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Increase of formation efficiency of gears contact spot at electrochemical-mechanical running-in

V. Aulin*, T. Zamota, A. Hrynkiv, S. Lysenko, O. Bondarets,V. Yatsun

Central Ukrainian National Technical University, Kropyvnytskyi, Ukraine
**E-mail: AulinVV@gmail.com*

Abstract

The analysis of literature sources showed that gears are the most common types of mechanical gears. They are widely used in all branches of mechanical engineering, in particular in metal-cutting machines, cars, tractors, agricultural machines, etc. Among the many advantages of this type of gear, there are disadvantages, among which it is worth noting increased demands on precision manufacturing and Assembly, which results in a greater complexity of the collaborative process of finishing gears in view of their complicated shape and heavy-duty loads for contour and complex mode of interaction.

This makes it particularly difficult to increase the durability when running gears. They require increased surface hardness, which is associated with small contact areas (in most cases-in line) and large specific loads. Even small distortions in this case lead to a significant complication of the process of their burn-in.

The results of experimental studies have shown that for elimination of inaccuracies of form of details and errors of assembling mechanism expose to running-in which running- in of the surfaces take place. The most effective factor of acceleration of running-in is to use the combined processes at running- in surfaces. One of them is the electrochemical - mechanical running-in (ECMR).

Key words: running-in, electrochemical - mechanical running-in (ECMR), gears, friction mode, contact spot.

Introduction

For the development of effective methods to improve the durability by eliminating micro geometrical deviations while running-mate details of components and machines' assemblies it is necessary to study the patterns of development of the area of the contact patch in $S_к$ at running-in details from the initial contact to the maximum possible, taking into account the mode coupling parts and the value micro geometrical deviations.

At present, many researchers associate the solution of the problem of increasing the durability of various mating of nodes and assemblies with the processes occurring in them, characteristic of this interface, and the specifics of its failures. For hardening of parts due to carburizing, hardening, nitriding and other processes increase the hardness, but it makes some difficulties while running-their-fold non-uniform surfaces [1 - 3].

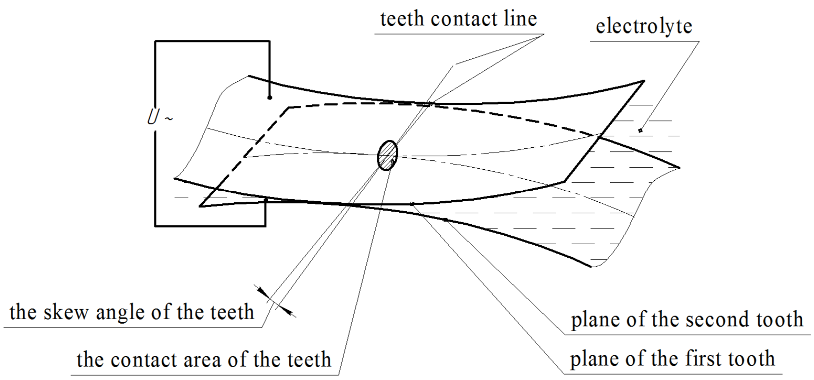
Significant deviations of the teeth from the correct geometric shape cannot be corrected by lapping, and if their deviations are more than 0,03 mm grinding is more economical than lapping. Increasing the duration of lapping is leading to distortion of the teeth's profile. A special allowance for lapping is usually not left and only at very small tolerances on the thickness of the teeth it is provided with a size of not more than 0,03 mm.

Literature Review

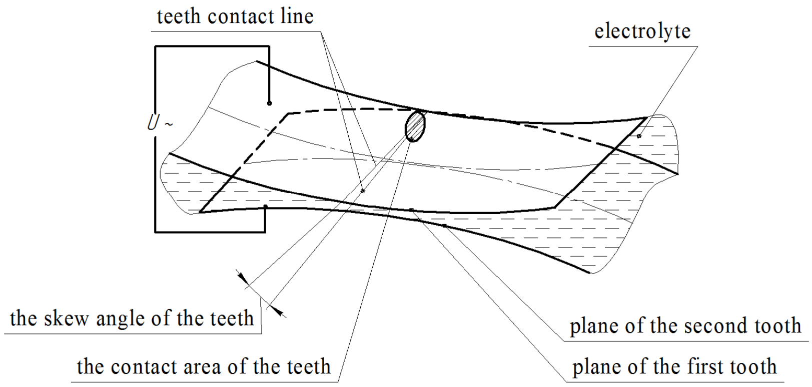
The mode of friction, the nature of the contact interaction, the actual contact stresses, the type of wear and the contact strength of the gear surfaces are largely determined by the thickness of the lubricant layer in contact. The predominant type of wear of the working surfaces of gears should be considered abrasive wear. This is evidenced by the characteristic risks on the working surfaces. The wear of the involutes profile of the teeth should be attributed to mechanical abrasion, and the splines of the drive gear are amenable to mechanical abrasion and crumpling [4 - 8].

Violation of the normal operation of the transmission can also be caused by macro geometric deviations made in the manufacture of individual parts. These inaccuracies lead to load concentration. Contact destruction caused by the thermal effect of grinding the side surfaces of the teeth, occur mainly in cemented and hardened wheels in connection with the formation of structural stress concentrators. Found that for cemented and hardened teeth is observed the formation of structural concentrators of stresses, chipping of the material (initial cracks) arise, usually in the released zones of tooth contact damage, which in the initial stages of a fully oriented in the direction of the grinding strokes [9 - 13].

The misalignment of the two surfaces they are in contact a small the actual area with large specific contact pressures. The scheme of burnishing of two skewed surfaces can be represented in a simplified form (Fig. 1).



a



b

Fig. 1. Diagram of the location of the contact spot when the gear teeth are running-in:
a – with a bias in the plane formed by the axes of the gears;
b – with a bias in the plane other than the plane formed by the axes of the gears

To improve the contact point of the teeth in height in high-speed gears with a large gear ratio, sometimes double finishing of the teeth is used, consisting of preliminary lapping of the gears with cast iron lapping and subsequent lapping of the wheels with gears in conjunction [14 - 19].

Running-in of the gear mating at high circumferential speeds of the wheels with the use of excessively thick abrasive paste can lead to jamming of the teeth, and when using insufficiently filtered abrasive - the formation of local damage to the teeth.

Lapping in the couplings, which were in operation of the gears, somewhat reduces their wear resistance and contact endurance, since this removes the surface layer of the teeth material riveted during operation. Adjustment of gears without abrasive is produced under stepwise increasing load. The maximum load in this case should obviously correspond to that which prevails during operation [17 - 19].

In order to work on the mating, it is necessary to approximate the area of the actual contact to the nominal area and form a roughness close to equilibrium. To ensure this process, it is necessary to apply a method that would allow doing it quickly, efficiently and with the minimum possible running-in wears - electrochemical-mechanical running-in (ECMR) [20].

Improving the quality of the running gears is possible using the proposed method applying an alternating electric current, but it is necessary to determine the effect of running-in quality on the durability and resource of gearing; to investigate the formation of contact spots in the presence of microgeometrical deviations of the axes and surfaces of the teeth; to study the effect of running the method on the formation of the contact patch and extend the service life of the gear; pick up the composition of the electrolyte, providing high-quality running-in.

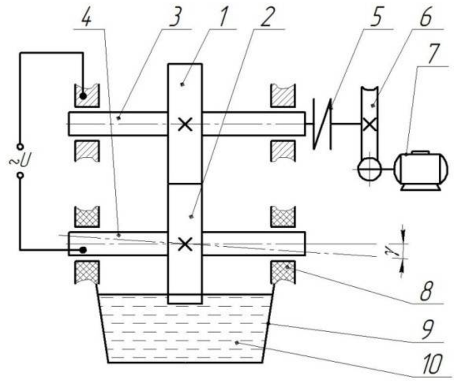
Purpose

The aim of the work is to increase of formation efficiency of gears contact spot at electrochemical-mechanical running-in.

Research Methodology

Research processes of running-in method of the gear (running-in tribotechnology) were carried out on gears spur gear oil pump of engine 4Ч12/14. This was made a special installation that probative gears gave the labor movement and set an appropriate distortion (Fig. 2).

a



b

Fig. 2. General view (a) and scheme (b) installation for fine-tuning gearing at running-in:
1, 2 – drive and driven gear;
3, 4 – drive and driven shafts;
5 – coupling; 6 – worm gear;
7 – DC motor;
8 – insulator (textolite);
9 – bath for electrolyte;
10 – electrolyte;
U – electrical voltage supplied to the gears, B;
g – the amount of distortion

The shaft 4 is electrically isolated from the shaft 3 by means of textolite plates fixed on a common frame, and has the ability to move relative to the second shaft, thus it is possible to set the desired skew. According to TU specifications for the internal combustion engine, the deviation from the perpendicular of the axis of the pressed roller to the end surface of the pump housing socket should not exceed 0,06 mm per 100 mm in length. Based on this, the following skew values γ were given = 0; 0,2; 0,4; 0,6; 0,8; 1,0 mm per 100 mm length of the working surface of the teeth along the contact line.

Fig. 3. General view of the installation for the implementation of technological processes of running-in methods of the gearing of the main transmission T-150K tractor

Conducted research of gears' mass wear, without filing with the supply of alternating electric current on a mating of parts, changes of roughness and contact area of the teeth' working surfaces at running-in with the misalignment of their axes [21].

The mass wear of gears was determined on the analytical scales WA-31 with an accuracy of 0,1 mg. Changes in the roughness of the working surfaces of the teeth were established using profilograms taken on the profilograph-profilometer model 201 of the «Kalibr» plant. The contact area of the teeth in the engagement was determined by the developed method using a PC.

An electrolyte consisting of glycerol and 20 % aqueous Na_2CO_3 solution in a ratio of 4:1 was taken as a technological medium. The strength of the current was 100 A. The frequency of rotation of the drive shaft gears is 8.3 s^{-1}. The total duration of the process is 10 minutes.

The procedure of experiments is the following. The current source was connected to the drive and driven gear. The no-load voltage of the current source was U = 4 V. The electric current, the drive shaft drive were included and the rotational speed was set to 8.3 s^{-1}.

Full-scale tests of finishing of gearing were carried out on the gearbox of the main transmission of the tractor T-150K (Fig. 3).

The test procedure is presented below:

- smooth out the gear (sandpaper);
- clean the gears from dust-like residues left from the previous treatment;
- determine the initial contact spot with a lead plate;
- pour the electrolyte into the reducer;
- carry out running-in;
- remove the electrolyte from the reducer;
- washed gear from the remnants of the electrolyte;
- define the spot of contact after running-in with lead plates;
- process the results.

Results

You can highlight that with the misalignment of the two surfaces contacting is implemented at a small the actual area with large specific pressures. According to [1], the loads in any mating of parts in the running-in process must correspond to the contact loads, which is especially important for the initial contact moment in the mating.

It is known that when working on the parts' mating, the actual contact area is close to the nominal contact area and a roughness close to the equilibrium is formed. To ensure this, it is necessary to apply a method that would allow implementing this quickly, efficiently and with the minimum possible working wear.

With the usual method of running-in, the removal of the allowance formed by the skew of the working surfaces will be associated with significant difficulties, since the surface of the teeth has increased wear resistance and running-in by increasing the contact pressure and the speed of mutual sliding is unacceptable, since this can lead to the appearance of scoring.

The application of the methods of the proposed method of running-in allows you to purposefully change the geometry of the working surfaces of the parts' mating and adapt them to each other after the assembly of mates.

Therefore, it is necessary to explore the possibilities of using the method to control the geometry of the working surfaces of the gear teeth and reduce the duration of their running-in.

As a result of the experimental studies, it was determined that the initial contact with the line, in the presence of even a small skew, dramatically reduces the initial contact spot area (Fig. 4) and considerably worsens the conditions of running-in.

Also revealed that the significant distortions of the surfaces of the teeth of the gears during running is difficult because with the increase of misalignment of the axes of the gears, the intensity increase of the area of the contact patch on the teeth is reduced. It was found that at zero skew the increase in the contact spot area was 41,6 %, and at a skew of 1 mm / 100 mm in length – this increase did not exceed 6,6 %.

There was no significant wear of the gear teeth and an increase in the contact spot area without alternating current supply to the mates. This suggests that the mechanical wear factor in the absence of loading teeth in the installation is not enough. The mechanical wear of this mate is hampered by the high contact strength of the mating surfaces.

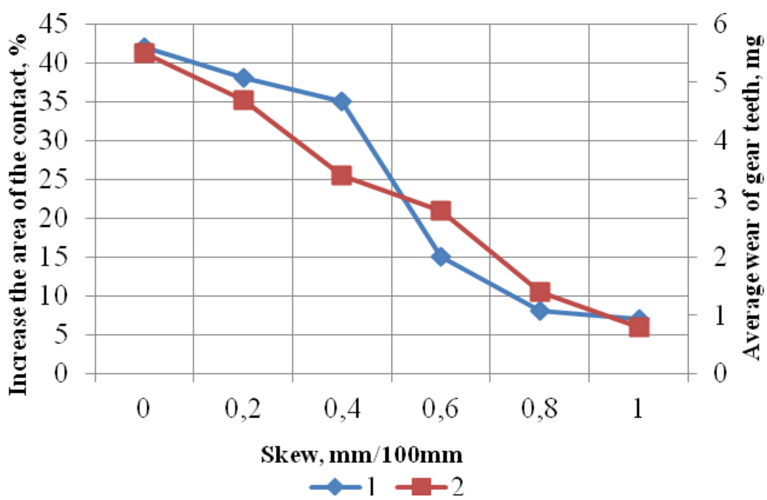


Fig. 4. The effect of the misalignment of the gear axes on the increase in the area of the contact spot of the teeth (1) and the mass wear of the gears (2) at ECMR

Studies of macro-and microgeometry of contacting surfaces have shown that in the process of running-in there is a decrease in the relief of the working surface of the tooth (Fig. 5).

Fig. 5. Change in the relief of the working surface of the tooth with a three-fold skew:
a – initial state$
b – state after running-in

These changes are due to electrochemical and mechanical factors that prevail in the selected conditions. The dependence of the wear of gear teeth during running of the value of the skew indicates the effectiveness of the process. It decreases with increasing skew, but with skewing up to 3 times higher than the permissible values - the method is effective.

The results of these studies make it possible to argue that the method of running-in the gear meshes can ensure the development of the contact spot area at a minimum contact load. The electrochemical component of the running-in process is thus the most effective, since it flows between the friction surfaces separated by a layer of electrolyte.

Schemes of formation of actual and electrochemical contact spots are shown in Fig. 6.

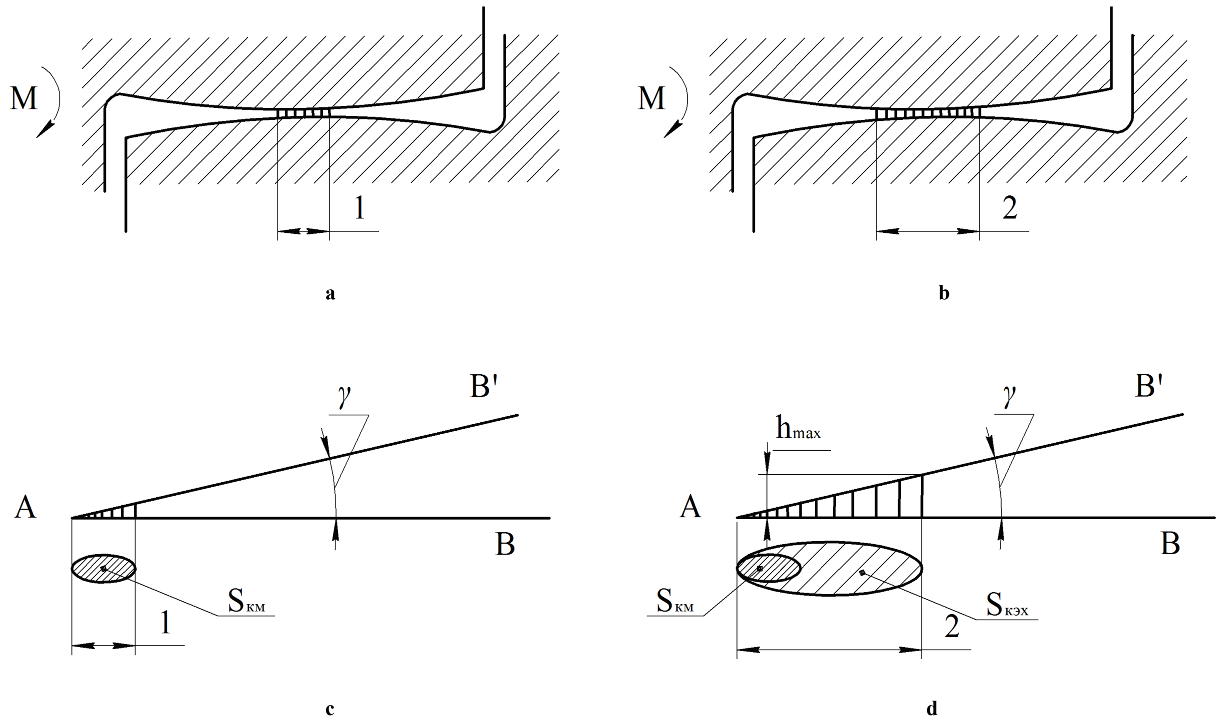


Fig. 6. Charts of creation of actual (a) (mechanical running-in) and electrochemical (b) (electrochemical break-in period) contact and the corresponding distortions (c, d):
1 – stain the actual mechanical contact;
2 – spot electrochemical contact;
$S_{км}$ – spot area of mechanical contact;
$S_{кэх}$ – spot area of electrochemical contact;
h_{max} – maximum layer of the electrolyte in which the electrochemical reaction proceeds;
γ – the skew angle

The area of the contact spot using the proposed method will be:

$$S_{к.эхм} = S_{к.м} + S_{к.эх}, \tag{1}$$

where's $S_{к.эхм}$ – contact area formed of electrochemical-mechanical running-in;

$S_{к.м}$ – the contact patch formed by a mechanical running-in;

$S_{к.эх}$ – the contact patch formed by electrochemical running-in.

Since the running-in process occurs as a result of mechanical and electrochemical interaction of friction surfaces, its nature is largely determined by the types of lubrication and the current (amount of electricity) flowing through the conjugated parts.

Based on the above, the process of running-in the gears can be represented as follows. Theoretically, the working surfaces of the teeth are in contact with the involutes, so the removal of metal from the surface of the teeth depends on both mechanical and electrochemical factors. The current passing through the gear coupling depends on the conditions and properties of the lubricant. On the mechanism of friction in this pair there is no consensus, but don't deny the existence of a separating film of lubricant between the friction surfaces.

It can be assumed that the studied surfaces interact under different friction regimes: boundary, transition and hydrodynamic lubrication. When hydrodynamic lubrication on the surfaces to be worked proceeds purely electrochemical reaction: the current passes through the parts, separated by a layer of electrolyte. The consequence of this is intensive etching of the surface during their anodic polarization with an alternating current frequency. The mode of boundary friction and the transition contributes to the mechanical activation of the surfaces, which enhances the effect of electrochemical reactions at a liquid friction.

Summary

The results of experimental studies of gear engagement revealed the following:

- break-in period with superimposed alternating current can be applied for finishing gears, as an effective method of correcting the geometry of the working surfaces of parts’ mating;
- in toothed engagement with the tilt axes of the gears within the acceptable range, the running application allows to increase the area of contact spot 41,6% of the initial;
- effectively, the running-in process takes place at distortions of gear surfaces up to 3 ... 4 times higher than the permissible values for TU.

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Аулін В.В., Замота Т.М., Гриньків А.В., Лисенко С.В., Бондарець О.А., Яцун В.В.
Підвищення ефективності формування плями контакту в зубчастих зчепленнях при електрохіміко-механічному припрацюванні.

Показано, що зубчасті зачеплення є найбільш поширеними типами механічних передач. Їх широко застосовують у всіх галузях машинобудування, зокрема в металорізальних верстатах, автомобілях, тракторах, сільгоспмашинах і т.д. Серед безлічі переваг цього типу передач, в якості недоліків можна зазначити підвищені вимоги до точності виготовлення і монтажу. Слід увагу зосередити на складному характері процесів доведення зубчастих зачеплень, враховуючи форму і важкі умови роботи при взаємодії.

Це обумовлює складність методів обробки робочих поверхонь з метою підвищення довговічності зубчастих зачеплень. Методи вимагають підвищення твердості робочої поверхні при малих площинах контакту і великих питомих навантажень. Навіть невеликі геометричні відхилення при цьому призводять до значного ускладнення процесу припрацювання поверхонь.

Результати експериментальних досліджень показали, що для усунення геометричних відхилень форми деталей і відхилень операцій від технології складання, механізм піддають обкатці, під час якої відбувається припрацювання робочих поверхонь. Найбільш ефективним фактором прискореного припрацювання є використання комбінованих технологій, що базуються на процесах електрохіміко-механічного припрацювання.

Ключові слова: обкатка, електрохіміко-механічне припрацювання (ЕХМП), зубчасті передачі, режим тертя, пляма контакту.