PERFECTING of the TECHNOLOGICAL SOLUTIONS AT MANUFACTURING of a ET MT[12]

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As shows long-term experience of manufacturing and tests for resource(safe life) of rocket engines of a small thrust (ET MT), the functionability and надёжность of items largely depends on workmanship of units of a design, in which are available паяные and клеено-modular details from alloys of a type ковар, titanum alloys and special electroinsulation, heat-resistant, "soft" керамик because of of nitride of a boron, горячепрессованных and реакционноспечённых.

At designing and manufacturing of a ET MT of a new generation is used accumulated ОКБ experience for perfecting the technological solutions with the purpose of increase of strength паяных both клеено-modular details and units of a ET MT.

The special kinds of processing, and also химико-thermal processing connected by the soldering and pasting together by high-temperature glues of units from керамик and precision alloys, allow to improve them прочностные of the characteristic in conditions of static and dynamic loads, and also at термоциклировании in conditions of full-scale maintenance and at zonal heatings in the working conditions of engines(thrusters).

The developed connections of units of a ET MT have passed full volume of ground qualification in a structure of propulsion systems, and also the flight tests in a structure of space vehicles and have shown efficiency(effectiveness) and expediency of application of the inproved technological solutions in a ET MT.

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During manufacturing SPT in EDB "Fakel" the efficiency of application in anodic and cathode units of two brands of ceramic materials is placed(installed). It горячее Hot pressing of bar from Boron nitride of silicon of ceramics of modifications БГП, БГП-10, БГП-М3 and sintering in an outcome of response from Aluminium of a boron nitride of ceramics АБН, subjected to machining and included in Connection by a gluely - modular subassembly consisting of metal lips and bodies of a titanium, Kovar, Invar, connected Made of a glue, by compositions with maximum operation temperatures 600-8000 °C, have agreed to. g. l. t. e. (factors of the linear thermal extension) ceramics - Made of a glue composition - metal [1-4, 6, 11]. SPT of a new generation, with the best power characteristics [11], the uses of the best composite, powder ceramic and metal materials and alloys with specific Thermal and physical by properties, with the stablis Physical -mechanical characteristics by hardness, strength, тепловой стойкостью By thermal stability and electroresistance can be created only because of.

In the article the electronics engineerings, electrical engineers are cited data both outcomes of researches and developments of new methods of the control of details and bars from several kinds electroinsulation constructional Boron of nitrid Ceramics, with allowance for of existing methods and volumes of tests of production [5, 7-10, 12, 13], and also on firms of instrument making.

Materials, instrumental maintenance at realization of experience.

The researches, which purpose, final total, was definition of ways and volumes of the control of ceramic bars and details from them, necessary and sufficient for manufacturing reliable both кондиционных of units and сборок a ET MT, are adduced on two kinds constructional Ceramics, borons, containing nitride, nitride of aluminium, dioxide of silicon and modifiers, Connection with oxygen Ytterby and zirconium. The brands, kind of bars, way of their obtaining and main properties, regulated till By specifications, are adduced in table 1.

Table 1.

Brand, sizes of bars	Technological parameters of manufacturing	Density, g/sm^3	Porosity, %	Electroresistance, Ohm	Assignment, boundary conditions of application
The Bohr nitride silicon with By Connection with oxygen of a zirconium and Ytterby, БГП-10, By specifications АДИ 108-85, diameter of 70-200 mm	Hot pressing in graphite moulds at induction heating up to 20000Ñ	2,20-2,30	2-5	10^{11}.. 10^{12}	Sources of plasma, environment argon, vacuum, xenon up to 1700-18000°C
Aluminium of a boron nitride, component of nitride of silicon or without them, АБН, СБН, By specifications of 88-УР-148-03-85, diameter of 110-140 mm	Pressing, Reactionary a sintering in a current of nitrogen, in a filling, Thermal high-frequency Heating up to 1800°C	1,98-2,10	3-8	10^{10}.. 10^{12}	Isolators of cathode and anodic units, vacuum, argon up to 1300°C

The measurements of physical, physical-mechanical properties not desroying control, Petrographie the analysis executed on the samples which have been cut out from bars on segments technological tolerances, in zones of critical thermal and erosive loads near to working surfaces of thin-walled details of anodes and cathodes designed by machining of pressed bars, and also immediately on thin-walled precision details firing electrodes and insulators from the same bars. On figure 1 the scheme of manufacturing of the thin-walled chamber of insulator from massive Hot pressing of bar БГП-10 is shown and zone of a clipping is exemplar for measurement of hardness, definition(determination) of strength at compression. In a figure 2 (a, b) the exterior Small size of bars, thin-walled details of cathode units is adduced.

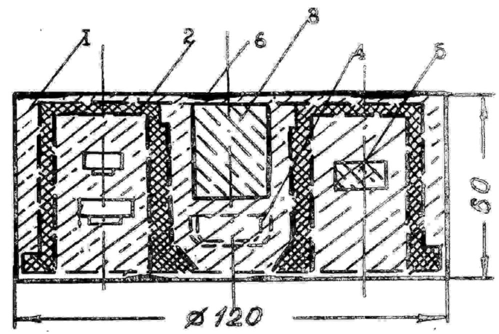

Fig.1 - Scheme of a clipping is exemplar also machining of thin-walled insulators of anodic units from ceramic bars БГП, БГП-10, АБН (1-bar up to Machining, 2- The chamber - insulator of the anodic unit, 3-samples for test for compression, measurement of hardness and Petrographie the analysis, 4,5- Small size of a detail of the cathode unit, 6 - zone of reduced hardness)

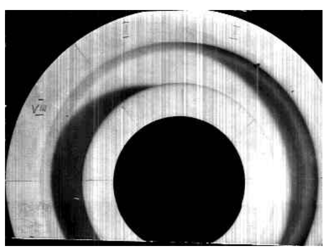

Fig.2 a

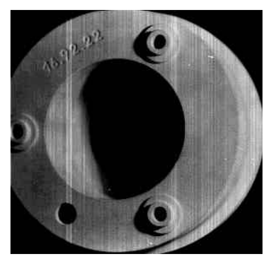

Fig.2b

For all is exemplar also of details from ceramic bars at the first phase of researches determined the class of a roughness of surfaces after turning. Milling processing or grinding. The scheme of a profiles from surfaces керамик Boron nitride of silicon and Aluminium of a boron nitride, obtained on The accelerometer of a profiles - recorder of a profiles before measurement of hardness, and also optical characteristics of a surface: a degree of blackness - E and absorption coefficient of solar radiation A_S, determined on the accelerometer of thermal radiations TPM-2M and photometers ФМ-58, ФМ-59 are adduced in a fig. 3.

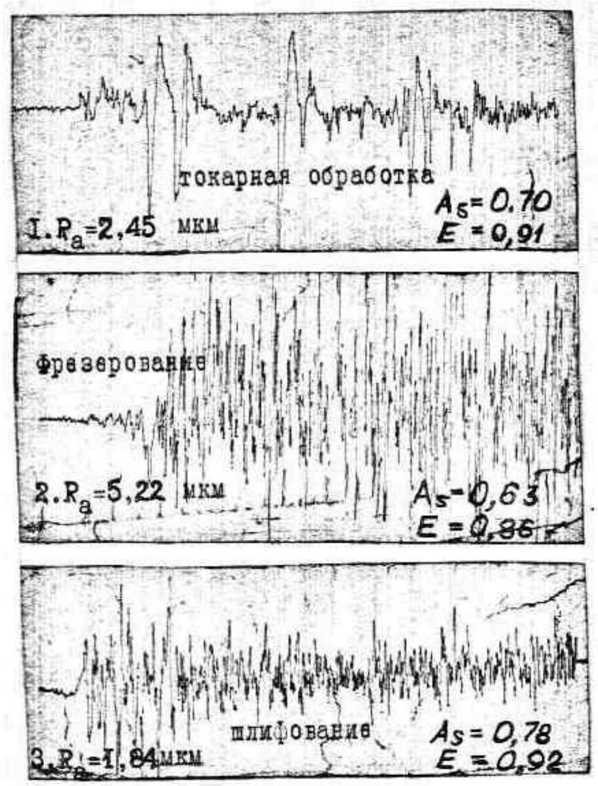

Fig. 3. The scheme of a profiles from a surface of ceramic bar from ceramics БГП-10 after determination of a non-uniformity by measurement on Micro accelerometer of hardness МИТ-2 (1-turning processing, 2-milling, 3-grinding, horizontal increase (ГУ)x300, vertical increase (ВУ) x10000)

Level-by-level hardness of bars of all kinds of ceramic bars determined, using non-standard Indentors - balls of diameter 5-6,35 mm for equipment of devices ТК-М, Роквелл and electromagnetic Accelerometer of hardnesses МИТ-2, МИТ-3 of the "Mitex" corporation. The structural tests at compression and bending conducted on machines P-0,5, P-5 and ZDM-10.

At preparation is exemplar also of details for researches, and also at technological tests applied vacuum electric furnaces СГВ-2-4/15-И2, electrocabinets СНВЛ - 3.3.3/3,5M and non-standard with small consumption of energy of the furnace with "hot" by retorta of a type СНОЛ - 1,6.2,5.1-/9,5M3. Definition of density ceramics by a method of hydrostatic weighing order on methods adduced in activity [13] with use special equipment and continuant of weights ВЛ-0,5 of chemical-spectral laboratory of firm.

Outcomes of the analyses and measurements of properties of ceramics.

The data about density, characteristics of a surface and properties of ceramic bars from ceramics boron silicon, is nitride of aluminium of a boron and boron silicon is NItride of aluminium, and also of thin-walled details from a bottom are adduced in tab. 2.

Table 2.

Brand of ceramics	Density, ã/ñì3	The class of cleanness RA, micron	Optical factors		Hardness условнаяX)	
			ÀS	E	$HB_{У1}$	$HB_{У2}^{X)}$
БГП, БГП-10	2,18-2,25	1,80-2,23	0,57-0,60	0,90-0,92	385-411	202-209
АБН, АБН-1	2,03-2,11	3,8-4,10	0,66-0,67	0,94-0,95	214-250	68-67
СБН, ÑÁÍÖ	2,47-2,51	1,65-1,90	0,77-0,78	0,89-0,90	670-671	413-445

õ) - $HB_{У1}$- impression of a ball of 6,35 mm by a load 150 kgf, $HB_{У2}$- hard-alloy индентор of the device МИТ-2

In tab. 3 the outcomes of measurements of main(basic) properties of two kinds investigated ceramics are adduced.

Table 3.

The defined characteristics	Way of measurements both tests of properties and defects	Actual value параметровх)	
		БГП-10	АБН
Density, ã/ñì3	Hydrostatic weighing	2,22-2,24	2,11-2,12
Hardness on section(cross-section)	Impression of a indentor -ball d = 6,35 mm, 150 kgf, $HB_{У1}$	385-416	220-265
	Dynamic operation indentor from ВК-6-Ом "МИТ-2", "МИТ-3", $HB_{У2}$	215-250	70-75
Strength at compression, kgf/sm^2	Load on the machine P-5, samples d = 20mm, I = 30 mm	1250-1300	450-500
Electroresistance, MOm	Voltage 2500 V, electrodes from БрБ2, base of 3 mm	1100	1200
Structural Non-uniformity, actuations, mm	X-ray snapshot on РУП-60, direct X-ray	0,8-1,0	0,2-0,4
Cracks current -leading graphite actuations, mm	The electrospark control on technological appliances оправках from Амг6, "Крона-1М"	0,2-3,0	0,2-4,5
Porosity, crack, availability of cavitces, micron	Capillary non-destructive testing пенетранты till Specifications 24.11.042-93	10-30	50-70
Macro structure of surfaces, fractures, microstructure	Mikroskop МБС-2, ММР-4, " Neofot "	See fig. 4	See fig. 4
Speed of distribution(propagation) of ultrasound, m\s	Flaw detectors USN-50, USK-75	5300	3150

x) - all kinds of tests on 10 bars of ceramics, strength on compression on two samples from bar.

Alongside with measurements of physical, electrical mechanical properties for керамик АБН and ÁÃÏ the speeds of distribution(propagation) of ultrasound with application of flaw detectors of the "Krautrament" corporation are certain(determined).

Macro structure of fractures and outcomes Petrographie of the analysis is exemplar also of details from Ceramics БГП and АБН before tests for hardness, compression are shown in a fig. 4, the change of hardness on section is adduced in a fig. 5.

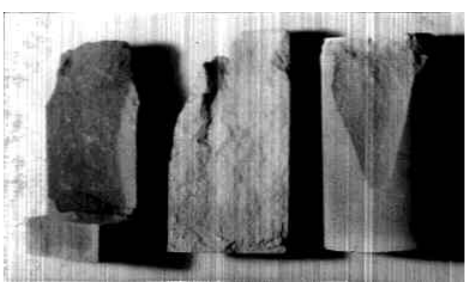

Fig.4-a

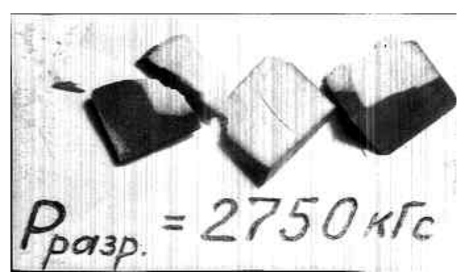

Fig.4-b

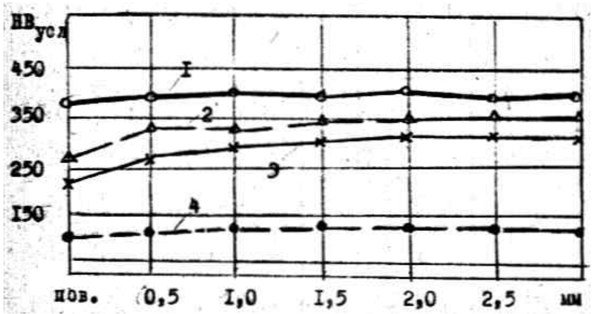

Fig.5-a - Change of hardness of ceramics Boron silicon (1,3) and is Nitride of aluminium borons (2,4) depending on pick up from a surface of pressing at impression of a ball 1,2 - load 588Í, and 3,4 - 441N

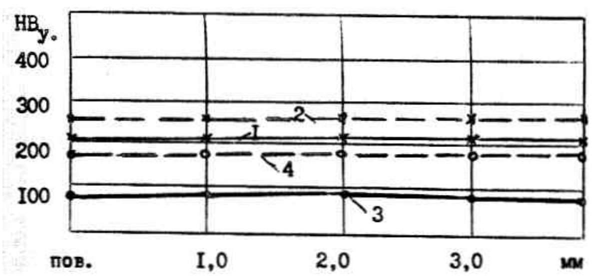

Fig 5. - Change of hardness on depth of diametrical pick up of cylindrical bars from ceramics БГП (1,2) and ceramics АБН (3,4) at measurement on the device МИТ-2 (1,3) and on the device ТК-2М at impression of a ball by a load 60 kgs.

Discussion, technical rules(situations,positions), conclusions(injections).

The experience and measurements conducted on samples and details with use of serial bars керамик БГП, БГП-М3, БГП-10 and АБН, production of firms of Russia and Ukraine, allow to conduct a comparative evaluation of efficiency each from approbation of test methods of two kinds electroinsulation ceramics for a ET MT.

So the method of hydrostatic weighing, elementary from used, has allowed along with the spectral and chemical analyses, to determine a brand of ceramics of off-the shelf details of a complex configuration.

The measurement of hardness by non-standard ways, in particular electromagnetic by accelerometer of hardnesses МИТ-2, МИТ-3 with hard-alloy by microIndentors, has appeared more effective and reliable for definition of a non-uniformity of ceramic bars, than ways on activities [8, 11]. Is installed, that hot pressing ceramics БГП-10 and the analogs БГП, БГП-М3 have higher hardness, strength, uniformity, than aluminium of a boron nitride, by jointed method of heating under pressure in nitrogen АБН. At the same time on rather soft ceramicses БГП-10 and АБН the measurement of microhardness by impression or царапаньем on a technique [7], acceptable for aggregates with hard by the ballasts is not obviously possible. At realization of researches it was not possible to install correlation relation of structural limit on compression and hardness at measurement by a method of impression of a ball at non-standard loads 30-600 N for each kind of electroinsulation heat-resistant ceramics. For this purpose the increase of volumes of tests and выборок is necessary, that is hindered by the significant cost of ceramic bars now.

The most simple and reliable method of detection of cracks, несплошностей, graphite actuations on thin-walled off-the shelf details of complex transient cross-sections and thread, is the electrospark method of the control permitting to determine defects from 0,2 mm and by expansion tens is cross-section. In a combination to the X-ray control the method has allowed to identify practically all most typical defects and imperfections, including zones of derivation kristoballit in ceramics БГП, БГП-10, БГП-М3.

Application new Penertats and developers deleted by water solutions, the fair quantities, not introducing to porous ceramics, organic and containing carbon of components influential on ability to conduct an electricity, electrical strength, on occassion allow as the additional information to use a colour non-destructive testing “soft” ceramics of a type БГП, АБН. In an equal measure the learning macro both microstructures of ceramic bars and details, should be determined by the purposes and capability of identification of defects, as the preparation microschliffs for called ceramics is largely hindered.

The ultrasonic control of internal defects is possible(probable) only on ceramics БГП, have speed of distribution of ultrasound of 5000-5200 m\s, but is impracticable on ceramics АБН, have the smaller similar characteristic.

Because of data obtained at quality control of bars, the optimum modes of cutting heat-resistant керамик БГП and АБН were selected at machining on turning, milling and drilling machine tools for obtaining thin-walled, ajour of chambers - isolators, electrodes of a complex configuration without origin of defects of cutting.

The conclusion

- The developed test methods of ceramic bars at incoming control allow to determine a degree of a non-uniformity and quality of bars and to reduce probability of origin of defects at the consequent machining.
- Implementation of the not desroying control on thin-walled ceramic details from ceramics БГП, АБН after machining, reduce probability of detection of defects on late operations in a structure of subassembly and items as a whole, thereby reduce(descend) possible(probable) unforeseen costs at manufacturing of a ET MT.
- The accumulation of experience and data under the control of ceramic details from soft heat-resistant electroinsulation керамик by various methods can open new directions of their application such in atomic engineering, metallurgy, to special engineering.

The literature.

1. Тарасов А.Н., Калачаева М.С., Åâñèíà Å.Í. Technological features of manufacturing of êëåâíî-modular details from heat-resistant electroinsulation êåðàìèê for units of a ET ÌÒ and TYPE // Technology of metals. 1999, ¹ 2. Ñ. 9-13.

2. Òàðàñîâ А.Н., Черепова Ë.Â., Колина ETC. Technological features of the vacuum soldering of details of a ET MT from ceramics and precision alloys // Inhomogeneous designs. Transactionses Ural Îòä. WOUNDS. Ekaterinburg. 1999. Ñ. 150-153.

3. Тарасов А.Н., Òîìàøåâñêàÿ Â.Â., Колина ETC. An evaluation of a structural non-uniformity горячепрессованных áîðíèòðèäíûõ êåðàìèê //

Engineering, 2000, ¹ 6, Ñ. 28-31.

4. Преснов В.А., Ceramics and it junctions with metal., Àòîìèçäàò., Ì.1970. С. 187.

5. Строганов Ã. Á., Áðàòóõèí А.Г., Ðîìàøèí А.Г., Constructional(structural) ceramics: problems and perspectives // an Air industry. 1983. ¹ 9 Ñ. 3-8.

6. Patent of Russian Federation ¹ 2 127 236. A way êëåâíîñáîðíîãî of connection of ceramics and metal. M, Ê. È. Ñ. 4 In 37/02., БИ ¹ 7. 1999 (àâò. À.Í. Тарасов etc.)

7. Ñàâåíêî Â.È., Городецкий А.Е. The micrometric characteristics of new composite materials because of рекристаллизованного of graphite // Ìàòåðèàëîâåäåíèå. 1999, ¹ 9 Ñ. 29-33.

8. Bugs Ю.Н., Черепанов А.В., Áåêåòîâà À. Ð., Øàáàëèí È. Ë., Control of a non-uniformity of

ceramic bar for machining by measurement of hardness // a powder Metallurgy. 1991. ¹ 4. Ñ.102-104.

9. Клюев Â.Â., Ñîñíèí Ô.Ð., Eagle Owles B.H., Not Desroying control and diagnostics: Справочник.- Ì. Engineering, 1995. Ñ. 488.

10. Грушевский Я.Р., Ôðîëîâ Â. È., Øàáàëèí È. Ë., Чебрюков À.Â. Mechanical behaviour of ceramics containing nitride of a boron // a powder Metallurgy. 1991. ¹ 4., С. 102-104.

11. Frosts А.И. A space electric locomotive // a Science and life. 1999. ¹ 9 Ñ. 28-33.

12. Mikoszewski. J. Twardosciomierze, Bd 2, Warszawa, 1985, s.91.

13. Соловьёв Â.À., Яхонтова Â. Å., Îcíîâû of engineering of measurements., Изд. Ëåí. Ãîñ. University, Ë., 1980. Ñ.216.