The equipment and technologies for ultra precision machining and grinding of tools from extra-hard materials

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Abstract

As a joint project several Russian companies have carried out research and development of equipment and technology required for ultra precise machining of surfaces for special devices, mirrors and lenses, crystals and other elements from different materials. Engineering Department and Research & Technological Centre was setup to research and develop ultra precise elements, systems and machines as well as technology for micro and nano processing.

1 The equipment, pieces and systems for ultra precise machining

Developed and built unique equipment: ultra precise 4-axis machine for machining spherical and aspherical metal-optic surfaces, fitted with special CNC “Micros 12TC1” with resolution of 1 nanometer; ultra precise experimental machine with ductile decrement for ultra precise technological research; ultra precise 3-axis machine for turning, milling and grinding of flat and spherical surfaces of mirrors up to 680 mm in diameter.

Main technological aspects of the machines include: aerostatic supports in all moving elements of the machine, synchronous internal linear and rotary drives with CNC feed control, vibration protection by means of pneumatic supports with their own oscillation frequency of 5 Hz.

CNC unit is based on an industrial computer running under a real time OS. Software has advanced capabilities to compensate mechanical errors of the machine and radius of cutting tool edges.

Figure 1: Ultra precise 4-axis machine

Currently research and development is focused on creation and trials of next generation of aerostatic systems with the use of porous throttling, pneumatic-vacuum supports for carriages and spherical supports for spindles, linear and rotary feed drives for ultra precise movement with steps of 1 nanometer, digital tracking of synchronous linear drive, linear axis with "U" shaped non-metallic low vibration synchronous motor.

Example machine tool units:

- ultra precise lathe spindle with internal synchronous motor, spherical aerostatic supports with porous throttling gives radial and axial vibration of less then 50 nm with axial rigidity of 500 N/μm, radial rigidity of 250 N/μm at 50…3000 PRM;
- fast spindles – milling head with electric motor at 50000 RPM;
- linear rest with T-shaped guides on aerostatic supports with porous throttling and vacuum locking;
- rotary movement unit with internal synchronous high torque motor manufactured by "Mashinoapparat" (Russia) with digital drive manufactured by "Modem-Techno" (Russia).

Developed principals of forecasting parameters of precision aerostatic parts with the use of finite elements method and optimised working technical characteristics: load, rigidity, decrement, gaps, pressure in supports, penetrability etc.

2 Technology of ultra precise machining

Examples of developed technology in ultra precise machining include:

- diamond cutting of copper spherical lens 1000 mm in diameter;
- simultaneous diamond cutting of three extra-axial paraboloids each 406 mm in diameter;
- diamond cutting of flat metal-optic surfaces up to 680 mm in diameter;
- diamond cutter used for finishing of polygonal prism for optical scanning system and special flat adaptive mirror for medicine;
- production of micro parts for blood vessel micro robot;
- production of Fresnel lens matrix in solar power engineering;
- processing of special press forms from hardened steel by nanodisperse high density CBN;
- processing of nickel matrix for Fresnel lens by PCD;
- ultra precise processing of extra hard and brittle materials by grinding etc.

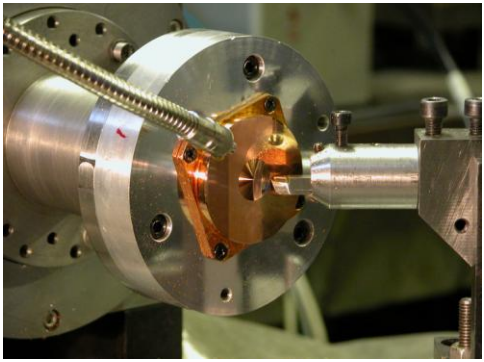

Figure 2: Production of Fresnel lens matrix in solar power engineering

3 Grinding and finishing of cutters from extra-hard materials

Developed and built ultra precise machine for grinding and finishing of cutters from extra hard materials: natural PCD; submicron and nanodisperse extra hard materials on the bases of CBN and PCD. Features of the grinding machine include: new generation pneumatic-vacuum aerostatics, grinding spindle with spherical porous supports and built in low vibration synchronous motor. Controlled movement of axis

within 0,1 µm; precision of cutter tip radius – 0,2 µm; roughness of cutting edge – Rz 0,02 µm; radius of PCD cutter edge – 20÷50 nm.

Carried out R&D and defined method of selection and certification of natural crystal diamonds of octahedron and rhombic-dodecahedron shapes in size of 0,7÷1,1 carats. Certified selected crystals using different methods: optical-polarisation, photometric, electro-microscopic. Determined durability characteristics of diamond cutters: experiments show that tool life of cutters is around 190 km of distance when cutting large aluminium and copper surfaces (the number of the tested tools is 17).

4 Quality parameters of the reflecting surfaces

The best results in the roughness of the machined surfaces have been received at diamond turning of special fine-grained alloy of system aluminum-magnesium. The research results of roughness in Rmax parameter make up: a range of change 14,2÷25,3 nm; average value of 17,3 nm; an average quadratic deviation of 1,05 nm; the factor of a variation 0,06 (46 measurements, feed 6,3÷9,6 µm/rev).

Quality characteristics of reflective surfaces after diamond cutting: surface roughness Ra = 5…6 nm; in IR spectrum – reflective coefficient of aluminium surface - 97,6%, copper surface – 98,9%, with Ag coating – up to 99,3%.

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