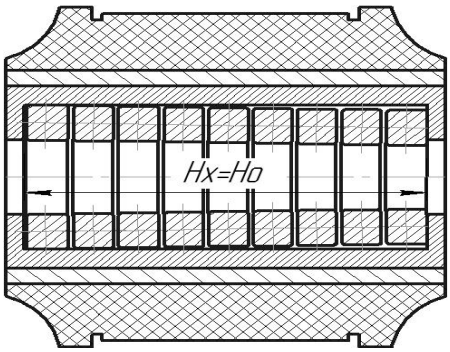


Figure 2 – Schematic view of damper rubber bushing with movable conical box

Mathematical model of size variation of conical movable spring box of sliding bearing of damper rubber bushing was developed [7].

The developed mathematical model can be applied to theoretical predictions of rubber bushing bearing included in the damper repair kit.

**Results and discussion.** Theoretical assumptions for development of sliding bearing with spring boxes are proved by laboratory studies of experimental repair kit of damper rubber bushing of passenger car performed with high precious instruments, as well as in working environment [8]. Practical

significance is that the developed repair kits of damper rubber bushing are characterized by operation lifetime higher by 1.5…2 times in comparison with regular kits operating in reciprocating/rotary mode.

**Conclusion.** The obtained results can be applied for development of new engineering solutions aimed at efficient operability maintenance of transport and agricultural equipment based on recovery improvement of couplings operating under high loads in reciprocating/rotary modes (for instance, steering, drive shafts, vehicle suspension) using repair kits.

**Д. К. Кушалиев[1], А. Н. Виноградов[2], Т. А. Балтаев[3], Б. А. Ерманова[3]**

[1]Жәңгір хан атындағы Батыс Қазақстан аграрлық-техникалық университеті, Орал, Қазақстан;
[2]Ю. А. Гагарин атындағы Саратов мемлекеттік техникалық университеті, Саратов, Ресей;
[3]Қазақстан инновациялық және телекоммуникациялық университеті, Орал, Қазақстан

## КӨЛІК ТЕХНИКАСЫНЫҢ ТҮЙІНІ МЕН ТЕХНОЛОГИЯЛЫҚ ЖАБДЫҚТАРҒА АРНАЛҒАН ЖӨНДЕУ ЖИЫНТЫҒЫН ДАМЫТУ

**Аннотация.** Көлік техникасы мен технологиялық жабдықтардың конструкцияларында қайтарымды-айналмалы режимде жоғары жүктеме кезінде жұмыс жасайтын шайқалмалы және жылжымалы подшипниктер қолданылады. Олар теміржол, автомобиль және ауылшаруашылық көліктерінде, аспалы қондырғыларда, амортизаторларда, рульдік басқаруда, кардан берілістерде, тігін, тау-кен, мұнай және газ өңдеу жабдықтарында және басқа да салаларда қолданылады. Алайда олардың ұзақ уақыт қызмет етуі көп жағдайда жеткіліксіз, және осындай интерфейстерді дәстүрлі әдістермен қалпына келтіру, ұқсас жөндеу жинақтарымен алмастыру бұл мәселені шеше алмайды.

Авторлардың ойынша, қайтарымды-айналмалы режимде үлкен жүктеме кезінде жұмыс істейтін түйін-демелердің ұзақ уақытқа төзімділігін арттырудың жолы – трибожұптасу жұмысының жаңа принциптеріне құрастырылған жөндеу жиынтықтарын, атап айтқанда, жылжымалы серіппелі жапсырмасы бар сырғу мойынтіректерін пайдалану арқылы олардың жұмысқа қабілеттілігін қалпына келтіру технологиясын жетілдіру.

Жылжымалы конустық серіппелі кірістері бар жылжымалы подшипник түріндегі жөндеу блогының дизайны теориялық тұрғыдан негізделген. Амортизатор сайлентблогының жылжымалы конустық серіппелі мөлшерін өзгерту процесінің математикалық модельдері жасалды.

Зерттеудің теориялық маңыздылығы келесілермен дәлелденеді: жылжымалы серіппелі кірістері бар жөндеу жинақтары көмегімен амортизаторлардың сайлентблогын қалпына келтіру әдістері туралы идеяны кеңейтетін теориялық ережелер дәлелденді. Тәжірибенің мәні амортизатордың сайлентблогының жетілдірілген жөндеу жиынтығы стандарттан 1,5 ... 2 есе көп ресурсқа ие екендігінде жатыр.

Ұсынылған ғылыми зерттеулердің нәтижелері ауыр жүк астында жұмыс жасайтын және кері – айналмалы қозғалыстар жасайтын көліктік жабдықтары мен технологиялық жабдықтардың түйіндерін қалпына келтіру әдістерін жетілдірудің жаңа техникалық және технологиялық шешімдерін жасау үшін қолданылады.

**Түйін сөздер:** жөндеу жиынтығы, серіппелі салма, автомобиль көтергіші, амортизаторлар.

**Д. К. Кушалиев[1], А. Н. Виноградов[2], Т. А. Балтаев[3], Б. А. Ерманова[3]**

[1]Западно-Казахстанский аграрно-технический университет им. Жангир хана, Уральск, Казахстан;
[2]Саратовский государственный технический университет им. Гагарина Ю. А., Саратов, Россия;
[3]Казахстанский университет инновационных и телекоммуникационных систем, Уральск, Казахстан

## РАЗРАБОТКА РЕМОНТНЫХ КОМПЛЕКТОВ ДЛЯ УЗЛОВ ТРАНСПОРТНОЙ ТЕХНИКИ И ТЕХНОЛОГИЧЕСКОГО ОБОРУДОВАНИЯ

**Аннотация.** В конструкциях транспортной техники и технологического оборудования применяются подшипники скольжения и качения, работающие при больших нагрузках в возвратно-вращательном режиме. Они используются в железнодорожном, автомобильном и сельскохозяйственном транспорте в узлах подвески, амортизаторах, рулевом управлении, карданных передачах, в оборудованиях швейного, горнодобывающего, нефтегазодобывающего и перерабатывающего и некоторых других производствах.

Вместе с тем их долговечность, зачастую, недостаточна, а восстановление таких сопряжений традиционными методами путем замены на ремонтные комплекты, аналогичные по конструкции, не позволяет решить эту проблему.

Авторами выдвинута идея, что резервом повышения долговечности сопряжений, работающих при больших нагрузках в возвратно-вращательном режиме, является совершенствование технологии восстановления их работоспособности путем использования ремонтных комплектов, сконструированными на новых принципах работы трибосопряжений, а именно – подшипников скольжения с подвижными пружинными вкладышами.

Теоретически обоснована конструкция ремонтного комплекта сайлентблока в виде подшипника скольжения с подвижными коническими пружинными вкладышами. Разработаны математические модели процесса изменения размера подвижного конического пружинного вкладыша подшипника скольжения сайлентблока амортизатора.

Теоретическая значимость исследования обоснована тем, что: доказаны теоретические положения, расширяющие представление о методах восстановления сайлентблоков амортизаторов применением ремонтных комплектов с подвижными пружинными вкладышами. Значение для практики заключается в том, что разработанные ремонтные комплекты сайлентблока амортизатора имеют ресурс в 1,5…2 раза больший по сравнению со стандартным.

Представленные результаты научного исследования могут быть использованы для разработки новых технических и технологических решений для совершенствования методов восстановления узлов транспортной техники и технологического оборудования, где имеются сопряжения, работающие при больших нагрузках и совершающие возвратно-вращательные движения.

**Ключевые слова:** ремонтный комплект, пружинные вкладыши, подвеска автомобиля, амортизаторы.

**Information about authors:**

Kushaliyev D.K., Candidate of Technical Sciences, PhD, Project Office Manager "AGROTECH HUB" Zhangir khan West Kazakhstan agrarian Technical university, Uralsk, Kazakhstan, Project Manager: № AP05133348; zkaty777@mail.ru; https://orcid.org/0000-0003-1389-5918

Vinogradov A.N., Doctor of technical sciences, associate professor, professor of Saratov State Technical University named after Gagarina Yu.A. Russia, Saratov, Russia; van56@mail.ru; https://orcid.org/0000-0003-1610-0973

Baltayev T.A., Candidate of Technical Sciences, PhD, Senior Lecturer "Department of Ecology and Life Safety" Kazakh IT University, Uralsk, Kazakhstan, Project Manager: № AP05133348; nb.ver@bk.ru; https://orcid.org/0000-0002-6161-4132

Ermanova B.A., Master of Technical Sciences, Senior Lecturer, "Department of Ecology and Life Safety" Kazakh IT University, Uralsk, Kazakhstan, Project Executor: № AP05133348; ermanova.b@mail.ru; https://orcid.org/0000-0002-7723-2999

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