

RESOURCE IMPROVING OF EQUIPMENT USING AUTOMATIC CENTRALIZED LUBRICATION SYSTEMS

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ПОВЫШЕНИЕ РЕСУРСА ОБОРУДОВАНИЯ ПУТЕМ ИСПОЛЬЗОВАНИЯ АВТОМАТИЧЕСКИХ ЦЕНТРАЛИЗОВАННЫХ СМАЗОЧНЫХ СИСТЕМ

The structure of energy losses due to friction of kinematical pairs has been studied. The main reasons of devices failure having friction pairs have been defined. The advantages and disadvantages of automatic centralized lubrication systems have been demonstrated and their classification and areas of application have been provided. The results of the comparison of resource and time-cost for equipment (mining excavators, trolleybuses) with and without centralized automatic lubrication systems have been presented. The concepts of improving the lubrication process and increasing the industrial equipment resource have been offered.

Keywords: regulation, automatic centralized lubrication system, pump unit, technological process.

Introduction

Ever since man picked up a stick and decided to dig up an edible root and after this process found bloody calluses on one's hands, it became clear that the problem of friction is very serious and it must be fought. Definitely, without friction our life is impossible, but in mechanics we have to, basically, overcome these forces by trying to reduce them to a minimum. From documented sources we see the attempts of ancient Egyptians pouring oil on the route of moving statues to reduce friction, and Virgil records of 100 BC of Roman carts with "squeaky" and "groaning" hubs, although they were tarred and greased, and Leonardo da Vinci's studies on friction in bearings, the prototypes of modern ones. Unfortunately, in our time in Ukraine lubrication technology level remains at the level of "carts".

Problem

About 25% of the energy used in the engineering in the world, is lost due to friction. Losses from the wear of mechanical components is estimated at 1.3 - 1.6% of the GDP of the developed countries. According to the European Commission, the costs associated with the problems of friction and wear in Europe are 350 billion Euros per year. Thirty three per cent of these losses are the losses of industrial production, 6.5% are losses in energy production. Given the fact that the depreciation of fixed assets in industry and energy reaches on average 60-70%, at the Ukrainian enterprises these costs differ many times to the worse from Europe. The repair of equipment in the developed countries employs about 30% of total workers and about the same proportion of the machine park. The repair takes fifth of all run metal. Friction energy is not only lost, but transformed into heat, which heats the mechanisms and machines units. Approximately 80-90% of machines failures are not due to immediate damage, but due to wear of parts and components, as well as operating tools. During a complete cycle of operation of machines, the operating costs, labor and maintenance costs of materials for repair are several times higher than the cost of producing new machines. Thus, the main objective of the research is to identify ways to improve industrial equipment resource using automatic centralized lubrication systems (ACLS).

The proposed solution

Such high costs are caused, inter alia, by underestimation of the importance of timely and quality lubrication processes. Lubrication dramatically reduces the intensity of wear. A small amount of lubricant injected into the contact area will reduce the friction by tenfolds and the wear of friction surfaces – by up to 1000. The traditional approach to the problem of reducing friction by improving lubricant materials, including using supplements and additives for oils and lubricants, does not solve all the problems of machines and mechanisms wear. To further improve the efficiency of industrial enterprises, it is required to modernize the used equipment aiming at ensuring its planned serviceability. Planned, trouble-free operation of the equipment (equipment's ability to meet specified characteristics within a certain time interval) directly affects the quality of the produced products and thus determines the competitiveness of total production. In addition, today's costs under the "maintenance fund" account are about 15-30% in the structure of estimate of expenditures (excluding basic raw materials, materials and components). In this area 60% of the production and engineering staff (including appropriate staff in the primary production workshops) are employed.

Of course, the use of ACLS does not solve all the problems of industrial equipment, but significantly increases the operation life. The practice of using ACLS shows that finances invested into improving lubrication system of basic units of any equipment is quickly returned on. Since in addition to the continuation of their lifetime, 30-50% less time goes to planned and unplanned downtime associated with maintenance and repair, power consumption is reduced. As well as the cost of spare parts and repairs is reduced by 50% of the current ones.

According to expert assessment, 85% of machinery and equipment should be fit with lubrication systems and multioutlet pumps to ensure the accuracy and timeliness of lubricants supply.

This is due to several reasons. For example, unexpected high load, improper mounting of bearings, inadequate effectiveness of sealing, bearing seating under excessive tension and, therefore, insufficient internal clearance or excessive internal tension is bearing. But most importantly, as established by SNR professionals, the vast majority (70%) of cases of bearings failure is associated with improper lubrication (Fig. 1).

Application of ACLS significantly reduces the number of premature bearing failure caused by insufficient lubrication, reduces repair costs for friction units, provides higher service life of equipment, and increases its reliability. Given the high cost of processing equipment and a natural intent of the operators to reduce nonproductive downtime, it is necessary to lubricate the points of friction during operation of the equipment and reduce mechanical losses in friction pairs, and most importantly, to continue fault-free service life of bearings and friction units. Usage of ACLS allows a more often than in manual operation, supply of lubricants in friction pairs in the required quantities without taking out machines of operation and extends their lifespan by 2.5 times or more.

Engineers and scientists of companies develop new bearing designs, spend years to thoroughly select construction materials, to develop the most efficient design, to study the kinematics, and to improve manufacturing processes. The result of this work is the emergence of technologies that set new standards for reliability of bearings. However, the bearings fail to function, and often earlier than the stated resource. Purchasing expensive imported bearings, the consumers want to use them instead of Ukrainian, Russian or Chinese, hoping that they will be more durable. Practical experience has shown that their life is the same. In most cases this is due to the fact that a top-quality imported bearing functions the same as others, it is not the quality of the bearing to be blamed, as the number of defects in modern bearings manufacturing is insignificant.

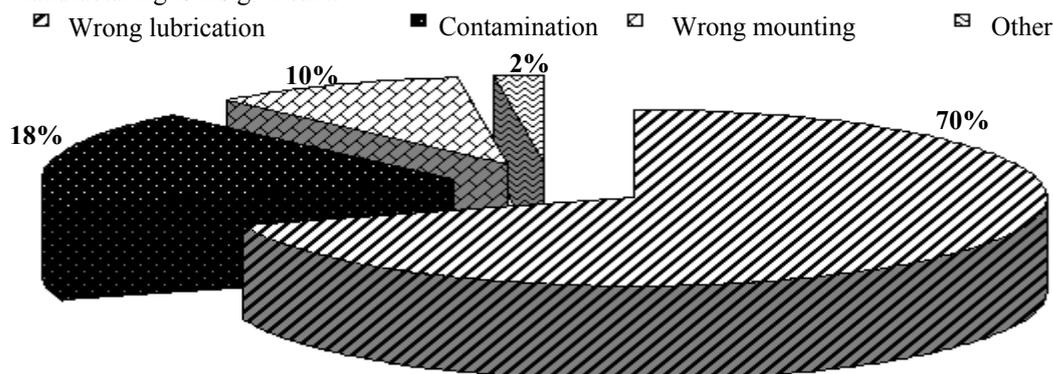


Fig. 1. Main reasons of bearings failure

Often, the main origin of the above is not the low qualification of engineering technical and working personnel or violations of labor discipline, but the attempts of enterprises to unadvisedly to save on everything, from recruitment and training of staff to using unsuitable lubricants. Damage to the bearing and its fail to function can cause an emergency situation, loss of life, downtime of equipment, material losses.

As far as bearings are usually only small parts of machines, poor lubrication is the cause of large complex problems. Often it is because of failure of lubricating film in the areas of contact of the rolling elements with the racer that is under a load, which leads to the so-called "dry" friction.

Common causes of breakdowns due to improper lubrication is the use of inappropriate lubricants, high concentration of contaminants, especially dirt and metal particles that bombard the details of the mechanism and cause premature wear.

Use of ACLS allows change the situation by filling the greasing substances into friction pairs or bearing by small portions in small intervals and exactly while the machine or mechanism is operating.

At present, the following systems are offered: multiline, progressive, single-line (centromatik), two-line, spray systems, oil-air, lubrication of chain belts, rails, circular, filling, gears lubricating, oil level support, as well as wide range of manual lubrication tools for lubricating bearings through a press lubricator.

Below, we consider some of them:

Multiline - each pumping element delivers lubricant to one bearing, a progressive one is when the lubricant is distributed by a feeder into several friction units. In such systems, the number of points can be up to 1000, but there is a limit related to distance from the pumping station to the lubrication points.

Pumps used in multiline and progressive systems are: electrical (from 1 up to 36 pumping elements), manual, hydraulic, and pneumatic.

The main part of multiline and progressive systems is the pumping element with unregulated and regulated supply.

The main element of the progressive system is the progressive distributor. Distributors ranging from 6 to 22 outputs are used, with dosed discharge, flange and for large diameter pipes.

Progressive system has found its application in the mobile and stationary equipment. These are loaders, motor vehicles, drilling rigs, small excavators, buses, trolleybuses, trams, tractors, cranes, grapples. Just in one Kriviy Rig region over 200 pieces of mobile equipment is operating with ACLS. Overall, in Ukraine, their number exceeds 2000.

On stationary equipment, the system is used on bottling lines (Obolon, Pepsi-Cola), packaging lines of cement and other materials, in roar machines, crushers, cooling drums, feeders, conveyors, car dumpers, cranes, wind turbines.

As an example, ACLS the efficiency can be seen on a municipal trolleybus (table 1).

In modern conditions, all plants that produce motive power for public municipal transport, seek to implement the strategy of "technological leadership", which assumes constant updates and additions to their product line. This is necessary in order to best meet the customer needs and to provide a competitiveness of their products. In the past, trolleybuses of domestic manufacture were exported to many foreign countries, including Greece and Argentina. But before 1990, our machinery had lapped behind the world level and was no longer in demand. Today, machine builders of the CIS are trying to regain the lost positions in the international market. Application of ACLS is one of the essential requirements of European customers.

Trolleybus chassis has lots of high-friction surfaces that require constant lubrication. To solve this problem, a manual syringe and a press lubricator are traditionally used as the most simple and cheap to operate. Along with such compelling factors as low cost and simplicity, this method has some significant drawbacks:

1. The possibility of clogging press lubricators, which might result in dirt getting into friction pair.
2. Impossibility of accurate dosing of the lubricant.
3. Varied frequency of lubrication of certain friction pairs.
4. For lubrication of units inspection pits or lifts are required.
5. The quality of the lubrication process largely depends on the integrity of the staff, their qualifications, and other subjective factors.

Often, because of the inconvenience in servicing of certain units, the lubrication is performed only in state of emergency.

The main technical task of ACLS is to achieve precisely dosed supply of lubrication to all points of friction of the chassis automatically during operation of municipal public transport. At the same time, having eliminated the need to conduct lubrication operations in the "Maintenance-1" and "Maintenance-2". Since 2006, an experimental operation is being held in SPB CUE of "MiskElektroTrans" "Trolley Park # 6." In August 2009, a comparative analysis was conducted between "TROLZA 62052B" machines, which came out of the factory assembly line at the same time, and the following results were obtained (data is provided by "EtalonBudService" Co Ltd, Kriviy Rig, the official representative of "Lincoln GmbH" in Ukraine):

№	Trolleybus «TROLZA 62052B»	Garage number 6009	Garage number 6010	Result
1.	ACLS «Lincoln» installed	January 12, 2006	Not installed	-
2.	Vehicle type	ZIU - 10	ZIU - 10	-
3.	Manufacturing number	213	214	-
4.	Full lifetime as of July 31, 2009	43 months		-
5.	Total mileage	146313 km	99517 km	№ 6009 more by 47%
6.	Time losses on the line	16 hours, due to factory defect	80 hours (including 16 hours due to factory defect)	№ 6009 less by 64 hours
7.	Conducted "Maintenance - 1". Time spent on lubrication work	180 times, 1 hour 15 min. (actually)	180 times 60 hours (estimated time)	№ 6009 48 times less
8.	Conducted "Maintenance - 2". Time spent on lubrication work	31 times, 15 min. (actually)	31 times, 10 hours 30 min. (estimated time)	№ 6009 52 times less
9.	Repair work: Overhaul of steering knuckles	Not conducted	3 times	№ 6009 wear reduced by 3 times
	Repair of trailer knuckles	1 time (Manufacturing defect)	time (Manufacturing defect)	The same
	Overhaul of slave arms of a towing machine	Not conducted	2 times	№ 6009 wear reduced by 2 times
10.	Lubricant type	LM-2EP	Litol 24 15 B. GPML/VD	Lubricant is the same
11.	Lubricant consumption, according to the lubrication chart of manufacturer, for 20 points: For 1 month Over the entire period	Estimated / Actual 0.619 kg / 0.400 kg 26.614 kg / 17.2 kg	Estimated / Actual 0.619 kg / 0.619 kg 26.614 kg / 26.614 kg	At № 6009 lubricant consumption compared with the required has decreased by 1.5 times without loss of quality

The comparison shows that automatic centralized lubrication system can significantly reduce unplanned downtime, lower by over 2 times the repair costs, and allow save lubricating material without losing the quality of the lubrication. All this, as well as reducing time for lubrication works, made it possible to increase total mileage of the trolleybus equipped with ACLS compared to the not equipped one by over 47%, an average by 1.000 km per month. Given that the difference in trolleybus cost is just 1.5% - the efficiency of the system is obvious.

The next item for consideration is the two-line system.

They work on the principle of half-cyclic lubrication feeding into one of the pipe-lines to the feeders that supply lubrication to half of the lubricated points, the second line is discharging. With the second filling the other portion of points is being lubricated. The cyclicity of switching on is determined by the time specified on the control unit based on the requirements of the unit lubrication. Such systems can provide lubrication of up to several thousand points and on long distances (up to 1000 m).

The elements of two-line systems are pressure regulation units, feeders, reversing mechanisms. One of the most demanded is the feeder with magnetic indicator. It has no moving seals - the main causes of feeder failure, and its ring is visually observed from a distance of 15-20 m, which makes it indispensable when approaching the feeder during equipment operation is impossible or dangerous.

Two-line lubrication systems are used in continuous casting machines, coke production, blast-furnace process, rolling, and in heavy equipment – walking excavators (WE), crawler mounted mining shovels (CMMS) (Table 2).

As an example, the effectiveness of such a system on the excavator CMMS8 (data is provided by "EtalonBudService" Co Ltd, Kriviy Rig, the official representative of "Lincoln GmbH" in Ukraine):

Table 2

№	Name of lubrication points	Number of points, pcs.	Consumption of lubricant per one point, liter (kg) *				Lubrication time of one point, min. **				Consumption of lubricants per month totally, liter (kg)		Saving of lubricants per month totally, liter (kg)	Lubrication time per month totally, min. ***		Saving of time per month totally, min. ***
			Per day		Per month***		Per day		Per month***		Without ACLS	With ACLS		Without ACLS	With ACLS	
			Without ACLS	With ACLS	Without ACLS	With ACLS	Without ACLS	With ACLS	Without ACLS	With ACLS						
1.	Bush roller bearing saddle	4	0,12	0,06	3	1,5	2	-	50	-	12	6	6	200	-	200
2.	Loose leaf bearing saddle	2	0,03	0,015	0,75	0,375	2	-	50	-	1,5	0,75	0,75	100	-	100
3.	Bearing of gear rotation	4	0,01	0,005	0,25	0,125	-	-	5	-	1	0,5	0,5	20	-	20
4.	Beam handle	1	0,24	0,08	6	2	5	-	125	-	6	2	4	125	-	125
5.	Teeth of the running gear	1	1,1	0,2	27,5	5	5	-	125	-	27,5	5	22,5	125	-	125
6.	Bushing separator of roller wheel	1	0,035	0,015	0,875	0,375	2	0,2	50	5	0,875	0,375	0,5	50	5	45
7.	The surface of the roller wheel bearings	2	0,675	0,2	16,875	5	5	-	125	-	33,75	10	23,75	250	-	250
8.	Bushings of roller wheel	40	0,05	0,02	1,25	0,5	1,5	0,2	37,5	5	50	20	30	1500	200	1300
9.	Central pin	1	0,035	0,070	0,875	1,75	1,5	-	37,5	-	0,875	1,75	-0,875	37,5	-	37,5
10.	Spherical disc of central pin	1	0,02	0,04	0,5	1	1	-	25	-	0,5	1	-0,5	25	-	25
11.	Bushings of tension wheels	2	0,011	0,02	0,275	0,5	1	-	25	-	0,55	1	-0,45	50	-	50
12.	Bushings of road wheels	8	0,005	0,015	0,125	0,375	1	-	25	-	1,0	3	-2,0	200	-	200
13.	Bearings of onboard gear	4	0,01	0,01	0,25	0,25	-	-	5	-	1,0	1	-	20	-	20
14.	Bushings of driving shafts	2(4)	0,015	0,015	0,375	0,375	1	-	25	-	0,75	0,75	-	50	-	50
15.	Maintenance time of ACLS (including fueling)													240	-240	
	Total	73									137,3	53,125	84,175	2752,5	445	2307,5

* Lubricant consumption at operation of excavator CMMS-8 is prepared in accordance with the operating instructions 3536.00.00.000TO

** Duration of manual lubrication is defined by operations timing of lubrication of excavator CMMS-8 elements

*** At the estimation of 25 working days per month

Saving of lubricant grease of excavator friction units equipped with ACLS is 84.175 kg * 12 months = 1010 kg per year.

The decrease of downtime during lubrication is 38.45 hrs * 12 months = 461.4 hours per year.

Number of additionally loaded rock (ore), at the rate of excavator's productivity of 1000 tons per hour is about 460 thousand tons per year.

Spray systems of lubricant grease.

The most efficient way to lubricate open toothed gears, which can significantly reduce the wear and tear of the elements, and as a result improve their reliability and durability, is spraying lubricant grease.

The main elements are a pumping station and spray nozzle.

The principle of this system is the following: lubricant is delivered by one of the pipelines into the nozzle, and the air is delivered by the other. Passing through the nozzle in separate channels, lubrication and air "meet" only on the way out, when the air, leaving four outlets around the perimeter of the nozzle injector, opens and picks up small drops of the lubricant, which are delivered by two holes, and moves them to the lubrication object.

The effectiveness of this method is mainly due to the fact that at the time of rubbing of the drive and the driven gears, such lubrication methods as "lubrication-air" and poured liquid lubricants do not provide availability of lubricant film needed to reduce shock loads that occur at gear clutch running-in. They are effective at very low speed and small modules of gear clutch. At high speeds, pouring lubricant on the drive gears or supply of liquid lubricant with air leads to bouncing of oil droplets from the tooth, thus, creating the effect of oil mist, which is inefficient at very large loads in the contact areas of drive and driven gears. In addition, the use of ACLS spraying lubricant grease can fully provide and maintain within the specified limits the guaranteed thickness of lubricating film of gear mills. Lubrication system applied at the mills of Kovdorsky ore-dressing and processing enterprise was awarded a gold medal at the St. Petersburg exhibition as the best innovative project in 2009 in Russia.

Depending on the conditions of the object with the toothed gear and its width, if necessary, design plates with jets and frames of their mounting can be developed. The main element of this system is the spray nozzle. It can be unregulated and regulated.

Spray systems of lubricant grease are installed at many enterprises, especially at the mills and furnaces of cement factories. The experience of ACLS spraying of lubricant grease of toothing gears of mills at Poltava ore-dressing and processing enterprise demonstrated that the wear rate decreased three times, therefore, increased the life of the gear-shaft and of the main gear tooth crown, and five times has decreased the consumption of lubricants. However, the operation of automatic lubrication system increased production culture and improved environmental conditions at the facility.

Efficacy can be traced by specific increase in ore processed per one gear. Installation of lubrication systems RZF2 of Poltava ore-dressing plant was conducted from September 2008 and during 2009, the launch of the latest system took place in January 2010, but already in five years 2004-2008, on average the running-in per one gear was 1255 thousand tons, whereas in 2009 it was 1729 tons. Shaft-gear at mill number 113, mounted in March 2007, on which the lubrication system was installed and which has been operating to this day, more than 3 times is higher than the average duration of operation shaft-gears of the plant (45 months vs. 15).

Oil filling system

Given the high cost of processing equipment and the natural intent of the operators to reduce its nonproductive downtime, it is reasonable to use a unified complex of lubricant delivery to ACLS pumps automatically.

The aim of introducing a unified complex of lubricant supply is modernization of existing production facilities to reduce production costs, improve performance and reliability of process equipment. This is achieved by replacing obsolete technological equipment and the introduction of automated filling pump centralized lubrication systems, which can significantly reduce material costs, improve productivity and environmental protection of the facility.

The main advantage of a unified complex lubricant supply to automatic centralized lubrication systems is the possibility of placing containers in central location in the place most convenient for refilling them with fresh grease.

For efficient use of the unified complex lubricant supply for long distances, pumps pumping to compensate for pressure losses in lubricating highways may be included into the complex.

The main advantages of a unified complex lubricant supply to pumps of the central lubrication systems automatically include:

- Significant reduction of technological losses;
- Maximum use of existing equipment;
- Optimization of staff;
- Lack of human factor;
- Reducing the cost of repairs, spare parts and lubricants;
- Better service life of the equipment;
- Reducing the number of costly interruptions for repairs and maintenance;
- Longer intervals between maintenance;
- Significant reduction in the incidence of failure of bearings;
- Increase machine reliability and environmental protection;
- Increased productivity technique by reducing its downtime.

Conclusions

Active implementation of the industrial production of automatic centralized lubrication systems will significantly improve the efficiency of equipment, reduce lubricant costs, reduce losses of unscheduled repairs resulting from poor lubrication equipment. Use of ACLS will allow professionally perform lubricating operations, the basic qualities of which are effectiveness, reliability, efficiency and ease of operation.

For maximum efficiency of lubrication systems usage, prior to that full technical audit of ACLS should be carried out. As a result of this audit:

- chart of a technical condition of lubricating equipment is made
- recommendations to correct deficiencies are offered,
- plans for remediation repairs are provided
- specification lists for the required spare parts, tools, devices are made
- technical and operational documentation are provided
- training of staff is conducted

After the audit projects should be proposed on the use of automatic centralized lubrication systems for solving problems to improve the efficiency of equipment, reduce energy consumption, reduce lubricant costs, lower the cost of unscheduled repairs that result from poor lubrication equipment.

Анотація. Розглянуто структуру енергетичних втрат за рахунок тертя кінематичних пар. Визначено основні причини виходу з ладу апаратів, які мають пари тертя. Показано переваги і недоліки автоматичних централізованих систем змащування, представлені їх класифікація і область використання. Представлено результати порівняння ресурсних і часових затрат для машин (кар'єрні екскаватори, троллейбуси) з використанням централізованих змащувальних систем і без. Запропоновано напрямки з покращення процесу змащення і підвищенню ресурсу промислового обладнання.

Ключові слова: регулювання, автоматическая централізована система смазки, насосний агрегат, технологический процес

Аннотация. Рассмотрена структура энергетических потерь за счет трения кинематических пар. Определены основные причины выхода из строя аппаратов, имеющих пары трения. Показаны преимущества и недостатки автоматических центральных систем смазывания, представлена их классификация и области применения. Представлены результаты сравнения ресурсных и временных затрат для машин (карьерные экскаваторы, троллейбусы) с использованием автоматических центральных смазочных систем и без. Предложены направления по улучшению процесса смазывания и повышению ресурса промышленного оборудования.

Ключевые слова: регулювання, автоматична централізована система мастила, насосний агрегат, технологічний процес.

1. *Реологические и теплофизические свойства пластичных смазок / Г. Б. Фройштетер, К. К. Трильский [и др.]*, Москва : Химия, 1980.
2. *Губарев А.П.* Причинно-следственная модель объектов гидропневмоавтоматики – особенности и свойства.-К.: НТУУ «КПИ», 1999.-107с.
3. *Трибология смазочных материалов / Ю. С. Заславский*, Москва: Химия, 1991.
4. *Автоматизированные смазочные системы и устройства / [Ред. Д. Н. Гаркунов]*. Москва : Машиностроение, 1982.
5. *Розенберг Ю.А.* Влияние смазочных масел на надежность и долговечность машин. М., «Машиностроение», 1970.
6. *Трофимов В.А.* Рабочие жидкости систем гидропривода / В.А. Трофимов, О.М. Яхно, А.П. Губарев, Р.И. Солонин. –К.: НТУУ «КПИ», 2009. -187с.
7. *Bock Wolfgang* Hydraulik-Fluide als Konstruktionselement / Vereinigte Fachverlage GmbH, Mainz, 2010. 144p.

REFERENCES

1. *Frojshteter G. B. K. K. Tryl'skyj.* Reologicheskye i teplofyzicheskye svojstva plastychnyh smazok. Moscow: Hymija, 1980.
2. *Gubarev A.P.* Prynynno-sledstvennaja model' ob'ektov gdropnevmoavtomatyky – osobennosty u svojstva. Kiev: NTUU «KPY», 1999. 107p.
3. *Trybologija smazochnyh materyalov. Ju. S. Zaslavskyj.*, Moscow, Hymija, 1991.
4. *Avtomatyzirovannye smazochnyye systemy y ustrojstva. [Red. D. N. Garkunov]*. Moscow, Mashynostroenye, 1982.
5. *Rozenberg J.A.* Vlyjanye smazochnyh masel na nadezhnost i dolgovechnost mashyn. Moscow, «Mashynostroenye», 1970.
6. *Trofymov V.A.*, O.M. Jahno, A.P. Gubarev, R.Y. Solonyn. Rabochye zhydkosty system gidropriyvoda. Kiev, NTUU «KPY», 2009. 187p.
7. *Bock Wolfgang* Hydraulik-Fluide als Konstruktionselement. Vereinigte Fachverlage GmbH, Mainz, 2010. 144p.