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SURVEY OF OPTIMAL MODES OF STRENGTHENING TREATMENT OF MACHINE PARTS

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The article deals with the issues of improving the reliability and durability of machine parts by improving the quality of their surface layer with various processing methods. The issues of the influence of surface plastic deformation on the quality indicators of processing are presented and the parameters of the processing tool are determined, and a mathematical relationship is obtained between the allowance for processing and the value of residual deformation. Presented the characteristic of methods of processing parts in the manufacture and restoration. Set out the method of vibration hardening in the development of the process. The classification and characteristics of the oscillatory processes used in the processing of the material of the restored parts are given. The search for optimal modes of surface plastic deformation both in our country and abroad has been carried out. The proposed processing modes are usually selected on the basis of experimental data and empirical dependencies obtained from testing samples or, more rarely, full-scale parts subjected to surface plastic deformation under different modes. In this case, the best of those used in the experience modes that provide the highest increment of the endurance limit of the part should be considered optimal.

Improving the reliability of machine parts is one of the most important tasks, both in mechanical engineering and in repair production. To solve this problem, there is a whole arsenal of modern methods: traditional constructive methods for improving the shape of parts; the use of high strength materials; methods of chemical heat treatment. Among these methods, a special place is occupied by surface plastic deformation (SPD), which is the final operation in the technological cycle of manufacturing or restoring parts and a very effective means of improving their strength and performance characteristics.

Hardening (surface cold working) of the material being processed is effective because it allows to significantly increase the endurance limits of a wide range of machine parts. Due to the SPD processing, favorable changes occur in the surface layers, which increase the fatigue resistance of the part material.

In most cases, the usage of SPD allows you to achieve a much greater effect than a constructive change in the shape of the workpiece.

Among the most important achievements of technical science is the development of studies on the quality of the surface layer and the creation of a new scientific and practical direction aimed at improving the performance of machine parts by technological methods.

The choice of certain SPD methods for their implementation is determined mainly by the level of physical and mechanical properties, shape, size and surface condition of the workpiece, as well as technological considerations [1].

In many areas of mechanical engineering, rolling in with rollers (balls) has become widespread, which makes it possible to increase fatigue strength and wear resistance [2]. Along with it, other SPD methods are used in industry: diamond smoothing, rolling holes, shot processing, hardening by coining.

Recently, much attention has been paid to various combined methods, combining the traditional SPD with some other types of heat and force effect on the machining tool. Among them, it should be noted electromechanical processing, vibration damping and vibrating ironing, vibration-centrifugal hardening processing [3,4,5].

The effectiveness of a particular processing method, that is the achievement of the required level of fatigue strength of parts is determined by a whole complex of physical factors and, first of all, by the size and distribution of residual stresses in the part after the SPD, the depth of the plastically deformed layer and physical hardening of the material. Therefore, for the purposeful control of these physical factors, it is necessary to ensure a rational combination of these parameters of the processing mode.

The search for optimal SPD regimes is conducted both in our country and abroad. The literature provides some data on the effect of the main parameters of the SPD on the hardening efficiency.

Theoretical and experimental studies conducted by I. Kudryavtsev, A. Babichev, A. Dudnikov and other scientists and aimed at finding methods and means of implementing reserves to increase the fatigue of parts, allowed to develop guidance materials on the choice of effective SPD modes for a wide range of parts.

It has been established that an increase in fatigue resistance due to SPD is primarily due to the favorable effect of compressive residual stresses in the surface layer of hardened parts. The hardening mode will be considered effective if it provides a sufficient level of these stresses.

Residual compressive stresses slow down the processes of nucleation and development of micro damages, reduce the sensitivity of the hardened surface layer of parts to the localization of stresses from external loads near structural and technological concentrators, as well as neutralize the adverse effect on tensile residual stresses on fatigue resistance.

It should be noted that when deforming the required system of residual compressive stresses in parts, it is necessary to take into account the magnitude and sign of the technological initial stresses that may remain in them from the previous treatment and which can significantly affect the final residual stress-strain state of the surface layer of the hardened part. This applies particularly to the details of reduced stiffness, where the role of the surface layer is very large. In our opinion, with an increase in the strength characteristics of the material being processed of parts, the relative thickness of the hardened layer will decrease.

The solution to the problem of hardening can be found in changing the geometry of the machining tool (punch), in particular, the need to change the pitch angle of the punch, the height of its calibrating part, which will change the degree of inclination of the surface layer of the part and thereby compensate for the relative reduction in processing effort.

When choosing the main parameters of the processing mode of hollow parts, it is recommended to vary their values in intervals that are wide enough for practical needs. Changes in the specified parameters, as well as processing modes (amplitude of oscillation of the machining tool, vibration frequency of the exciter, processing time) should be considered as an important reserve for increasing the efficiency of vibration formation during the restoration (manufacturing) of parts such as a sleeve.

The amount of processing effort is recommended to be assigned depending on the allowance for processing and on the yield strength of the material of the workpiece and the state of its surface before processing.

As a criterion, when choosing the optimal modes of hardening processing of parts made of soft materials (copper, bronze, brass, etc.) to obtain a roughness close to the minimum, as well as the greatest hardening and optimal level of residual stresses in the surface layer, we can recommend using the average pressure p_{av} in the contact the area of the machining tool with the workpiece [6]:

$$p_{av} = \frac{P}{F_c}, \qquad (1)$$

where: P – is the processing force; F_c – is the actual surface contact area.

So when processing parts made of bronze p_{av} assigned within 400...450 MPa. Determination of the workload should be made depending on the size of the processing tool and the mode of vibro-processing.

When selecting modes of hardening treatment, one should also take into account the parameters characterizing the physicomechanical properties of the material of the workpiece, its shape and dimensions [7].

Those who have approaches do not solve the generally considered problem of hardening the material of workpieces, because they reveal the problem of predicting the possible damage to the surface of parts in case of SPD only at the empirical level. The proposed criteria and dependencies in the literature determine only the critical (limiting) processing conditions, under which the surface layer of the parts is destroyed, and therefore do not allow to fully assess the physical state of this layer after processing.

According to the mechanical theory of the formation of the surface layer, developed by V. Smelyansky [8], SPD is considered as a process of plastic flow of metal, and the properties of the surface layer – as a result of its deformation. This theory takes into account both the laws of plastic accumulation of deformations, and the features of the kinematics of the interaction of the tool with the workpiece. As a criterion for assessing the physical state of the surface layer of the part, a dimensionless quantity Ψ was taken, reflecting the degree of damage to the material in the course of SPD and determined by the intensity of the strain rate and the limiting degree of shear deformation of the material of the surface layer. To calculate, the real profile of the deformation zone is used, the shape and dimensions of which depend on the processing modes.

The effectiveness of the application of strengthening technology is also influenced by the structure of the material; the degree of strain hardening of materials depends on it. The smallest increase in the hardness of the surface layer of parts with the same deformation gives steel with a sorbitol structure. The presence of martensitic in the structure enhances the effect of strain hardening as a result of the partial transformation of residual austenite into martensitic. Hardening reserves can be used more fully on low carbon steels with a martensitic structure than on high strength steels with the same structure, despite the greater increase in hardness.

This situation is due to the fact that on low carbon steels subjected to SPD, the center of destruction originates under the surface that is in the zone of lower operating stresses and therefore fatigue cracks mainly propagate in the hardened layer, as a result of which the hardening effect is realized.

In recent years, some work has been done in the field of analysis of the heat generation process in the contact zone of the machining tool with a part for the SPD of various materials, which is of great interest in connection with the problem of increasing the durability of the strengthening tool, clarifying the nature of residual stresses and finally SPD.

Among the tasks arising from the SPD, an important place is occupied by the search for optimal modes of deforming machine parts in order to maximize their fatigue resistance and to make the most complete use of hardening reserves of materials.

The parameters of the processing mode are usually chosen on the basis of experimental data and empirical dependencies obtained from testing samples or, more rarely, full-scale parts subjected to SPD under different conditions. In this case, the best of those used in the experience modes that provide the highest increment of the endurance limit of the part should be considered optimal.

Such a technique cannot be considered completely perfect, since:

a) by varying in experience the workload with a given shape of the working tool or the geometry of the tool under constant load, change simultaneously both the depth of work and the intensity of deformation of the surface layer;

b) the number of combinations of values of the workload and geometric parameters of the punches can be infinitely large and therefore even the most extensive experiment cannot cover all possible options.

Under these conditions, the best option selected from experience is not the objectively best of all possible, but only the most rational of those that were implemented in the tests.

During cold working, an increase in the strain rate above certain values leads to an increase in the temperature of the material being processed due to the release of considerable heat of friction on the slip planes, which do not have time to spread in space. An increase in temperature leads to a softening and an increase in plastic properties.

The noted imperfections can be eliminated if the generalized physical parameter is used as an objective criterion for evaluating the SPD process, which equally takes into account various changes in the mode of strengthening treatment.

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Анотація

ПОШУК ОПТИМАЛЬНИХ РЕЖИМІВ ЗМІЦНЮЮЧОЇ ОБРОБКИ ДЕТАЛЕЙ МАШИН

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У статті розглядаються питання підвищення надійності та довговічності деталей машин за рахунок підвищення якості їх поверхневого шару при різних способах обробки. Представлені питання впливу поверхневого пластичного деформування на якісні показники обробки та визначено параметри оброблюваного інструменту, а також отримана математична залежність між припуском на обробку і величиною залишкової деформації.

Дається характеристика методів обробки деталей при виготовленні і відновленні. Викладено метод вібраційного зміцнення при розробці технологічного процесу. Наведено класифікація і характеристика коливальних процесів, що застосовуються при обробці матеріалу відновлюваних деталей. Проведено дослідження оптимальних режимів поверхневого пластичного деформування як в нашій країні, так і за кордоном. Запропоновані режими обробки вибираються зазвичай на підставі експериментальних даних і емпіричних залежностей, одержуваних з випробувань зразків або, рідше, натурних деталей, підданих поверхневому пластичному деформуванню при різних режимах. При цьому оптимальними слід вважати ті з застосованих в досвіді режимів, які забезпечують найбільшу приріст межі витривалості деталі.

Аннотация

ИЗЫСКАНИЕ ОПТИМАЛЬНЫХ РЕЖИМОВ УПРОЧНЯЮЩЕЙ ОБРАБОТКИ ДЕТАЛЕЙ МАШИН

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В статье рассматриваются вопросы повышения надежности и долговечности деталей машин за счёт повышения качества их поверхностного слоя при различных способах обработки. Представлены вопросы влияния поверхностного пластического деформирования на качественные показатели обработки и определены параметры обрабатывающего инструмента, а также получена математическая зависимость между припуском на обработку и величиной остаточной деформации. Даётся характеристика методов обработки деталей при изготовлении и восстановлении. Изложен метод вибрационного упрочнения при разработке технологического процесса. Приведены классификация и характеристика колебательных процессов, применяемых при обработке материала восстанавливаемых деталей. Проведено изыскание оптимальных режимов поверхностного пластического деформирования как в нашей стране, так и за рубежом. Предложенные режимы обработки выбираются обычно на основании экспериментальных данных и эмпирических зависимостей, получаемых из испытаний образцов или, реже, натурных деталей, подвергнутых поверхностному пластическому деформированию при разных режимах. При этом оптимальными следует считать те из применённых в опыте режимов, которые обеспечивают наибольшее приращение предела выносливости детали.