II ТЕХНОЛОГІЇ ОТРИМАННЯ ТА ОБРОБКИ КОНСТРУКЦІЙНИХ МАТЕРІАЛІВ

УДК 621.891

Doct. of Philosoph. Science, Cand. of Techn. Sciences Popov S. N.

Cand. of Techn. Sciences, Ass. Prof. Shumykin S. O.

National University «Zaporizhzhia Polytechnic», Zaporizhzhia

STUDY OF THE FEATURES OF THE WEAR OF A FRICTION PAIR OF A DRIVE WHEEL WITH A MOVER CATERPILLAR UNDER ABRASIVE CONDITIONS

Purpose of work. *The aim of this work is to study the features of the wear mechanism of the working surface of the drive wheel of a caterpillar mover.*

Research methods. *Macro and micro analysis of the friction surfaces of the drive wheel of a mover using optical instruments. Experimental determination of linear wear of a tooth of a wheel after certain periods of operation. Conducting laboratory tests. Multicriteria tribosystem analysis.*

Results obtained. *The mechanism of abrasive wear is determined under the complex influence of both fixed and semi-fixed contact interaction of the tribosystem, which causes an increase in the wear rate of the part. The percentage composition of various real mechanisms of complex destruction of the surface of a friction pair of a wheel and a caterpillar is established.*

Scientific novelty. *For the first time, the features of the metal-metal contact interaction mechanism were established in the presence of abrasive wear in specific operating conditions. The main factors of their range and the level of their variation in the studied devices of the friction pair are analyzed. The degree of joint influence of various factors causing wear of the drive wheel of the caterpillar mover is determined.*

Practical meaning. *The results of the performed scientific work can be used to develop wear-resistant, economically alloyed materials with optimal physical and mechanical properties, structural phase state, as well as technology for hardening and repair restoration of the drive wheel of the device or other parts with similar operating conditions.*

Key words: *caterpillar mover, drive wheel, friction pairs, wear factors, wear mechanism, abrasive particles.*

Formulation of the problem

Self-propelled caterpillar mechanisms are an important means of mechanization of construction, agricultural, geological exploration and other works and are widely used if necessary to provide mobile relocation and maneuvering of equipment in the absence of road surface.

Parts of the equipment such as drive wheels of caterpillar movers made of iron-based alloys are important elements of the whole mechanism. The teeth of the drive wheels, transmitting the transmission torque to the track chain, wear out during operation, which changes the kinematic scheme of the mating parts of the friction pairs. The consequence of this is a reduction in the power and efficiency of the mover, and when critical wear is achieved, an emergency situation is created, which in turn threatens the failure to fulfill the set plans and tasks, which leads to idle equipment and necessitates unscheduled repairs.

DOI 10.15588/1607-6885-2020-1-7

In addition, the implementation of maneuvering operations with a full mass (about 30–60 tons) requires high accuracy and smooth operation of mechanisms and equipment, including a caterpillar mover. The presence of backlashes between the mating parts of the friction pair of the mover, as well as the hit of abrasive particles into the gaps between them and their crushing, reduce the necessary accuracy and smoothness of the operations that can lead to the occurrence of negative consequences, and also significantly increases the possibility of breakdown of the entire mechanism.

The solution to these problems may be the development of an optimal method of restoration and hardening of the drive wheels of the friction pair of the drive wheel-caterpillar. Moreover, the development of such a method should begin with an analysis of the operating conditions and wear of the friction pair of the drive wheel of the caterpillar mover.

Existing literature data that address the issue of wear of the drive wheel of the mover [1, 2] and wear of parts with similar operating conditions [3] do not provide a clear and comprehensive description of the mechanism of destruction of the friction surface of this part.

The above makes it necessary to study the features of wear of the part in question, as the first and necessary stage in the development of technology for its restoration and hardening.

Based on the analysis of a priori data on the indicated problems and the results of experiments, it is necessary to investigate the wear mechanism of the friction pair of the working surface of the drive wheel of the caterpillar mover.

Existing scientific works on the subject [1–3] give, to one degree or another, justified solutions to the problem of hardening the drive wheel. First of all, in the works, when analyzing the wear mechanism of the drive wheel, an intensification of the process of destruction of the teeth of the wheel due to the ingress of the abrasive into the gearing between the teeth and the track is noted.

Moreover, the studies do not fully study the influence of external factors of the tribosystem on the process and the wear rate of the friction pair of the caterpillar mover. In the framework of a multicriteria analysis of the mechanism of steels and alloys [4], consideration of the influence of tribosystem factors on part wear is an important condition for the development of an optimal hardening technology.

Materials and research methods

To determine the features of the wear mechanism, an examination was made of the friction surfaces of the drive wheel of the mover using optical instruments. The determination of the linear wear of the tooth of the wheel to obtain an idea of the wear rate of the part was carried out through the conditional periods of operation.

To describe the significance of the soil composition on which the machine is operated, the dependence of the wear rate of the material of the part on the coefficient Ha / Hm, showing the ratio of the hardness of the abrasive to the hardness of the material, was determined experimentally.

Based on experimental and a priori data, significant factors of the tribosystem under consideration were identified and the degree of their influence was determined to conclude on the contributions of various wear mechanisms to the process of destruction of the working surfaces of the part. This was done in accordance with the multicriteria analysis of the tribosystem [4].

The influence of the abrasive medium on the wear resistance of the material of the part was studi d in accordance with the requirements of GOST 23.208-79 (Fig. 1). But it was not the material of the samples that varied, but the abrasive material. The essence of the method is as follows: the abrasion of the samples and the reference material about abrasive particles, supplied to the friction zone and pressed to the sample by a rotating rubber roller, is performed. As an abrasive, a certain abrasive material was used, particle size distribution - not more than 2.0 mm. Relative wear resistance is evaluated by the ratio of the mass loss of the standard to the mass loss of the sample.

Wear was carried out over 3600 revolutions with an average speed of 9.6 m / min. The force of pressing the sample to the roller was 45 H. The samples were made of steel 45 according to GOST 1050-88.

The study of the working surface of the teeth of the drive wheel (Fig. 2) showed the presence of grooves, scratches and holes, which indicates a complex mechanism of destruction of the friction surface, which consists of the interaction of metal - metal, and metal - abrasive particle. At the same time, the mechanism of abrasive wear is fixed under conditions of both fixed and semi-fixed contacting of the tribosystem, which causes an increase in the wear rate of the part.

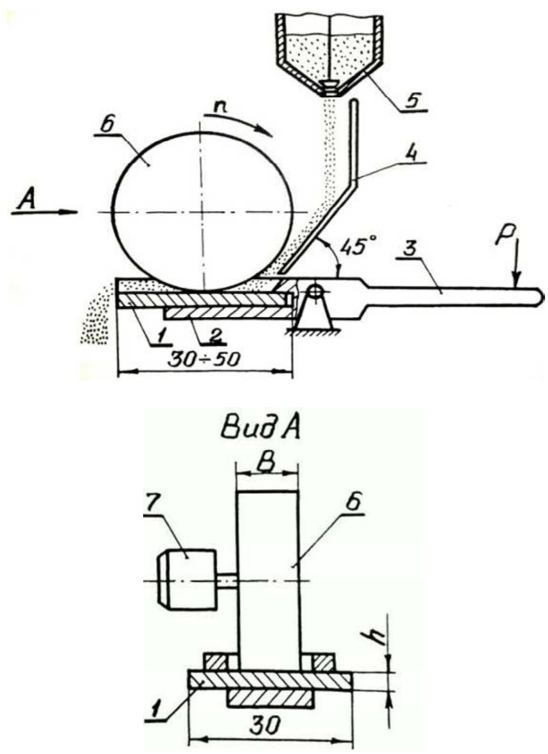


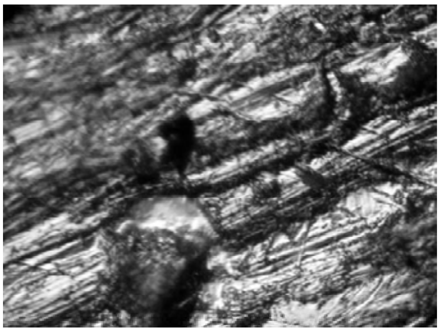
Fig. 1. Scheme of the laboratory setup for determining the relative wear resistance:

1 – sample; 2 – holder; 3 – lever; 4 – a directing tray; 5 – dosing device; 6 – rubber roller; 7 – drive

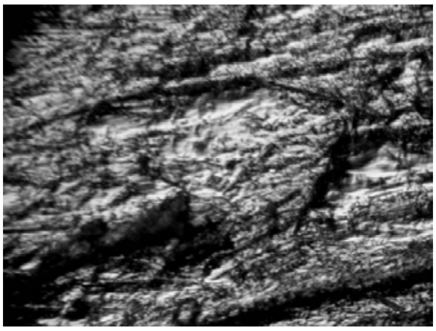
Fig. 2. The nature of the destruction of the working surface of the drive wheel

The destruction of the friction surface of this kind is a consequence of the fact that in the conditions of industrial and construction areas where there are no hard coatings, as well as in the conditions of impassability, plowing, and loose soils, the abrasive particles get into the engagement between the friction pair of the wheel – caterpillar. Analysis of the wear surface registers the presence of damage associated with the contact of the metal with abrasive particles. On the surface (Fig. 3), tracks from the passage of the abrasive are visible, as evidenced by the presence of grooves and scratches.

× 50



×1 00



× 150

Fig. 3. The friction surface after wear with the presence of grooves, scratches and holes

In addition, traces of the irregular shape of ovals are clearly visible, which is typical for the formation of deep holes (150–650 microns), which arise as a result of local shock loading. This picture indicates the possibility of jamming and the likely process of crushing of abrasive particles in the gap between the mating surfaces. Consideration of the latter can be classified as elements of impact-abrasive wear in the conditions of a fixed and semi-fixed abrasive.

The measurements of linear wear and mass loss coefficient $K^{\Delta M}$, g (Fig. 4) of the part after certain periods of intensive use of the parts showed an increase in the unevenness of wear along the length of the tooth.

Also, after 7 months (the distance traveled S = 240–260 km) of operation, the amount of wear of most of the teeth of the wheel reached a boundary mark of 3–4 mm, after which, according to technical standards for such mechanisms, this part cannot be operated and needs repair. At the same time, the recommended service life before repairing the drive wheel is 9 months with intensive use of this equipment. Thus, a premature failure of the part and a loss of 22 % of the overhaul time of equipment operation were noted.

Further, taking into account the recommendations [4] of the list of external and internal wear conditions, the most significant ones were selected, namely, the ratio of the mechanical properties of the mating surfaces, the degree of corrosion effect and the ratio of the hardness indices of the abrasive and the material of the part.

It is worth noting that the influence of the first factor was taken into account by the designers when designing the mover. Therefore, the interaction of the teeth of the wheel and the caterpillar causes long-term fatigue wear of parts, as a result of multi-cycle over-deformation of the microvolumes of the working surfaces. The second factor, the corrosive effect, is due to the weather conditions in which the equipment operates. And the interaction of the part with the abrasive, as already indicated, is associated with the possibility of abrasive particles entering the wheel-caterpillar into the gap.

Given the diversity of the composition of soils on which caterpillar self-movers can be used, it became necessary to conduct an experiment to analyze the mineralogical, granulometric, and composition of abrasive particles. This is necessary to study the influence of their physical and mechanical characteristics, since the presence of various abrasive materials can significantly affect the wear rate of the friction pair of the drive wheel of the mover (Fig. 5).

The experiments were carried out on samples of steel 45, which corresponds to the material of the part under consideration. The type of abrasive used to wear varied. One type of abrasive material was taken from groups such as low abrasive, medium abrasive, high abrasive and highly abrasive [5]. The test results are shown in table 1.

Thus, we noted that the transition in a wear medium from quartz sand to more abrasive materials causes a lower increase in wear rate than before this material. This tendency is comparable with a priori data [6] of the influence of the coefficient of the ratio of the hardness of the wear material and abrasive. Given such a result and the fact that quartz sand is more abundant as a natural abrasive material compared to others, it was concluded that in order to develop wheel hardening technology, it is necessary to focus on the potential negative impact of abrasive material such as quartz sand and granite on this tribosystem.

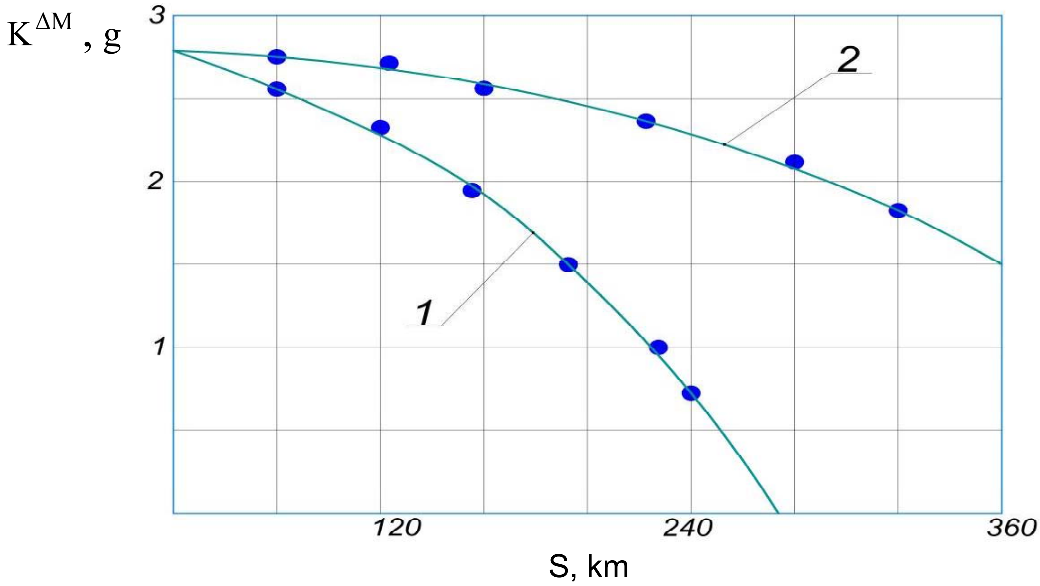


Fig. 4. The dependence of the coefficient of mass loss $K^{\Delta M}$, g, depending on the distance traveled S, km: 1 – steel 45; 2 – 150X10P4Ф2

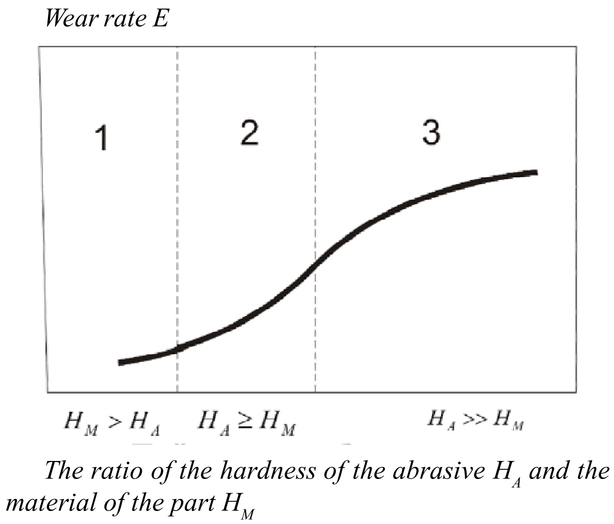


Fig. 5. The dependence of the wear rate on the ratio of the hardness of the abrasive and the material of the part

Table 1 – Test results of steel 45 for wear by various types of abrasive

Abrasive material	Microhardness, GPa	Coefficient H_A/H_M	Wear rate E, g / min
1. Dolomite	4,1	1,1	7,4
2. Quartz sand	13,5	3,3	18,2
3. Granite	15,5	3,9	22,3
4. Corundum	18	4,5	24,1

Summing up the study, relying on the data obtained in the course of experimental and analytical work, as well as on the data of literature [1–6], we found that the complex mechanism of surface destruction of the friction pair of the wheel and track consists of such destruction mechanisms: fatigue – 75 % (metal-metal interaction – contact between the tooth of the wheel and the tooth of the caterpillar), single-cycle – 20 % (interaction of the metal-abrasive particle, through micro cutting and plastic displacement of volumes of the wearing surface), corrosive - 5% (interaction with environmental moisture).

The authors of this work for the first time noted the features and showed the degree of negative impact of acquired wear on the wheels of a tracked vehicle. Also, a distinctive feature of this work is the identification of the main factors of wear of the wheel and a description of the structure of the mechanism of destruction of the wear surface. It is worth noting the selection of the type of abrasive material, on which it is necessary to give attention to the solution of the problem of hardening this part. That is, the described work concretizes and complements the already existing scientific achievements on the specified topic.

The results of the performed scientific work can be used to develop the optimal technology for restoration and hardening of the drive wheel of a tracked vehicle or other parts, the operating conditions of which are similar to those considered. Wherein, further studies can be aimed at finding a set of mechanical properties and chemical composition of the reinforcing layer for the working surface of the part.

Findings

Identification of the main factors of wear of the drive wheel of caterpillar movers, namely, metal-metal contact interaction, metal-abrasive particle and environmental corrosion, as well as an assessment of their influence on the wear process made it possible to identify the structure of the mechanism of destruction of the working surface of the wheel: fatigue – 75 %, single-cycle – 20 %, corrosive – 5 %.

The paper shows the features of unevenness and wear rate of the considered part. Also, from the list of abrasive materials that may be components of the tribosystem under consideration, such material as quartz sand was selected using the experiment and analysis of a priori data. The authors of the work recommended to focus on this abrasive material in subsequent research activities on the subject. The main factors and the degree of their influence on the wear of the friction pair of the drive wheel of the caterpillar mover are revealed. The drive wheel destruction mechanism is proposed. The features of wear of the working surface of the friction of parts working in pairs in the presence of an abrasive are shown. The properties of abrasive materials are analyzed taking into account their complex potential impact in the tribosystem considered of the friction pair of the drive wheel with the caterpillar under the conditions of the abrasive.

These results provide the basis for developing recovery technology and increasing the wear resistance of the caterpillar drive wheel, as well as parts with similar operating conditions.

References

1. Григоров О. В. Современные гусеничные краны / О. В. Григоров // Строительная техника. – 2008. – № 1. – С. 1–9.
2. Черняк Я. П. Материалы и технологии наплавки деталей строительной и дорожной техники / Я. П. Черняк // НАН Украины. Ин-т электросварки им. Е.О. Патона. – К., 2005. – 19 с.
3. Иншаков С. В. Износ и восстановление зубьев ведущего колеса гусеничного движителя / С. В. Иншаков // Вестник ФГОУ ВПО МГАУ – 2010 – № 1. – С. 89–92.
4. Попов С. М. Структурно-логічний синтез та математична оптимізація фізико-механічних параметрів при зношуванні матеріалів в умовах низьких температур / С. Н. Попов, В. В. Нетребко // Нові матеріали і технології в металургії та машинобудуванні. – 2019. – № 2. – С. 72–78.
5. Попов С. М. Триботехнічні та матеріалознавчі аспекти руйнування сталей і сплавів при зношуванні : Навчальний посібник / С. М. Попов, Д. А. Антонюк В. В. Нетребко. – Запоріжжя : ЗНТУ, ВАТ «Мотор Січ», 2010. – 368 с.
6. Багатокритеріальний підхід до аналізу визначення основних критеріїв зношування деталей / [С. М. Попов, С. О. Шумикін, І. М. Білоник, О. М. Захаренко] // Scientific achievements of modern society. Abstracts of the 6th International scientific and practical conference (February5–7, 2020). Cognum Publishing House. Liverpool, United Kingdom. 2020. P. 1048–1053. URL: http://sci-conf.com.ua

Одержано 03.12.2020

Попов С. М., Шумикін С. О. Дослідження особливостей зношування пари тертя ведучого колеса з гусеницею рушія в умовах абразиву

Мета роботи. *Метою даної роботи є дослідження особливостей механізму зношування робочої поверхні ведучого колеса гусеничного рушія.*

Методи дослідження. *Макро- і мікроаналіз поверхонь тертя ведучого колеса рушія, із застосуванням оптичних приладів. Експериментальне визначення лінійного зносу зуба колеса через певні періоди експлуатації. Проведення лабораторних випробувань. Багатокритеріальний аналіз трибосистеми.*

Отримані результати. *Визначено механізм абразивного зношування в умовах комплексного впливу як закріпленого, так і напівзакріпленого контактної взаємодії трибосистеми, що викликає збільшення інтенсивності зношування деталі. Встановлено процентний склад різних реальних механізмів комплексного руйнування поверхні пари тертя колеса і гусениці.*

Наукова новизна. *Вперше були встановлені особливості механізму контактної взаємодії метал-метал при наявності абразивного зношування в конкретних умовах експлуатації. Проаналізовано основні чинники, їх діапазон і рівень їх варіювання в пристроях, що вивчаються пари тертя. Визначено ступінь сумісного впливу різних чинників, що викликають знос ведучого колеса гусеничного рушія.*

Практичне значення. *Результати виконаної наукової роботи можуть бути використані для розробки зносостійких економнолегованих матеріалів з оптимальними фізико-механічними властивостями, структурно-фазовим станом, а також технології зміцнення та ремонтного відновлення ведучого колеса пристрою або інших деталей з аналогічними умовами експлуатації.*

Ключові слова: *гусеничний рушій, ведуче колесо, пари тертя, фактори зношування, механізм зношування, абразивні частинки.*

Попов С. Н., Шумикин С. А. Исследование особенностей изнашивания пары трения ведущего колеса с гусеницей движителя в условиях абразива

Цель работы. *Целью данной работы является исследование особенностей механизма изнашивания рабочей поверхности ведущего колеса гусеничного движителя.*

Методы исследования. *Макро- и микроанализ поверхностей трения ведущего колеса движителя, с применением оптических приборов. Экспериментальное определение линейного износа зуба колеса через определенные периоды эксплуатации. Проведение лабораторных испытаний. Многокритериальный анализ трибосистемы.*

Полученные результаты. *Определен механизм абразивного изнашивания в условиях комплексного влияния как закрепленного, так и полузакреплённого контактного взаимодействия трибосистемы, что вызывает увеличение интенсивности изнашивания детали. Установлен процентный состав различных реальных механизмов комплексного разрушения поверхности пары трения колеса и гусеницы.*

Научная новизна. *Впервые были установлены особенности механизма контактного взаимодействия металл-металл при наличии абразивного изнашивания в конкретных условиях эксплуатации. Проанализированы основные факторы, их диапазон и уровень их варьирования в изучаемых устройствах пары трения. Определена степень совместного влияния различных факторов, вызывающих износ ведущего колеса гусеничного движителя.*

Практическое значение. *Результаты выполненной научной работы могут быть использованы для разработки износостойких экономнолегированных материалов с оптимальными физико-механическими свойствами, структурно-фазовым состоянием, а также технологии упрочнения и ремонтного восстановления ведущего колеса устройства или других деталей с аналогичными условиями эксплуатации.*

Ключевые слова: *гусеничный движитель, ведущее колесо, пары трения, факторы изнашивания, механизм изнашивания, абразивные частицы.*