ПРОГРЕСИВНІ ТЕХНОЛОГІЧНІ ПРОЦЕСИ ОБРОБЛЕННЯ РІЗАННЯМ, МЕТОДИ ФОРМОУТВОРЕННЯ І ПОВЕРХНЕВОГО ЗМІЦНЕННЯ

UDK 621.787, 620.176.162

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IMPROVING THE DURADILITY OF THE FRICTION PAIR AFTER FRICTION HARDENING

Проведені дослідження показали, що фрикційне зміцнення значно підвищує зносостійкість пари тертя сталь 40Х – сталь 40Х. На зносостійкість впливають отримання зміцненого нанокристалічного шару, його товщина, твердість та розмір зерна.

Frictional hardening increases the wear resistance of the friction pair steel 40X - steel 40X studies have shown. Process production nanocrystalline white layer, thickness, hardness, grain size influence for wear resistence.

Problem Statement. The maintainability and performance of assembly parts of machines and mechanisms in most cases depends on the physical and mechanical condition of the surface layers, specifically on the hardness, viscosity, tensions, arising in the macro- and microvolumes, structure and other characteristics of metal. This state is formed during the process of production of assembly parts both during the finishing and preceding operations of mechanical treatment. Condition of the surface layer is known to determine the intensity of wearing, amount of contact deformations, fatigue and corrosion processes and determines the performance and maintainability of the assembly parts of machines in the course of operation.

Analysis of recent research and publications. Friction without lubrication is used in friction joints of the machines of textile, food, chemical industries where oil is unacceptable in order not to damage the products or on the basis of safety regulations. Friction without lubrication is the hardest mode of friction pairs' wearing. In this case material properties related to the resistance to wearing show themselves most clearly. There is a direct interaction between the contacting surfaces. In this case energy that facilitates the conduct of complex chemical and tribochemical reactions on the friction surfaces is locally concentrated in the area of contact. Secondary structures that consist, as it is known, mostly of iron oxides and that positively affect the processes of wearing, are formed here. They prevent the setting of the contacting surfaces of the friction pair, decrease the friction coefficient and reduce the amount of wearing.

Various kinds of coatings and modifications of the surface layer of metal are often used to improve the durability of the friction pair. Friction treatment refers to methods of modification of the surface layer of metal, in the course of which a hardening nanocrystalline white layer is formed. The hardening nanocrystalline layer with different characteristics is formed depending on the parameters of the process of friction treatment, form of the tool's working surface, applied technological environment [1, 2, 3].

Statement of the article objective. The aim of this work was to study the influence of the parameters of process of friction treatment on the durability of the hardening friction pair.

Body part. Experimental researches on the calculation of wearing resistance during the process of friction without lubrication were performed on a “finger-disk” circuit on the universal friction installation of UMT-1 type. Researches of wearing resistance in case of friction without lubrication were carried out at the unit load P = 1 MPa and sliding velocity of 0.25 m/s to 3 m/s.

Test piece “finger” were made of steel 40X in the tempered and low-tempered state (HRC 48-52). Movable test piece “disc” were made of steel 40X in the normalized state. Working surfaces of “finger” test piece were hardening by the friction treatment using tools with a smooth working surface and inclined multidirectional grooves on the working unit. Contacting surface of “disc” test piece was just ground. The friction pair that was not hardening was tested for comparison.

Experimental researches have shown that the frictional hardening using the tool with inclined grooves significantly increases the wearing resistance in case of sliding friction without lubrication at different sliding velocities (Fig. 1). With the increase of the friction pair’s sliding velocity the wearing intensity increases sharply at first, reaches its maximum at the sliding velocities of 0.9 m/s to 1.1 m/s, and then decreases.

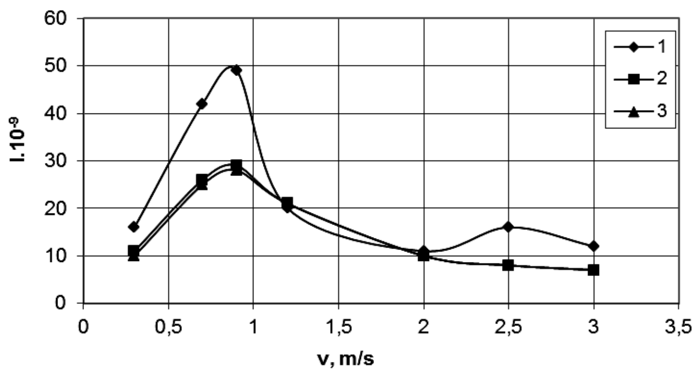

Fig. 1. Dependence of wear resistens pair Steel 40X - Steel 40X after frictional hardening tool with different working part of the wear velocity (P = 1 MPa): 1 – initial; 2 – with a smooth surface; 3 – with the cut slots inclined in different direction

The maximum effect of the increase of wearing resistance after the hardening in comparison to the samples that were not hardening is observed at low sliding velocities of 0.7 m/s to 1 m/s and attains about 4 times. With the increase of sliding velocity the effect of hardening is slightly decreasing and is equal to 2.4-3.3 times. This change of the effect of hardening is explained by the change of the wearing mechanism.

At low sliding velocities (0.25-0.5 m/s) the oxidative wearing of the contacting surfaces of the friction pair takes place, with the increase of sliding velocity up to 0.6-1.1 m/s the setting of the first type takes place. With the increase of sliding velocity of the friction pair in the area of contact the setting of the second type is observed. When the setting processes of the first type take place, an oxide film of small thickness that is rapidly destroyed is formed on the working surfaces of the friction pair. The wearing speed exceeds the speed of film formation and therefore an intense destruction of unprotected base metal takes place.

The nature of the curves of samples’ wearing after the frictional hardening is similar to the one of the pair that was not hardening; but the intensity of wearing is smaller in comparison with the original pair. The improvement of the durability of hardening friction pair with a help of frictional hardening can be explained by the fact that nanocrystalline white layer has a higher hardness, viscosity and strength than the original metal and therefore is less prone to setting. Also, as it was noted in the study [4], the surface layer of the samples with a white layer, thickness of which is about 1 mcm, is enriched with iron oxides (30 %).

White layer from the very beginning of wearing has a favorable durable interlayer. The improvement of treatment and further formation of quality secondary structures in the area of contact is largely dependent on it.

The temperature in the area of contact of the friction pair in case of wearing without lubrication determines the conditions of formation processes conduct of secondary structures on the contacting surfaces. An increase in temperature can cause local softening of the contacting surfaces, melting of the metal and its setting.

Experimental researches have shown that in case of friction without lubrication of the pair Steel 40X - Steel 40X in the area of contact "finger-disk" the temperature monotonically increases with the increase of the sliding velocity (Fig. 2).

Frictional hardening of samples significantly influences the temperature that forms on the contacting surfaces of the friction pair. On the whole range of sliding velocities the temperature in the area of contact of the friction pair decreases, especially after the frictional hardening with a help of the tool with multidirectional inclined grooves.

At the same time the temperature decreases in 1.4-2.1 times in comparison with the wearing of the original friction pair that was not hardening. The highest decrease in temperature is observed in case of friction at the sliding velocity 0.9-1.2 m/s. This occurs in the area of maximum intensity of friction pair's wearing, where the processes of setting of the first type take place.

When a tool with a smooth working unit is used during the frictional hardening of the contacting surfaces of friction pair's samples, the decrease in temperature in the area of their contact during the wearing is equal to 1.25-1.5 times in comparison with the wearing of the pair that was not hardening.

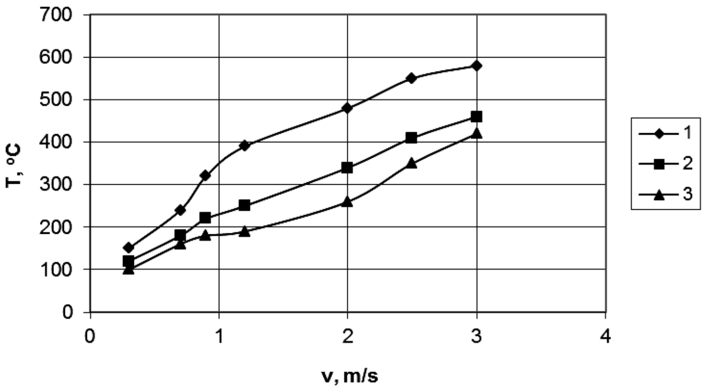

Fig. 2. The dependence of the temperature in the contact zone with wear pair Steel 40X - Steel 40X after frictional hardening tool with different working part of the wear velocity (P = 1 MPa): 1 – initial; 2 – with a smooth surface; 3 – with the cut slots inclined in different direction

In case of wearing of samples that were hardening with a help of friction treatment using the tool with the inclined transverse grooves, the temperature in the area of contact of the friction pair at the sliding velocity of 3 m/s is similar to the one that is in case of wearing of pair that was not hardening at the sliding velocity of 1.2 m/s.

In the initial period of wearing of the friction pair the value of the coefficient increases sharply and attains its maximum, then the process of friction stabilizes and the friction coefficient somewhat decreases. During this period of time secondary structures are formed on the contacting surfaces of the friction pair. A structural adaptation of the friction pair takes place, which leads to a constant value of the friction coefficient.

Experimental researches have shown that the highest friction coefficient is obtained at the minimum friction velocity (0.25 m/s), both in case of the hardening friction pair and the friction pair that was not hardening (Fig. 3). The friction coefficient decreases with the increase of sliding velocity, but at the sliding velocity of 0.9 m/s it begins to increase again. It attains a maximum at the sliding velocity of 1.2 m/s and the friction coefficient decreases monotonically with a further increase of sliding velocity.

The friction coefficient of the hardening pair after treatment with a help of tool with a smooth working surface has decreased in 1.2-1.5 times, and after the treatment with a help of tool with inclined multidirectional grooves has decreased in 1,3-1,7 times in comparison with the one of the friction pair that was not hardening. It should be noted that the highest decrease of the friction coefficient of sliding pair is observed at the sliding velocity of 0.9 m/s. The decrease of the friction coefficient attains smaller values at other sliding velocities.

Frictional hardening increases the wearing resistance of the friction pair as a whole. Quality of the white layer affects the process of wearing insignificantly. It can be noted that only one assembly part of friction pair was hardening using the friction treatment, that is the “finger” sample; “disc” countersample was not hardening in the initial state. Nevertheless, the hardening of only one assembly part of the friction pair leads to a decrease of wearing intensity of the friction pair as a whole.

The decrease of the friction coefficient with the increase of sliding velocity can be explained by a more intensive development of oxidative processes as a result of an increase in temperature in the area of contact. High temperatures contribute to the formation of quality secondary structures, which in turn reduces the role of setting.

Sliding velocity significantly affects the formation of the oxide film. Fe_2O_3 film is formed at low sliding velocities. Under these friction conditions the speed of formation of film is higher than the speed of its destruction. The film protects the base metal from the intense destruction. With the increase of sliding velocity the wearing of the base metal takes place in addition to the wearing of the Fe_2O_3 film.

In this case, the temperature conditions in the area of contact of the friction pair are not enough to form the necessary thickness of the oxide film. The wearing speed of film exceeds the speed of its formation. Due to the further increase of the sliding velocity on the surface of contacting bodies, the temperature on the contacting surfaces of the friction pair attains the values at which the oxide film Fe_3O_4 is formed. The wearing of the film and partly of the base metal takes place under these conditions. With the further increase of sliding velocity only the wearing of Fe_3O_4 film is observed [5].

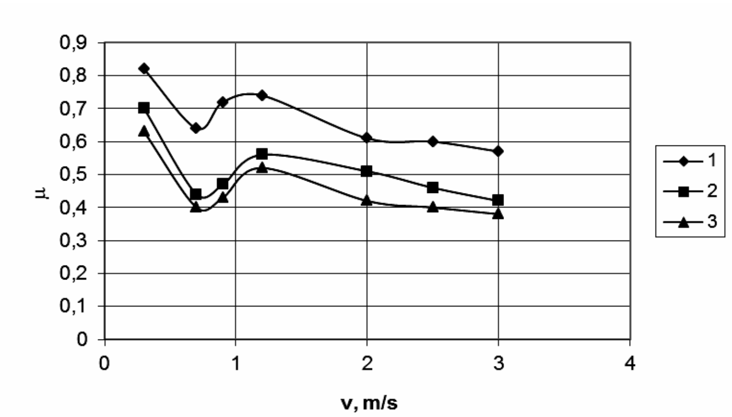

Fig. 3. Dependence of friction wear pair Steel 40X - Steel 40X after frictional hardening tool with different working part of the wear velocity (P = 1 MPa): 1 – initial; 2 – with a smooth surface; 3 – with the cut slots inclined in different direction

The kinetics of wearing depends significantly on the processes that occur in the thin layers under the influence of high local temperatures, pressures and deformations. A change of chemical composition of the metal takes place in the surface layers. This requires additional energy that can be accumulated in the form of energy of dislocations, which contributes to the conduct of tribochemical reactions [5].

As the metallographic researches have shown, the white layer consists of a finely dispersed martensite, residual austenite and finely dispersed carbides. The size of grain varies within 20-60 nm, this layer can be attributed to the nanocrystalline structures. The quantity of the residual austenite is much higher and the dislocation density is almost order of magnitude greater than the one of the basic structure of the metal. Residual austenite being a soft layer increases the viscosity of the surface layer while at the same time increasing its hardness due to the fine dispersion of the martensite. The increased number of dislocations activates the surface, increases the speed of diffusion and chemical reactions, accelerates the formation of oxide films. At the same time the blocking of the dislocation, the slowdown in their movement and the inhibition of the initiation of cracks take place in the white layer. All of this together increases the durability of the friction pair.

Conclusions. Frictional hardening not only increases the durability of the friction pair considerably, but also reduces the influence of the structural state of the original metal on the performance. The testings of samples after the frictional hardening using the tool with inclined multidirectional grooves have shown that the intensity of their wearing is lower (by 23 %) than after the frictional hardening with a help of the tool with a smooth working unit.

The maximum effect of the increase of wearing resistance after the hardening in comparison with the samples that were not hardening is observed at the low sliding velocities of 0.7 m/s to 1 m/s and attains about 4 times. The effect of hardening somewhat decreases with the increase of sliding velocity and is equal to 2.4-3.3 times.

1. Бабей Ю.И., Бутаков Б.И., Сысоев В.Г. Поверхностное упрочнение металлов. – К.: Наук. думка, 1995. – 253 с. 2. Гриднев В.А., Трефилов В.И. Фазовые и структурные превращения и метастабильное состояние в металлах. – К.: Наук. думка, 1988. – 264 с. 3. Гурей І.В., Гурей Т.А., Плахтій Л.В. Вплив фрикційного зміцнення на товщину поверхневого шару чавуну // Вісник Тернопільського державного технічного університету. – 1999. – Т. 4, № 2. – С. 45–50. 4. Кальнер В.Д. О природе упрочненных железоуглеродистых сплавов фрикционной обработкой / В.Д. Кальнер // Физико-химическая механика материалов. – 1988. – № 1. – С. 112–115. 5. Основы трения и изнашивания / [Г. Польцер, Ф. Майсснер]; под ред. М.Н. Добычина; пер. с нем. О.Н. Озерского, В.Н. Пальянова. – М.: Машиностроение, 1984. – 264 с.