***Problems of Tribology**, V. 26, No 2/100-2021,65-70*

Problems of Tribology
Website: http://tribology.khnu.km.ua/index.php/ProbTrib
E-mail: tribosenator@gmail.com

DOI: https://doi.org/10.31891/2079-1372-2021-100-2-65-70

Theoretical research of the technology of finishing cylinders with antifriction materials

D.D. Marchenko*, K.S. Matvyeyeva

Mykolayiv National Agrarian University, Mykolayiv, Ukraine
**E-mail: marchenkodd@mnau.edu.ua*

Abstract

The article analyzes the research aimed at the use of various materials, additives and additives to oils. It is established that their application is mainly limited to the stages of operation, bench and operational running-in. The use of antifriction materials at the stage of processing the parts of internal combustion engines, limiting the resource, is small, despite the fact that such treatment reduces the running-in time and improves the finish of the friction surfaces. Theoretical calculation of the parameters of the working surface of the engine cylinder liner during their finishing using special antifriction materials showed a 2-fold increase in the bearing surface (from 0.2 to 0.4 of the nominal surface area at the level of the middle line of the profile) and a roughness of 0.27 µm, which is close to the values after the bench run-in. This proves the possibility of using this treatment in order to reduce the time of preparation of CNG and improve the characteristics of the surfaces to be worked. It is established that the finishing of engine cylinder liners with antifriction materials should be carried out at the contact pressure of the working tool (brass bars) on the surface of the sleeve 3 MPa, the speed of the working tool 5.5 m/s, the processing time of the sleeve 20 min. Finishing of sleeves with use of compositions TSK-B100 + SURM-KV, SURM-UO and RVS allows to reduce mechanical losses on friction in TsPG by 5-19% at the beginning of process of running in after processing in comparison with mechanical losses at the end of cold running in without finishing sleeves; to obtain the roughness parameters after finishing the same as after cold running in without additional processing of the sleeves; increase the bearing surface by 2 - 2.5 times (from 0.2 - 0.25 to 0.4 - 0.5 of the nominal surface area at the level of the middle line of the profile), which confirms the calculated data. The final treatment of sleeves with compositions based on antifriction materials TSK-B100 + SURM-KV, SURM-UO and RVS allows to provide values of parameters of a working surface of sleeves (reduction of roughness, increase of a basic surface) approaching their values after cold running in, therefore allows to increase contact loadings. in the connection "sleeve - piston ring" after this treatment and reduce the time of the bench run-in (to the values required for the attachment of other engine connections).

Key words: finishing, wear resistance, friction reduction, antifriction materials, nanocompositions, resource.

Introduction

One of the factors that determine the durability of engines is the condition of the friction surfaces. It is known that wear resistance depends on the finishing (final) technological treatment of the surfaces of parts. There are experimental studies on the effect of roughness of friction surfaces on the intensity of wear. For widespread joints, the optimal values of roughness parameters have been identified, at which wear of parts is minimal. It is established that not only the primary (running-in) wear, but also constant wear depends on finishing of details, ie primary finishing can influence intensity of wear at long operation of cars. First of all, this applies to the parts of the cylinder-piston group (CPG) of internal combustion engines. When forming friction surfaces, it is necessary to ensure the optimal tribotechnical characteristics of the mating surfaces, such as low coefficient of friction, high wear resistance, optimal physical and mechanical properties. To a large extent, they are determined by the methods of treatment of friction surfaces. Recently, new technological processes of finishing have been developed, which allow to reduce running wear and increase antifriction properties (increase the lubrication of parts, reduce the coefficient of friction, etc.), as well as reduce the time of friction pairs [1].

However, the analysis of information obtained from printed and electronic sources makes it possible to state that not all reserves of intensification of CPG production processes in terms of application of new methods of finishing cylinder liners are exhausted.

Recently, the market for a variety of antifriction materials, additives and additives in oils, which form protective films on friction surfaces, is developing rapidly. The possibility of using such drugs to provide the working surfaces of the sleeves with optimal tribotechnical characteristics at the stage of their final processing in the repair or manufacture of internal combustion engines has been little studied [2]. Therefore, the influence of the treatment of cylinder liners with different antifriction materials in the repair or manufacture of internal combustion engines on the characteristics of working surfaces and processes of making connections is a relevant topic for research.

Literature review

Operating conditions of agricultural machinery reduce the service life of engines, which is largely determined by the service life of cylinder liners. Wear resistance and serviceability of cylinder liners depend on the quality of their working surfaces, which, in turn, is due to a combination of characteristics of roughness and corrugation, physical, mechanical and chemical properties, as well as the microstructure of the surface layer. The quality of the inner surfaces of the sleeves is formed in the process of performing a set of technological operations, taking into account the manifestation of technological heredity. Especially important are the finishing operations, as a result of which the main characteristics of the surface layer are finally formed.

Many scientists have studied the processes of making friction surfaces during the running-in of internal combustion engines, methods of processing the working surfaces of CPG parts, and the application of various antifriction materials. The following authors devoted their scientific works to these topics: S.G. Arabyan, V.I. Balabanov, N.S. Zhdanovsky, V.F. Karpenkov, V.S. Kombalov, V.N. Kuzmin, V.N. Listovsky, I.A. Mishin, V.S. Nekrasov, S.A. Ovodov, L.I. Pogodayev, G. Polzer, V.N. Popov, E.V. Ryzhov, V.V. Striltsiv, V.I. Tsyptsin and many others [3, 4].

The analysis of the conducted researches shows that, despite a very large number of works devoted to quality improvement and reduction of time of finishing of surfaces of the rubbing engines, some questions demand the further studying. In particular, little research has been presented on the application of new methods of finishing cylinders based on various antifriction materials in order to intensify the processes of LNG production [5].

Despite the achieved level of development of traditional methods of finishing cylinders of internal combustion engines (ICE), their application in agricultural repair practice is associated with considerable complexity, and the use of the most advanced technological processes is unable to meet modern requirements for quality cylinders and holes. to increase their reliability and durability [6]. In this regard, there is a need to develop a new method of finishing the cylinder liners using a tool design available to agricultural repair companies and provides the necessary characteristics of the surface layer.

Purpose

The purpose of the research is to improve the processes of CPG production by applying the finishing of cylinder liners with antifriction materials.

Research methodology

When the contact surfaces slide, first the process of attachment takes place, which is accompanied by a change in the microgeometry, as a result of which some constant roughness characteristic of these friction conditions is established. In the process of finishing, the physical and mechanical properties of the surface layers also change, because the contact is usually dominated by plastic deformations. Therefore, based on the initial microgeometry and the initial properties of the surfaces, it is possible to determine the contact characteristics only in the initial period of attachment. The process of finishing can be considered as a gradual increase in the bearing surface and the elastic component of the contact area, reducing the proportion of plastic, resulting in reduced total wear.

The process of finishing can be assessed by changing the reference curve. The reference curve characterizes the distribution of material along the height of the rough layer and plays an important role in calculating the area of rough bodies. According to N.B. Demkin and I.V. Kragelskiy initial part of the reference curve can be represented as:

$$t_p = \frac{\sum \Delta l_p}{l} = \frac{A_p}{A_c} = b\left(\frac{a}{R_{\max}}\right)^v, \tag{1}$$

where t_p – is a parameter of the relative reference length of the profile;

$\sum \Delta l_p$ – the total length of the sections of the protrusions at the level of p, mm;

l – base length of the profile, mm;

A_p – cross-sectional area of the protrusions at the level of p, mm^2;

A_c – nominal area, mm;

b and v – are the coefficients of static approximation of the reference curve (obtained by appropriate processing of surface profiles);

a – is the distance from the line of protrusions to the level of the section, μm;

R_{max} – maximum height of profile irregularities, μm.

Dependence (1) well approximates the initial section of the reference curve (to the middle line of the roughness profile).

The approximate values of the parameters of the roughness of the sleeve at different stages of its processing and running-in, used to calculate the reference curve, are presented in table. 1, which is compiled according to V.S. Kombalov, E.V. Ryzhov and S.A. Ovodov, as well as obtained during previous experiments [7].

Table 1

The value of the parameters of the roughness of the sleeve to calculate the reference curve

Processing stage	R_{max}, μm	R_a, μm	r, μm	b	v
After honing	4,7	0,65	15	0,7	1,8
After finishing with special drugs	2,4	0,27	30	1,4	1,7
After the bench run-in	2,3	0,25	35	2,0	2,0

Research results

In Fig. 1 presents the calculated values of the initial section of the reference curve.

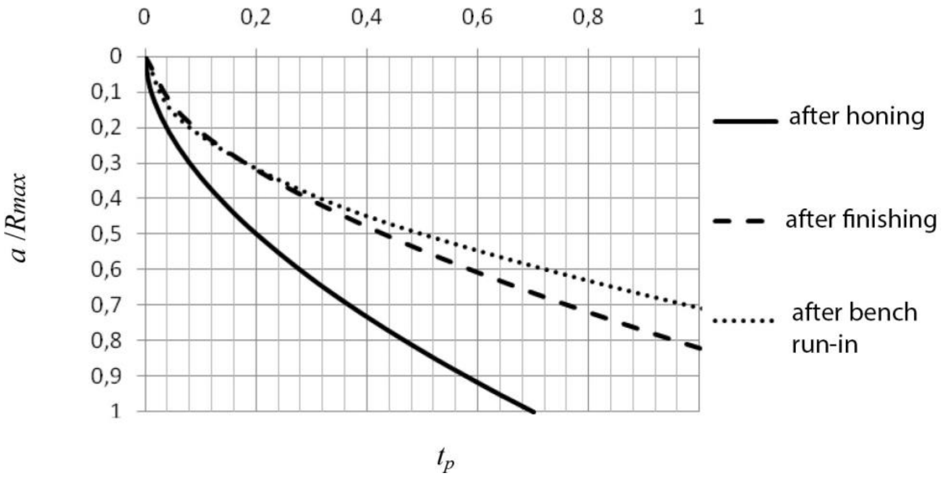

Fig. 1. Estimated values of the initial section of the reference curve

Also, the process of finishing can be assessed by changing the roughness parameters. For cylinder liners of the D-240 engine the normative and technical documentation normalizes the parameter R_a (arithmetic mean deviation of the profile).

According to L.E. Hallstani change of the arithmetic mean deviation of the R_a profile during surface finishing occurs according to the hyperbolic law:

$$Ra(t) = \frac{k \cdot Ra_H}{t \cdot Ra_H + k}, \tag{2}$$

where $Ra(t)$ is the arithmetic mean deviation of the profile, which varies depending on the wear time, μm;

$Ra_{н}$ – the initial value of the arithmetic mean deviation of the profile, μm;

t – time of preparation, h;

k – coefficient depending on the time of attachment [8].

Using the empirical Bosch formula $f = \dfrac{k}{1 + c \cdot v}$, the coefficient *k* was expressed:

$$k = f \cdot (1 + c \cdot v), \tag{3}$$

where f – is the coefficient of sliding friction (dimensionless), with time f decreases and for different times of attachment t will be different; *c* is the coefficient (for metals c = 3÷4);

v – is the speed of the piston, m/s (accepted speed v = 3.36 m/s).

The data obtained by S.A. Ovodov were used to calculate the coefficient of friction during the running-in of the CHP and the change in the intensity of wear during the running-in [9].

After conducting preliminary laboratory tests, the dependences of the coefficient of friction f on the time of attachment for different methods of processing the working surface of the sleeves were derived. At the initial coefficient of friction f = 0.1 on the oil M-10G2 were obtained dependences of the coefficient of friction during running after honing f_x and after finishing with antifriction materials $f_ф$ from time t.

$$f_x = 0{,}1006 - 0{,}0414 \cdot t + 0{,}0246 \cdot t^2 - 0{,}0050 \cdot t^3 \tag{4}$$

$$f_ф = 0{,}0691 - 0{,}422 \cdot t + 0{,}0343 \cdot t^2 - 0{,}0089 \cdot t^3 . \tag{5}$$

Suppose formulas (4) and (5), as well as the value c = 3.5 and v = 3.36 m/s in the fallowness (3), and then the formula in the fallowness (2) is taken away, the bullets neglected the formulas for the size of $Ra(t)$:

$$Ra_x = \left(t / \left(1{,}183 - 0{,}487 \cdot t + 0{,}289 \cdot t^2 - 0{,}059 \cdot t^3 \right) + 1 / Ra_{нх} \right)^{-1}; \tag{6}$$

$$Ra_ф = \left(t / \left(0{,}813 - 0{,}496 \cdot t + 0{,}403 \cdot t^2 - 0{,}105 \cdot t^3 \right) + 1 / Ra_{нф} \right)^{-1}, \tag{7}$$

where Ra_x, $Ra_ф$ – the average arithmetical view of the profile, which changes fallowly during the hour of growth, when used for honing and processing with antifriction materials of microns [10].

Deposits (6) and (7) are shown graphically in Fig. 2 at: cob value for the reduction of fine grain processing $Ra_{нх}$ = 0.65 microns, cob value for the reduction of fineness processing with antifriction materials $Ra_{нф}$ = 0.27 microns.

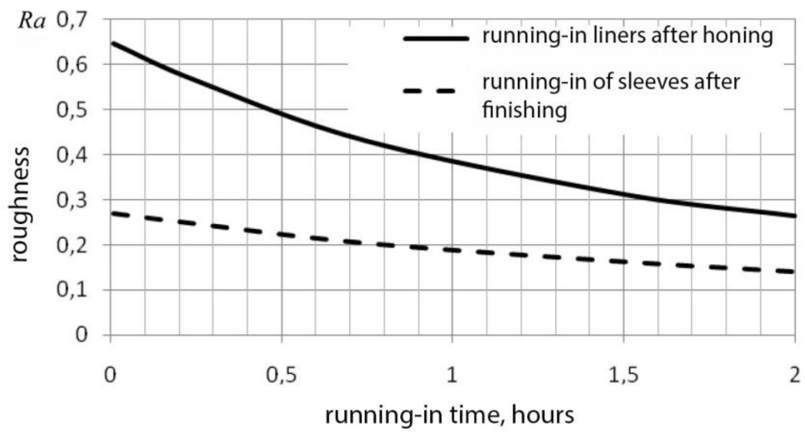

Fig. 2. The prevalence of the mean arithmetic output to the profile at the hour of growth

Conclusions

Calculation and theoretical analysis of the process of making cylinder liners allowed us to draw the following conclusions:

- finishing of cylinder liners increases the bearing surface by 2 - 2.5 times (see Fig. 1), while the values of the reference curve after finishing are close to its values after the bench run-in CPG;
- coefficient of friction and roughness at the beginning of the process of CPG preparation in the case of pre-treatment of sleeves with antifriction materials, equal to the values of these parameters at the end of the bench running of CPG in the case of sleeves after honing (see Fig. 2);
- since the intensity of wear is directly proportional to the coefficient of friction and pressure in the friction pair, the finishing of antifriction materials reduces the running-in wear, which affects the durability of the sleeves;
- based on the above, it can be argued that the finishing of the cylinder liners with antifriction materials can intensify the process of finishing CPG, which is expressed in reducing the hour of running and running-in wear.

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Марченко Д.Д., Матвєєва К.С. Теоретичні дослідження технології обробки циліндрів антифрикційними матеріалами.

В статті приведено аналіз досліджень, спрямованих на застосування різних матеріалів, добавок і присадок до масел. Встановлено, що їх застосування в основному обмежується етапами експлуатації, стендової і експлуатаційної обкатки. Застосування антифрикційних матеріалів на етапі обробки деталей двигунів внутрішнього згорання, лімітуючих ресурс, мало, не дивлячись на те, що така обробка дозволяє скоротити час проведення обкатки і поліпшити приroблення поверхонь, що труться. Теоретичний розрахунок параметрів робочої поверхні гільзи циліндра двигуна при їх фінішній обробці із застосуванням спеціальних антифрикційних матеріалів показав збільшення опорної поверхні в 2 рази (з 0,2 до 0,4 від номінальної площі поверхні на рівні середньої лінії профілю) і отримання шорсткості 0,27 мкм, що близько до значень після стендової обкатки. Це доводить можливість застосування цієї обробки з метою зменшення часу приroблення ЦПГ і поліпшення характеристик поверхонь, що приробляються. Встановлено, що фінішну обробку гільз циліндрів двигуна антифрикційними матеріалами слід проводити при контактному тиску робочого інструменту (латунних брусків) на поверхню гільзи 3 МПа, швидкості робочого інструменту 5,5 м/с, часу обробки гільзи 20 хв. Фінішна обробка гільз із застосуванням композицій ТСК-В100+СУРМ- КВ, СУРМ-УО і РВС дозволяє понизити механічні втрати на тертя в ЦПГ на 5-19% на початку процесу обкатки після обробки в порівнянні з механічними втратами у кінці холодної обкатки без фінішної обробки гільз; отримати параметри шорсткості після фінішної обробки такі ж, як після холодної обкатки без додаткової обробки гільз; збільшити опорну поверхню в 2 - 2,5 разу (з 0,2-0,25 до 0,4-0,5 від номінальної площі поверхні на рівні середньої лінії профілю), що підтверджує розрахункові дані. Остаточна обробка гільз композиціями на основі антифрикційних матеріалів ТСК-В100+СУРМ-КВ, СУРМ-УО і РВС дозволяє забезпечити значення параметрів робочої поверхні гільз (зменшення шорсткості, збільшення опорної поверхні) що наближаються до їх значень після холодної обкатки, отже дозволяє збільшити контактні навантаження в сполученні "гільза - поршневе кільце" після цієї обробки і зменшити час стендової обкатки (до значень, необхідних для приroблення інших сполучень двигуна).

Ключові слова: фінішна обробка, зносостійкість, зменшення тертя, антифрикційні матеріали, нанокомпозиції, ресурс.