Removal of burrs from small-size high-precise parts for SHF electronics

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Abstract. The technology of signal transmission without distortion and loss is critical to modern electronic equipment. To reduce direct SHF losses, ensure solderability and corrosion resistance, the outer and inner conductors for SHF electronics are mainly made of 29HK alloy for hermetic connectors and beryllium bronze for non-hermetic galvanized connectors. These parts require high dimensional accuracy (10-50 microns) and surface cleanliness: no burrs are allowed. The production of such small-sized high-precision products from hard-to-machine materials requires the use of special manufacturing techniques and appropriate equipment.

1. Introduction
Import substitution of the electronic component base is one of the promising areas of development at the enterprises of the radio-electronic industry. Coaxial radio components for super high frequency (SHF) microelectronics, such as connectors, SHF inputs, noise filters, low-frequency inputs and racks, are part of the electronic component base. The technology of transmitting signals without distortion and loss from a microstrip line to an RF cable or another line, power supply voltage and control signals, and filtering interference is highly important in modern electronic equipment.

2. Basic technical requirements for SHF electronic products
The electromagnetic field in the coaxial line is between the inner and outer conductors. When a signal is transmitted through these conductors, currents flow in the thin surface layer. The thickness of the metal layer required to reduce the amplitude of an electromagnetic wave 2.71 times is called the depth of the “skin layer”. The higher the frequency and the greater the electrical conductivity and magnetic permeability of the metal, the smaller the depth of the “skin layer”. Currents flow through the outer layer of the inner conductor and the inner layer of the outer conductor. The depth of the “skin layer” determines the choice of the composition and thickness of the coating. For SHF technology, it is necessary to cover the conductors with a layer of silver or gold several micrometers thick in order to ensure the flow of surface current through a well-conducting layer and reduce losses in the transmission line. Moreover, gold is preferable for most cases, since, unlike silver, it is not oxidized.

The main parts of radio components for SHF electronics are the inner and outer conductors and an insulator between them. For hermetic connectors, shells are made of alloy 29NK or steel 15Kh25T to
obtain consistent thermal expansion coefficients for the S52-l glass welds. For connectors with unregulated sealing capacity of the body, they are made of stainless steel or beryllium bronze for military products, and brass for cheap utility connectors [1].

Brass or beryllium bronze is used for the manufacture of internal conductors. As for scaled connectors, the internal conductor, as well as the body, must form a reliable alloy with a glass insulator, for which alloy 29NK is used. The female contact of the connectors must be sufficiently elastic and have a high electrical conductivity. Beryllium bronze successfully combines these properties.

Internal and external conductors require high dimensional accuracy (10-50 microns) and surface cleanliness: no burrs are allowed.

Female contacts are made of beryllium bronze due to its elasticity. After turning machining and cutting the slits between the segments, beryllium bronze is hardened and becomes plastic, which allows one to compress the segments of the socket.

To reduce the direct losses of the SHF, ensure solderability and corrosion resistance, the inner and outer conductors are made with electroplated coating. The thickness of the coating should be several times greater than the depth of the “skin-layer”. The best coating is wear-resistant gold: alloys of gold and cobalt, nickel and antimony. Electroplated coating of gold-cobalt alloy forms a solid (microhardness less than 190 kgf / mm²) wear-resistant coating with low contact resistance (0.4 milliohms) [2-5]. Coating thickness is not more than 2-3 microns.

3. Features of technology of manufacturing parts of SHF electronics

Internal and external conductors are produced using high-precision CNC machines or watch lathes with subsequent electroplating. In rare cases, the simplest current leads are manufactured in a cheap way - by stamping. Many products that have the same technical specifications need to be produced in a different design, taking into account the connecting dimensions used by specific developers of radio electronic equipment.

In order to use typical operating procedures, the range of products manufactured on CNC machines at JSC Irkutsk Relay Plant is divided into groups depending on the geometry of the products and materials used. Depending on the geometry, the parts can be produced using turning (bodies of rotation) and milling machines, as well as products that do not have internal surfaces (burrs are removed by tumble finishing) and having internal surfaces (burrs are removed by tumble finishing only from external surfaces). According to the materials used, the range of products is divided into classes based on the workability of the material on CNC machines (the presence of burrs, their nature, methods of elimination, tool durability).

From the range of products manufactured on longitudinal turning automatic lathes, we can distinguish two large groups of products that have the same features and problems [2, 6-9].

The first one is the parts made of beryllium bronze (BrB) material, having gutters, pockets, side holes, grooves, threads, etc., for example, KAPD.724212030-02 housing.

The second one is the parts made of the material of iron-nickel alloy 29NK, having grooves, pockets, side holes, grooves, threads, etc., for example, FIMD.713.751.004 Sleeve.

The main problem in the manufacture of these parts is the presence of burrs, which are not allowed according to the technical documentation. According to international and industry standards [10, 11], all billets should be descaled, burrs removed, sharp edges blunted. Insufficient preparation of the surface of parts before coating (burrs, sharp edges, the presence of dirt) leads to a deterioration of adhesion, the formation of growths on the surface of the parts [12].

The selection of tools and processing parameters for parts from beryllium bronze showed that the burrs on these parts appear immediately even with the use of a new high-quality tool and optimal processing modes. Tool durability for beryllium bronze parts is high. These parts are necessarily sent for additional processing: tumble finishing (cleans external surfaces from burrs) and ironworking (the scraping of internal surfaces, gutters, pockets, etc.). The material is quite easily processed when peeling.

By reducing the processing speed, installing a new tool and conducting re-processing with the new tool, the character of the burrs changes, their quantity decreases, but the burrs remain.
Selection of tools and processing parameters for parts from iron-nickel alloy 29NK showed that burrs on these parts do not appear immediately. When installing a new tool, there are no burrs for about 12 hours of machine operation. There is a statistics of the dependence of the quality of components made of 29NK on tool wear, which showed that the runtime of the machine tool before the burrs appear on the components of the existing stock list with the optimum treatment regimes ranges from 12 to 14 hours. If to change the tool after 12 hours, the parts do not require additional processing, but as the wear of the tool remains slight, it can be used for the manufacture of parts from softer materials. Further processing without a tool change requires additional processing: tumble finishing (which cleans external surfaces from burrs) and ironworking (scraping of internal surfaces, gutters, pockets, etc.). The material is difficult to process when peeling.

4. Methods of deburring and their applicability in the conditions of this production

In the conditions of the production of components for SHF electronics, various methods of deburring can be used: chemical etching, tumble finishing, thermal deburring, electrochemical deburring, ironworking, installing steel or ceramic brushes on the machine, selection of cutting tools, using robots for cleaning. The use of a particular method has different cost, time and quality of processing [2, 13-15].

The literature describes the finishing methods of processing [12]:
- processing complex shaped surfaces and holes of parts by air-abrasive or air-liquid-abrasive jets;
- impact treatment by shot blasting, sandblasting, hydro sandblasting and hydro cavitation methods;
- the impact on a portion of abrasive material with counter-directed spiral-shaped flows of compressed air during processing of internal surfaces;
- ultrasonic removal by ice crystals;
- anode-abrasive method, processing is carried out in an environment of electrolyte and abrasive filler, which are located in a rotating cylindrical drum, where an electrode is also placed;
- centrifugal treatment of the inner surfaces of small parts in containers with planetary rotation, in particular, for polishing the walls of the channels of the bushings, rings, pipes;
- repeated pumping of the abrasive mass by pressure of 1.5-15 MPa through the channels in detail;
- jet-abrasive treatment based on vortex swirling of the suspension flow allows to increase the tangential components of the speed of the jet, which makes it possible to increase the productivity of the process;
- filling the part’s hole with a liquid that has the property of hardening in a magnetic field, followed by discharge along with the chip collection;
- magneto-abrasive processing of holes, in which a ferro-abrasive powder is placed in the gap between the hole and the inductor. and the magneto-abrasive processing device is rotated around its own axis and in planetary motion. The inductor is also given axial oscillatory motion;
- vibration processing;
- centrifugal-rotary finishing and cleaning of holes.

And also, not abrasive-finishing methods:
- thermal impulse deburring using the Pulsar TI-576 device for deburring metal parts of any profile using a thermal short-term pulse, due to which the heat wave removes the shortcomings of machining [16];
- Robotic complexes for deburring, for example, the industrial robot KUKAKR210 R2700 prime with an additional seventh linear axis, which allows to increase the working area of the robotic complex and increase processing productivity [17].

The following methods of deburring have been investigated:
- chemical etching: removes thin burrs, not wide ones;
- tumble finishing: removes burrs only from external surfaces. The concentrated shampoo compound OTEC SC96 and granite fillers are selected: granules GRA 2-5 or ceramic pyramids of different sizes, such as OTEC D2S4*4, used depending on the material;
thermal deburring: the equipment is very expensive (about 55 million rubles). There is no possibility to test it in Russia;

- electrochemical deburring: is not tested, but it is known that if chemical elimination (etching) does not remove large burrs but only smooths them, then electrochemical one (the same acid reagent acts in the electroplating bath) will only add penetration to the internal surfaces, but not improve the result;

- ironworking when using a scraping tool, drill, abrasive circles with a rubber bond, is an additional manual operation that gives a good result, increased labour input and time costs;

- installing steel brushes on the machine: not all burrs are scraped; installing abrasive wheels with a rubber bond: the wheels are destroyed by cutting compound; installing ceramic brushes: is not tested;

- selection of the cutting tool: tools of about 30 manufacturers have been tested. Swiss tools UTILIS and Fraisa have the best result;

- the use of robots for peeling is expensive (a robot installed on each machine costs about 20 million rubles).

Thus, quality deburring is possible when applying a peeling robot, installed on each machine tool, and tumble finishing with the subsequent manual ironworking, the thermal deburring, and the shift replacement of the selected cutting tool for 29NK. The application of robots for the peeling and thermal deburring require the additional capital investments, whose expediency must be calculated individually and depends on the planned volumes of production output with their aid. Tumble finishing, followed by manual scraping with a scraper tool, increases the labor intensity and may lead to the breakdown of production time. Shift replacement of the cutting tool significantly increases the cost of the tool. It is possible to further use the tool that has worked with 29NK before the burrs occurred to produce parts from other materials. For parts made from 29NK, it is advisable to continue the selection of the tool, explore the nature of its wear, and possible ways to reduce wear and repair the tool.

5. Conclusion
The outer and inner conductors for SHF electronics are mainly made of 29NK alloy for hermetic connectors and beryllium bronze for non-hermetic connectors. These parts require high dimensional accuracy (10-50 microns) and surface cleanliness: no burrs are allowed. The production of such small-sized high-precision products from hard-to-machine materials requires the use of special manufacturing techniques and appropriate equipment. The production facilities are required to be retrofitted with high-precision CNC machines, as well as additional deburring equipment. If the facilities are insufficiently retrofitted with deburring equipment, it is possible to use additional processing by tumble finishing, followed by manual scraping. Shift replacement of the cutting tool significantly increases the cost of parts made of 29NK. The main measures to reduce tooling costs are tool selection, research on the nature of its wear, possible ways to reduce tool wear and repair, use of algorithms to select optimal routes for manufacturing parts on the site with the possibility of combining part stripping, tool waste without manual cleaning and 29NK for processing other materials.

6. Acknowledgments
The reported study was funded by RFBR, project number 19-38-90184.

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