Holographic 3-D control devices of the new generation

E A Belkin¹, V N Poyarkov¹ and O I Markov²

¹ Bolhov Plant of semiconductor devices Bolhov, 17, K. Marksa str., Orel region, Bolkhov, 303140, Russia
² Orel State University named after I. S. Turgenev, 95, Komsomolskaya str., Orel, 302026, Russia

E-mail: BelkinE.A@yandex.ru

Abstract. The types of new-generation devices designed for non-destructive control over the formation of the topography of a micro relief and the external geometry of a complex surface are determined. Passive control devices: a holographic Profiler operating in the visible range of electromagnetic waves. Active monitoring devices: a holographic Profiler operating in the x-ray range. A tool for structuring a three-dimensional geometric model of a complex shape surface is specified. This tool is a modular geometric approach. The modular-geometric approach allows you to restore the natural curvature of the surface in the local area of the point. The connection between the design of the control device and the method of surface modeling is established.

1. Introduction

Non-destructive testing devices for geometric characteristics of the part surface and its microrelief used in industrial production do not allow determining the numerical values of parameters for constructing the topography of the microrelief. Therefore, among the parts that have the same roughness, the topography of the surface microrelief may be different within a wide range [1-3]. During operation, this leads to a reduction in service life, rapid wear, changes in functional characteristics, and a reduction in the efficiency of components and assemblies where this part is included as a component element.

Some of the used nondestructive testing devices examine the external geometry, others internal, and others determine internal defects. Also, the devices differ in the ability to control the details of the round handicap, having flat faces, having frame discrete-defined surfaces. There is no universal device that would allow metrological measurements regardless of the size and shape of the part.

The structural defects of devices of nondestructive control is to limit their functionality. As a rule, the design of control devices allows you to measure numerically one-dimensional estimated parameter-the height of the micrometer in the study of surface roughness and fix the surface profile in a flat section. The consequence of this is that: in the calculation of the forming surface of the tool, there is no calculation of the topography of its microrelief. This is due to the lack of sufficient information about the geometric structure of the microrelief [2-4] as a three-dimensional image, due to the use of a one-dimensional estimation parameter. The use of a one-dimensional estimation parameter-the height of the micro-area-for geometric modeling of the shape of the microrelief gives an idea of the microrelief as a surface with numerical marks. The description of a surface with numeric marks does not define the curvature in the local neighborhood of this point. Also, the uncertainty of the surface geometry between sections makes it impossible to build a complete geometric image of the surface.
2. 3-D technologies for non-destructive control of micro-relief topography

In modern geometric models of the blade of a gas turbine aircraft engine of a military aircraft, there is no information about the change in its curvature and about the topography of its microrelief. In the working drawing, the blade is represented as oriented sections. Between cross sections, the geometry is not defined. Therefore, the control devices for the formation of the external geometry of the blade and its microrelief are designed in accordance with these models, so that they can only perform passive control in the selected plane. The microrelief is estimated by the height of the microrelief. There is no topography of the microrelief in the working drawing [5-6]. In the production of blades, the compliance of the micro-relief of the surface with the type of wear and the compliance of the change in the curvature of the working part of the blade with the flow modes of its gas medium having a high temperature and high pressure is not taken into account. Gas turbine blades in modern production conditions can be manufactured with an accuracy of 0.1-0.01 microns.

The modular-geometric approach allows us to obtain a superposition of the external geometry of the blade and its topography of the microrelief with an analytical description and preservation of the natural curvature of the surface, i.e. to obtain a fairly complete 3-D model of it. The external geometry of the blade is represented as a smooth "cross-linking" of oblique helicoids with a certain twist angle. The topography of the microrelief is represented as a smooth "cross-linking" of contiguous paraboloids. In the 3-D model of the blade, a "crosslinking" of contiguous paraboloids is located on the "crosslinking" of oblique helicoids.

A holographic 3-D control system has been developed that allows building a 3-D model of a gas turbine blade based on a modular geometric approach. The holographic 3-D control system is a complex of systems that include laser, optical, Electromechanical, and microprocessor subsystems. The combined operation of these systems under the control of the controller allows for high-precision passive (before and after processing) and active (during processing at various stages) holographic 3D control of complex profile parts up to 2000 mm×500 mm×1000 mm. With an error of no more than 245 nm (blue-green light) when working in the visible range (holographic Profiler). And an error of no more than 0.5 nm when working in the x-ray range for ~ (soft x-ray) and an error of no more than 0.0005 nm for ~0.001 nm (x-ray profilograph).

A prototype of a holographic Profiler for passive control that operates in the visible range of electromagnetic waves (red light) has been created. The prototype [7] includes a table mounted on gas shock absorbers. The table has a system for suppressing mechanical vibrations of low, medium and high frequency. Optical systems for recording and reproducing holographic images are installed at random, i.e. not along a linear guide, as is customary. Mandrels for optical elements: mirrors, micro-lenses, light flow dividers, pin-halls (spatial filters), etc. have magnetic pads because the table surface is made of a material with high ferromagnetic properties. The mandrels for optical elements are mounted on ball bearings, which allows them to be oriented at a certain angle in an arbitrarily selected plane, i.e. the mandrels have six degrees of freedom [8]. This allows you to quickly and accurately configure the equipment for recording holographic images without a complex and expensive electronic control system. Such a number of degrees of freedom is technically difficult to obtain in the manufacture of classical platforms for positioning optical elements.

Installation of an optical Profiler provides a pre-screen image of the object (the image "hanging in the air") for the subsequent generation of contour maps of the microrelief, the studied surface.

The subsystem that removes maps from the holographic image of the surface layer is a mechanical arm whose position is fixed in space. A piezo-nano positioner is attached to the arm. A camera-free video camera with an interface is mounted on the positioner.

Maps are transferred to a personal computer for geometric modeling of the surface layer.

High-precision control of complex profile parts is required in the implementation of industrial production of modern mechanical engineering products: precision mechanics, dies, spindles, lunettes, carbide tools in machine tool construction; animating parts, cumulative funnels of the warhead, gyroscopes, rudders. As well as in the production of projectiles and missiles; turbine blades and compressors in gas turbine aircraft engines, turbopump units [9-11] and other similar elements.
A 3-D sensor for monitoring the wear of the working part of a gas turbine blade during its operation in an aircraft engine of a military aircraft is being developed on the basis of an x-ray screen.

For precision production of a gas turbine blade based on its 3-D model, structured on the basis of a modular geometric approach, a cyclotron machine is developed. The machine is a resonant accelerator-cyclotron. In it, charged abrasive particles are dispersed in an electric field, then falling into the magnetic field that controls them, they move [12] along trajectories corresponding to the 3-D model of the blade. The accuracy of the blade pen processing is 0.001mkm.

3-D production of gas turbine blades on a cyclotron machine dramatically reduces the cavitation wear of their working part, as the principle of matching the topography of the microrelief to the type of wear is implemented. It also significantly increases the service life of the engine's blade units and increases its efficiency, power and thrust. Accordingly, the speed of a military aircraft increases several times.

In 2013, on the basis of BZPP together with Oryol state University. I. S. Turgenev created a research laboratory.

The purpose of creating the laboratory: research work on the development of new technologies for 3-D processing of parts with complex surfaces (Aerohydrodynamic) and devices for 3-D control of the new generation over the formation [13] of their external geometry, internal structure and topography of the microrelief.

Tasks: creation of a prototype for the installation of holographic 3-D control over the geometry and topography of the microrelief and the internal structure of the Aerohydrodynamic surfaces of parts made of hard-to-process materials. Creating a prototype of a precision 3-D production plant for grinding the blade pen of a gas turbine with a tool on a flexible bundle in a magnetic field. Creating a prototype of the 3-D sensor for monitoring the wear of the working part of the gas turbine blade during its operation in the aircraft engine of a military aircraft.

3. Conclusion

Thus, the problem is that no modern nondestructive testing device, due to its design features, can make metrological measurements necessary to build a three-dimensional geometric model. Thus, the problem is that no modern nondestructive testing device, due to its design features, can make metrological measurements necessary to build a three-dimensional geometric model of the surface of the part, which is a superposition of the geometric image of the surface and the topography of its microrelief. This problem is relevant in the manufacture of parts for operational properties, which, in the tribo-conjugations of contacting surfaces, have high requirements. This also applies to blade machines [14] that operate in aggressive gas and liquid environments. It is known that wear resistance, fatigue strength, and other performance properties in tribo-stresses, as well as cavitation wear, are determined by the geometry of the surface and the topography of its microrelief. This problem is relevant in the manufacture of parts for operational properties, which, in the tribo-conjugations of contacting surfaces, have high requirements. This also applies to blade machines that operate in aggressive gas and liquid environments. It is known that wear resistance, fatigue strength, and other performance properties in triboextensions, as well as cavitation wear, are determined by the geometry of the surface and the topography of its microrelief. Solution of the problem in the development of new-generation nondestructive testing devices [15] that allow making metrological measurements necessary for applying the modular-geometric approach in structuring a three-dimensional geometric model of the surface.

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