UDC 621.891

ANALYSIS OF DISCRETE STRUCTURE STRESS-STRAIN STATES

B. Liashenko[2], V. Marchuk[1], V. Kalinichenko[2], Y. Gradysky[3]
[1]*National Aviation University*
[2]*Institute of Strength Problems G. Pysarenko National Academy of Sciences*
[3]*Kharkiv Petro Vasylenko National Technical University of Agriculture*

A brief review of the stress-strain state of the discrete structure coatings formed by various methods is presented. Problems and ways of reduction of residual stresses in discrete areas of textured surfaces are shown.

Key words: *stress-strain state, discrete coverage, discrete areas*

The problem general formulation and its relation to the scientific and practical tasks. Increasing the life of modern machines and mechanisms is one of the important problems of improving the quality and competitiveness of the machine-building industry. Significant material losses due to friction and depreciation have put forward the task of increasing the durability of friction units. The high cost of constructions, the complexity of the conditions of the work of tribosystems, imposes high requirements for the selection of tribo compound materials, the search for new effective technologies for increasing the re-sourcing of tribunes, and the analysis of processes occurring between contacting surfaces.

Today, the broad opportunities open up the technology of discrete strengthening of the surface layers, as the most perspective, viable direction of in-nying the surface. The result of the introduction of such technology is the expansion of the diapazone of the work of parts in extreme conditions of operation while simultaneously moving the tribological and physico-mechanical characteristics of the friction pairs. The dimensions and configuration of the textured (discrete) surface are determined on the basis of the conditions for minimizing the stress-strain state at the power (temperature-mu) impact on the surface, which allows it to multiply its limit state. The study of the stress-deformed state of textured surface layers with variables in depth properties is an important and topical task. The lack of such information is a significant obstacle in the interpretation of processes that accompany the processes of friction and wear of machines and mechanisms.

Review of publications and analysis results. A significant role is assigned to the level of residual stresses that correlate with practically all of the operational properties of the parts, when constructing friction pairs with textured surfaces,. In dependence on the method of forming textured surfaces in tribosystems, residual stresses such as compression and stretching may appear. Particularly the heavens-wings are the residual tensile stresses, which adversely affect the operational characteristics of the contacting parts.

Among the existing methods for determining the residual stresses in textured surfaces, the simplest and most accessible method is to determine the magnitude of residual stresses by the curvature of a rectangular sample. The essence of the method lies in the fact that forming such a surface on the basis of a small thickness residual on-elasticity leads to deformation of the base in the form of a circle arc.

For spark plugs, which are essentially discrete, residual stresses are formed as a result of the difference in the coefficients of thermal expansion of the base materials and coatings. Since the coefficient of thermal expansion of the electrode material is less than the coefficient of thermal expansion of the reinforced surface material, in the coating there are longitudinal tensile stresses [1].

A positive effect in the application of discrete coatings is provided by the use of flexible vacuum-plasma technologies, especially on the cutting tool. It has been established [2] that there are residual compressive stresses in PVD coatings of discrete type (Ti, Al) N whose level is much lower in comparison with similar continuous coatings. At the same continuity, the coating voltage is reduced with decreasing of the size of the discrete areas, which allows to limit the residual stresses of compression and reduce the probability of fracture in the conditions of contact load while maintaining high continuity, as well as reduce the tensile stress in the main material.

When friction of contacting surfaces in the places of actual contact formed a certain roughness (texture) due to the deformation of surfaces with the simultaneous action of normal and tangential stresses with the exit to the surface of the slip lines and other dislocation formations. The textured layer is characterized by very small height and depends on the direction of movement of the contacting surfaces when rubbed.

V. Kostetskyi noted [3] that the discreteness of the actual contact of the friction surface is characterized by a complex strained-deformed state, the presence of a supporting effect of the lateral and lower layers of the undeformed matrix, the change of the sign (compression-stretching) of stresses. The load diagram for friction involves the presence of two zones with different stress-deformed states: the first is the elastic-plastic deformation zone (10-100 nm), and the second is the zone of elastic deformations (hundreds of microns). In this case, the processes of destruction (wear) are localized in the first zone, and the processes of heat formation occur in both.

In such a scheme of stress-strain state, in combination with the discreteness of the contact, it is possible to deform predominantly in the direction of re-placement with friction, the ductility of hard and soft surface-non-ionic films sharply increases, the internal crystalline structure is crushed, grains of grains and fragments are eliminated. The dimensions of the blocks (coherent scattering) at the same time reach the minimum values (1,5-5 nm). In addition, eliminate linear and superficial defects - dislocations, cracks, defects. Due to the discreteness of contact and relaxation of stresses on submicrosets of the actual contact, the possibility of gradual accumulation of stresses and submicroscopic imperfections is eliminated [4].

Investigation of the tense state of the hardened steel surface 40X showed that in the process of discrete laser processing residual stresses are formed which are non-homogeneously distributed over the section of the strengthened zone (paths with continuously and stains under pulsed operating modes). There are significant tensions on the surface of the track, which decrease with the distance from the centre to the edge of the tower almost to zero. In samples subjected to additional nitriding, the whole pressure decreases in the centre of the track by 3-4 times. This is mainly due to the temperature influence in the process of nitriding [5].

The principle of creating discrete coatings allows you to multiply their limit state several times: contact loads 3-5 times, critical deformations of the stretch of the base - up to 2 orders, durability several times in a pore with a continuous coating of the same thickness, composition and hardness [6]. In this case, the question remains to determine the rational parameters of the technological process of discrete strengthening. Experimental investigations have established that the area of treatment should be 15-25%. This is conditioned by the creation of such a stress-strain state, which provides the micro-stress at friction, which is confirmed by analytical calculations [5, 7].

The amount of stress-deformed state of a discrete surface is significantly influenced by blunting the edges of a single discrete area. The optimum angle of blunting of the edge should be $\theta \geq 60°$, which will reduce stresses in the plane of adhesion contact by at least 30% [8].

In order to increase the fatigue strength of the parts working in the ferret-g, an effective method for reducing the stress concentration of the bolted connection was proposed, which is to apply a grid of grooves of a certain depth to the surface to protect against fracture. As a result, the durability of the bolted connection in the conditions of fretting-wear has increased threefold [9].

The effect of the grooves is the main reason that the rough surface has a higher fatigue strength during fretting than smooth. Fracture in this case is absent on the roughness projections, which are not subjected to alternating stresses acting in the material. The flow of the groove reduces the stress concentration at the place of the "fretting", but creates a concentration of stresses at its bottom. The rectification must be designed in such a way that an optimal balance of these two effects can be achieved [10].

In the formation of textured surfaces formed by a mechanical method, the essence of which is the dynamic effect of the indenter on the surface of the part and the creation of the depths due to PPE, there are residual stresses of tension, the separation of which is uneven and depends on the location and depth of the depths on the surface, as well as the elastic-plastic properties of the material. The smallest residual stresses arise when the values of the optimization parameters are X_1 = 3,0 mm, X_2 = 2,0 mm and X_3 = 1,5 mm (the spacing between the rows is X1, the distance in the row is X_2, the head of the installation is X_3). Choosing the optimal location of the pits allows you to construct a surface with given operational properties, improve tribotechnical characteristics, reduce the stressed state of the surface. The depth improves the lubricating properties of the surface, increases resistance to clogging and corrosion, shortens the period of ginning. [11, 12].

Simulation of the stress-strain state of this type of texturing by the finite element method showed that this type of texture on the upper surface in the form of droplets, due to the absence of significant residual stresses, has advantages over the coatings for which different coefficients of temperature expansion of the base material are characteristic and coverage. On the surface of the sample, the stress-strain was distributed in the form of islets with maximum values near the edges of the depths [13].

Thus, the study of a stress-deformed state during the formation of textured surfaces by different methods showed that they may have residual stresses both compression and stretching. The active means of regulating the level of remaining tensions remains the optimization of the parameters of discrete parts, which unfortunately today is carried out using the method of trials and errors. The lack of such data makes it impossible to construct textured surfaces with maximum benefit from the operational properties and is a significant obstacle in the interpretation of processes that accompany the friction and depreciation of machines and mechanisms.

The technologies of discrete strengthening of surface layers today require some standards, the transfer of scientific developments from laboratories to industry, and the improvement of existing ones and the development of new techniques for accurate prediction of long-term surface behaviour during operation based on short-term laboratory tests.

List of references

1. Дискретні покриття для підвищення зносостійкості деталей машин і механізмів [Ляшенко Б.А., Марчук В.Є., Калініченко В.І., Градиський Ю.О.] // Вісник Харківського НТУСГ ім. Петра Василенка. – Харків: Вид-во Харківського НТУСГ ім. Петра Василенка, 2010. – Вип. 94. – С. 324–335.

2. Антонюк В.С. Конструирование дискретно-модифицированных износостойких поверхностей / Антонюк В.С., Сорока Е.Б. // Упрочняющие технологии и покрытия. - 2008. - № 10. - С. 8-13.

3. Поверхностная прочность материалов при трении [Костецкий Б.И., Носовский И.Г, Караулов А.К. и др.]; под общ. ред. Б.И. Костецкого. – К.: Техніка, 1976. – 296 с.

4. Костецкий Б.И. Управление изнашиванием машин / Костецкий Б.И. – К.: Общ-во "Знание", 1984. – 19 с.

5. Кіндрачук М.В. Напружено-деформований стан дискретно оброблених лазером сталей під час контактної взаємодії / Кіндрачук М.В., Яхья М.С., Іщук Н.В. // Проблеми тертя та зношування: наук.-техн. зб. / Нац. авіац. ун-т. – 2006. – Вип. 46. – С. 29–39.

6. Ляшенко Б.А. Упрочняющие покрытия дискретной структуры / Ляшенко Б.А., Мовшович А.Я., Долматов А.И. // Технологические системы. – 2001. – № 4. – С. 17–25.

7. Кіндрачук М.В. Триботехнічні властивості плазмових покриттів з дискретною структурою / Кіндрачук М.В., Ішук Н.В., Пастернак В.В. // Проблеми трибології. – 2003. – № 1. – С. 75–81.

8. Технологическое обеспечение вакуум-плазменных покрытий дискретной структуры / [Соловых Е.К., Ляшенко Б.А., Рутковский А.В. и др.] // Технологические системы. – 2007. – № 2. – С. 22–27.

9. Вахтель В.Ю. Повышение усталостной прочности деталей, работающих в условиях контактной коррозии трения // Вестник машиностроения. – 1969. - № 2.

10. Heywood R.B. Designing against fatigue //Chapman and Hall. – London. – 1962.

11. Пат. 13762 Україна, МПК (06) F01L 1/20, F01L 1/46. Пристрій для утворення на плоскій поверхні тертя рельєфу заглибин, що утримують мастильні матеріали / Марчук В.Є., Шульга І.Ф., Шульга О.І., Плюснін О.Є.; заявник та патентовласник Національна академія оборони України. – № u200509981; заявл. 24.10.2005; опубл. 17.04.2006, Бюл. № 4.

12. Пат. 44643 Україна, F01L 1/20 C23C 8/02. Спосіб отримання рельєфних зносостійких азотованих шарів стальних деталей / Марчук В.Є., Шульга І.Ф., Ляшенко Б.А., Цибаньов Г.В., Рутковський А.В., Калініченко В.В.; заявник та патентовласник Національний авіаційний університет. – № u200904236; заявл. 29.04.2009; опубл. 12.10.2009, Бюл. № 19.

13. Марчук В.Є., Ляшенко Б.А., Калініченко В.І. Моделювання напружено-деформованого стану дискретної поверхні // Проблеми тертя та зношування: Науково-технічний збірник – К.: НАУ. - 2008. – Вип. 49. – Т. 2. – С. 25-30.

Анотація

АНАЛІЗ НАПРУЖЕНО-ДЕФОРМОВАНОГО СТАНУ ПОКРИТТІВ ДИСКРЕТНОЇ СТРУКТУРИ

Ляшенко Б.А., Марчук В.Є., Калініченко В.І., Градиський Ю.О.

Представлено короткий огляд напружено-деформованого стану текстурованих поверхонь, сформованих різними методами. Показано проблеми та шляхи зменшення залишкових напружень в дискретних ділянках текстурованих поверхонь.

Аннотация

АНАЛИЗ НАПРЯЖЕННО-ДЕФОРМИРОВАННОГО СОСТОЯНИЯ ПОКРЫТИЙ ДИСКРЕТНОЙ СТРУКТУРЫ

Ляшенко Б.А., Марчук В.Е., Калиниченко В.И., Градыский Ю.А.

Представлен короткий обзор напряженно-деформированного состояния текстурированных поверхностей, сформированных разными методами. Показаны проблемы и пути уменьшения остаточных напряжений в дискретных участках текстурированных поверхностей.