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Analysis of modern methods for preparing parts in surface engineering technologies

Serik Nurakov[1], Aigul Tulembayeva[2], Gulnara Merzadinova[3], Merkhat Shugayev[4]

[1]National University of Defense of the First President of the Republic of Kazakhstan - Elbasy, Nur-Sultan, Kazakhstan, serik.nurakov@inbox.ru
[2] National University of Defense of the First President of the Republic of Kazakhstan - Elbasy, Nur-Sultan, Kazakhstan, aigul.tulembayeva@mail.ru
[3]L.N.Gumilyov Eurasian National University, Nur-Sultan, Kazakhstan, gulnara.merzadinova@mail.ru
[4]National University of Defense of the First President of the Republic of Kazakhstan - Elbasy, Nur-Sultan, Kazakhstan, merkhat.shugayev@inbox.ru

ABSTRACT

The process of forming a new direction in mechanical engineering - surface engineering - was considered. The stages of assessing the quality of surfaces and indicators used, the corresponding development of a system of standards are shown. Methods of processing parts during their manufacture and restoration and the roughness parameters provided by them are presented. It is noted that the combined use of the proposed new devices to ensure the required surface roughness of the part and 4 patents obtained earlier by the authors on the technology and design of supersonic spraying machines made it possible to obtain a significant increase in adhesion between the coating and the workpiece. The stages of development of the roughness standards system are analyzed. The creation of an international standard for topographic (3D) surface assessment and the need to develop relevant national standards of the Republic of Kazakhstan were noted.

Key words : surface engineering, roughness, processing, standards.

1. INTRODUCTION

In modern conditions, at the stage of professionalization of the Consideration of the quality of the surface layer of machine parts at all stages of their life cycle (design, processing, testing, diagnostics, operation, repair, restoration and disposal) laid the foundation for the study of surface engineering, which led to innovative methods and a completely new approach to mechanical engineering. The wear and tear of parts during the operation of the equipment showed that these processes depend primarily on the quality of surfaces, which led to the formation of a new direction in mechanical engineering - "surface engineering" [1,2].

The most acute problem of the surface arose in the sixties, when it was decided to repeatedly increase the resource of gas turbine engines. Already then it became clear that the optimization of the cutting process should be carried out not only from the point of view of minimizing the wear rate of the tool, but also taking into account the resulting structure, properties, and tension of the surface layer of the part.

Due to the importance of the surface problem, it was created the International Federation for Heat Treatment and Surface Engineering.

As is well known, at first the surface quality of the parts was determined by the cleanliness of the surface, indicated in the form of signs ▼ on the drawings of the parts, and which was ensured during their processing on the machines. It was believed that the "cleaner" surface is better. Achieving the required purity was ensured by various types of blade and abrasive processing [3,4].

The quality of the parts is determined by the accuracy expressed by the tolerance for size, the tolerance of the shape and the tolerance of the location of the surfaces, as well as their roughness parameters. Of the listed quality indicators, the surface roughness is currently the most difficult in standardization, measurement and metrological support [5,6]. It is the surface roughness that determines many functional properties of the surface: the quality of the interface (fit); transmitted loads (wear resistance); contact strength; grease retention; adhesion; heat transfer temperature; reflective ability.

Requirements for surfaces are established in order to ensure their functional properties, laid down by the designer during the design of parts and the technologist in the design of manufacturing technology, restoration, operation of parts and their connections.

Recently, the technology of cleaning the surface with a jet of compressed air mixed with a suspension consisting of a mixture of water with an abrasive powder of a certain concentration (hydroabrasive treatment) is gaining ground in industry [7]. Working air pressure - up to 10 bar. A distinction is made between injection and forced suspension systems in the mixing chamber. The method has great technological capabilities. It can be used to clean the surface of old coatings, traces of corrosion, scale, oxide films, oil bitumen and other contaminants, remove defective layers, burrs, surface matting, etc. In contrast to sandblasting, the amount of suspended dust generated during the cleaning process is insignificant; therefore it is possible to use grinding powders and micro grinding powders as abrasives [8]. The use of fine-grained abrasive provides surface treatment with an initial roughness of less than Ra 0.5 μm without noticeable deterioration in quality. The use of a suspension as a working medium ensures the removal of contaminants not only from the surface of parts, but also from pores and small and hidden defects [9].

Such information is necessary for designers and technologists and allows them to solve problems by choosing the range of parameters and assigning their numerical values, which, in turn, must be provided at the factory during the surface manufacturing process with the appropriate choice of tools and equipment.

2. MATERIALS AND METHODS

Whole series of interrelated problems have to be solved, related to the fields of materials science, design, technology, diagnostics, control, modeling, etc., during solving the problem of ensuring strength with technological methods, of course, taking into account economic and environmental aspects.

Concerning the solution of these problems, it should be noted that the technological effect on the workpiece, as a rule, leads to dramatic changes in the physical and mechanical properties, chemical and structural-phase composition of the metal of the surface layer. For each process, these changes are different, but they always take place. When forming by cutting, for example, due to very high temperatures and contact loads, the speed and intensity of plastic deformation, adhesive and diffusion processes between the tool and the processed material, the surface layer up to 40 μm thick differs sharply in internal tension, structure, chemical and phase composition, hardness, strength, ductility, impact toughness, linear expansion coefficient, etc. from the bulk of the part.

The surface cleanliness of the parts was checked visually using samples of "cleanliness", and in laboratory conditions was measured by profilometers according to the average in accordance with GOST 2789-59. The surface cleanliness was denoted by one triangle with a digital indicator of the class of cleanliness, for example ▼ 5. In the USSR in 1973 GOST 2789-73 was introduced on the roughness parameters: Ra, Rz, Rmax, tp, Sm, S and the relative position of the roughness profile: ‖ (parallel), ⊥ (perpendicular) instead of cleanliness classes. Similar parameters of the surfaces of parts were adopted in the standards of other countries.

3. RESULTS AND DISCUSSION

Table 1 shows the roughness parameters provided by traditional types of processing of parts during their manufacture.

Table 1: Methods of surface treatment of metal in their manufacture

Type of treatment	**Methods**	**Roughness parameters; Ra, μm**
Longitudinal turning	1. Peeling 2. Semi-finished 3. Fine 4.Thin (diamond)	100 – 25 12,5 – 6,3 3,2 – 1,6*(0,80) 0,80 – 0,40*(0,20)
Boring	1. Draft 2. Semi-finished 3. Fine 4.Thin (diamond)	100 – 50 25 – 12,5 3,2 – 1,6*(0,80) 0,80 – 0,40*(0,20)
Drilling over 15 mm	1. Without conductor 2. Conductor	25* - 12,5 -
Deployment	1. Semi-finished 2. Fine 3. Thin	12,5 – 6,3* 3,2 – 1,6* 0,80 – (0,40)
Stretching	1. Semi-finished 2. Fine 3. Finishing	6,3 3,2 – 0,80* 0,40 – (0,20)
Round grinding	1. Semi-finished 2. Fine 3. Thin	6,3 – 3,2 1,6 – 0,80* 0,40 – 0,20*(0,050)
Honing cylindrical holes		0,20 – (0,050)

Special surface treatment methods are used to increase their roughness, during repairing parts with various coatings, (table 2). To ensure sufficient adhesion of the applied coating layer to the base metal, it is necessary to give the surface to be coated a certain roughness. Now in practice, the most common way to create roughness is to *cut torn or round threads with run-in*. In addition to cutting torn threads and notches with a chisel, anodic-mechanical processing is used, which ensures good adhesion of the sprayed layer to the metal of the part. But these methods significantly reduce fatigue strength, and, therefore, they cannot be used to prepare the surfaces of parts operating under cyclic loads. Inkjet methods are more advanced than previous ones. They use a pneumatic feed of small particles of the processing material (corundum, steel and cast iron, sand) to process the surfaces, which are dispersed by compressed air, flowing out of the nozzle in the form of a jet and, striking at a high speed against the surface being treated, create the necessary roughness.

Table 2: The roughness parameters of various methods of processing parts during their repair

Type of treatment	Roughness parameters; Ra, µm
Thread cutting a) round b) torn	 12,5 – 8,5 90 – 100
Sandblasting, bead-blasting	50 – 60
Friction treatment	25 – 12,5
Mechanical anode	25 – 50
Electrospark	30 – 40
Honing	0,80 – 0,40
Ultrasound	3,2 – 1,6
Electrochemical mechanical	12,5 – 6,3

As can be seen from tables 1 and 2, the roughness parameters obtained by existing machining methods in the manufacture or restoration of parts can be applied to ensure roughness. This makes it possible to use them for various purposes: both in the manufacture and restoration of surfaces when preparing rough surfaces for applying various coatings and, first of all, by supersonic spraying - one of the promising methods at the present stage of development of mechanical engineering [9,10,11]. However, not all of them can be used for machining parts of military hardware made of high quality steels and using special technologies, which are much higher compared to general engineering.

In this regard, the authors are conducting research on the creation of new, more effective processing methods for preparing the surfaces of parts for applying wear-resistant coatings by such a most effective spraying method as supersonic [12]. According to their results, 4 patents for the design of devices for processing internal surfaces were obtained: patent of the Republic of Kazakhstan No. 3865 "Nozzles to the metallizer for spraying coatings on the internal surfaces", patent of the Republic of Kazakhstan No. 4171 "Acupuncture with adjustable stiffness of cutting elements for processing surfaces of various hardness", patent of the Republic of Kazakhstan No. 4180 "Acupuncture for processing engine cylinders", patent of the Republic of Kazakhstan No. 4385 "Device for cladding internal surfaces".

As a prototype in the needles patents, the first development was adopted, which has received worldwide recognition [13]. For this patent, the author received patents in Italy, Sweden, France. Licenses for it were bought by well-known companies in the USA and Japan. Many firms from the Federal Republic of Germany, Belgium, England and other foreign countries became interested in them and began to produce needle cutters. The instrument was exhibited at the Exhibition of Achievements of National Economy in Moscow and awarded with medals of the USSR, and at the International Exhibition in BRNO it was awarded the Big Gold Medal. The reason for its wide distribution in the world was the simplicity of design, versatility, high cleaning efficiency of metal surfaces, low cost.

Earlier, 4 patents for the technology and design of apparatus for supersonic spraying were protected: patent of the Republic of Kazakhstan No. 22522 “Plasmatron for restoration of parts”, patent of the Republic of Kazakhstan No. 31894 “Device for high-speed spraying of coatings”, patent of the Republic of Kazakhstan No. 32267 “Method of forming a wear-resistant coating of high alloy steels”, patent of the Republic of Kazakhstan No. 2295 "Stand for the study of nodes with anti-friction coatings", patent of the Republic of Kazakhstan No. 1556 "Method of hypersonic metallization and a device for its implementation."

As a result of the experiments on supersonic spraying, a significant increase in the adhesion between the coating and the treated surface was obtained. It was found that existing technologies still do not pay enough attention to the preliminary preparation of surfaces before spraying. At the same time, high-quality surface preparation before spraying is an important and integral part of the coating process, since it can significantly increase adhesion - this is the main problem during spraying.

At the same time, the choice of surface preparation method depends on many factors: coating thickness, spraying method, product configuration and dimensions, product functionality, etc. The surface preparation method significantly affects the strength characteristics of the substrate.

An analysis of ongoing research on this topic showed that the use of ultrasonic vibrations is very promising for preparing surfaces for spraying. For example, the use of ultrasonic processing in layer-by-layer processing allows to obtain a high setting load value and low wear value.

The authors' search for new ways to obtain the required roughness led to an analysis of the suitability for this idea of deformation cutting (DR) - a machining method based on cutting the surface layer of the workpiece material and subsequent bending of the trimmed layer with the formation of a micro relief in the form of ribs, spikes, cells. The essence of the method is that the tool for the DR has an auxiliary edge on which the cutting process is excluded. Thus, the auxiliary edge becomes deforming and bends the layer cut by the main edge. The combination of cut and bent layers that are associated with the main material of the workpiece form a developed microrelief on the surface of the part. The DR method is non-waste, it is implemented on standard metal-cutting equipment and allows you to process a wide range of plastic materials, such as: steel, titanium, copper, aluminum, thermoplastic polymers (polyethylene, polypropylene, fluoroplastic). The surface structure obtained in this way has an increased surface area (up to 14 times compared with the initial workpiece), which led, first of all, to the application of the method to create developed heat transfer surfaces, for example, to obtain heat transfer tubes and heat exchangers, flat finned fins for cooling microchips .

Although at present the DR method does not allow obtaining small-step finning (less than 1 mm), it is promising and is the goal of our further study. Therefore, a new approach when creating wear-resistant coatings is to obtain by the DR method such a microrelief that can be used in spraying technologies. The objective is to obtain a microrelief with shallow and narrow intercostal gaps with a minimum width of 0 to 40-60-90 μm.

In order to create new effective methods for preparing the surfaces of parts before spraying at L.N. Gumilyov Eurasian National University, the results were studied and obtained confirming the possibility of using two promising methods of processing with a flexible tool: needle milling and deformation cladding [14]. At the same time, needle-milling can provide roughness parameters in the widest range - from replacing degreasing to obtaining optimal roughness parameters (Rz = 40 μm). Cladding is promising not only for creating a sublayer before spraying, but also as an independent technology for restoring worn surfaces of parts.

In addition, the authors' studies have shown the new capabilities of such surface treatment methods as chemical-thermal and microplasma modification (Polyanski, 2014), as independent technologies in surface engineering.

The obtained patents for utility models for needle milling and cladding of internal surfaces are promising for the restoration of weapons and military equipment, for example, openings of firearms barrels, which are currently processed by traditional methods, expensive and not economical enough for widespread use. The devices we offer allow us to replace outdated technology for processing internal surfaces.

Accordingly, with increasing requirements for the quality of machines and their competitiveness in the market, the system of standards in this area is being improved. In this regard, the modern development of national and international standardization in the field of surface roughness assessment by the currently used profile method has led to the creation in the world of the currently existing system of international, national, regional standards for surface roughness by the profile method. Now in the world the standards of the International Organization for Standardization (ISO) and the regional (EN) and national standards developed on their basis are becoming more widespread.

The popularity of these standards is explained by the fact that they absorbed the experience of normalizing the roughness parameters of leading industrial countries such as the USSR, France, Germany, the USA and others. So, in the 60-70s, French functional parameters were included in them according to the method “Motif”, and in the 80s - a group of parameters Rk (Germany) and a group of parameters Rpq (USA).

The modern stage in the development of this system of standards is the development of national standards, standards and instruments for measuring surface roughness based on its three-dimensional analysis. This is due to the fact that profile measurements of the surface and the surface assessment carried out on their basis are limited. It should also be noted that according to current ISO plans, the characterization standards for surface profiles will become a subset of the standards characterizing the three-dimensional surface texture, although the content of the standards will not undergo significant changes.

In accordance with this, the L.N. Gumilyov Eurasian National University is working on the study of new methods of surface treatment and improving their adhesive properties in spray coating technologies by supersonic spraying, which take into account the requirements of new methods for assessing surface roughness in ISO standards.

5. CONCLUSION

In connection with the above, for the speedy development by the domestic industry of international experience in normalizing surfaces and the formation of a modern level of requirements for surface roughness, we consider it necessary:

- develop standards at the national level that are authentic to international standards for profile surface assessment (ISO 4287, ISO 4288, ISO 1302, ISO 11562, ISO 12085, ISO 13565, etc.);
- develop a national standard that is authentic to the international standard for topographic (3D) surface assessment [15].

Thus, the new technologies of supersonic spraying and surface preparation of parts investigated by the authors correspond to modern trends in the development of a new approach in mechanical engineering - surface engineering.

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