Small-Size Electromagnetic Valves for SC's EPs[1,2].

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IEPC-01-319

EDB «FAKEL» is able to perform the closed cycle of manufacturing of electric propulsion systems (EPS) for spacecrafts (SC): propellant storage and supply systems (PSS), propulsion systems on the basis of stationary plasma thrusters (SPT) and thermal-electrocatalytic thrusters (TECT)). EDB "Fakel" has accumulated 30-year experience of EPS in-flight operation in structure Russian and foreign SCs.

The key parameters and characteristics of small-sized electromagnetic valves (EMV) produced by EDB «FAKEL» for EPS of SCs are considered in the report.

EMV are used in PSS of EPS of SCs. It is expedient for EPS of SCs of new generation to execute modernization of existing EMV models such as МЭК developed by EDB "Fakel" and used in propellant (xenon) supply systems with the purpose of increase of entrance pressure and lifetime resource by quantity of actuations, and for optimization of other parameters and characteristics.

Hence, the advanced EMV - small-sized КЭМ EMV has been developed by EDB «FAKEL».

At the same weight-dimensional parameters, as existing МЭК EMV, the operational pressure of the new valve has been increased from 30 up to 190 kilogram-force/sq.sm, and durability test pressure has risen from 60 to 290 kilogram-force/sq.sm.

EMV and SPT manufacturing is conducted on the basis of developed in EDB "Fakel" technologies.

During the lifetime testing of EMV propellant supply in structure of SPT it has been shown that they provide ~10^7-10^8 actuations without any change of the working parameters.

Their pilot-scale production in EDB «FAKEL» has allowed to improve quality and reliability of products at a reduction of 30-35 % of power-consuming and labor expenditures.

Nowadays, such alloys as 36НХТЮ, 36НХТЮ5М, 40ХЮ-ВИ using various technologies of forming and thermal processing are widely applied for manufacturing of elastic spring high-sensitivity elements of electromagnetic microvalves (EMV), membranes, contacts, leafed and disk spring elements for instrument making, electronics, and also of technological plasma sources (plasma-excitation source) elements and electric propulsion thrusters (EPT) [1-3]. The tapes of 0,08-0.5 mm thickness from preliminary tempered semi-finished rolled stock have high plasticity, corrosion-resistance, weldability and are used for manufacturing of complex configuration elements by methods of press forming, cutting down, electrochemically-physical cuttings, magnetic-discharge stamping. In this case, final ageing at temperatures of 600-740º is carried out in vacuum, argon, neutral atmospheres and is finished with fair polishing or electrochemical processing [3~5].

Some aspects of designing in EDB «FAKEL» of small-sized EMV and vacuum thermal processing of their details from precision steels and alloys are considered in the report with reference to EPS of SCs.

The special place in PSS of EPS SC is occupied by locking and regulating armature, and in particular, EMV. The existing EMV models application, for example EMV of a МЭК-type developed by EDB "Fakel" is impossible in

[1] Presented as Paper IEPC-01-000 at the 27th International Electric Propulsion Conference, Pasadena, CA, 15-19 October, 2001.

propellant (xenon) supply systems of SC's EPS of new generation without their appropriate modernization.

At the same weight-dimensional parameters, as existing EMV МЭК, the operational pressure of the new valve has been increased up to 190 kilogram-force/sq.sm, and durability test pressure has risen up to 290 kilogram-force/sq.sm. The valve tightness is provided by a valve pair with condensation by "metal on fluoroplastic" method. A screw spring is applied as an elastic element. Diameter of a conditional through passage section of the valve is ~ 0.25mm.

EMV manufacturing is conducted on the basis of EDB "Fakel" developed technology of vacuum annealing of elastic elements (membranes) made from 36 tape.

The researches aimed on perfection of technology of vacuum thermal processing of details from 36НХТЮ alloy in low-energy-consuming furnaces such as SNVL-0,8.0,5./9,5M and modernized SNOL-V-1,6.2,5.1./9I with a "hot" retort were carried out during the mastering of new generation EPT production process. The experiments have been conducted on membranes of the microvalves made of 36НХТЮ alloy tapes of 0,10-0,12 mm thickness. The chemical compound of a material of the tape used for manufacturing of membranes and samples for microhardness measurement and metallographic analysis is given in tab. 1.

Таблица 1

Sample material, thickness of a tape, mm	Contents of elements, % *						
	C	Si	Mn	Cr	Ti	Al	Ni
36НХТЮ; 0,12 (ГОСТ 14117-85)	0,03	0,41	0.78	12,20	2,76	0,97	35,41

 Sulfur and phosphorus contain within the limits of 0,005-0,01 %.

In all series of experiments, the samples and membranes have been processed by two comparative technologies: existing technology of ageing in large two-bell-type SGV-2.4./15M-2 furnaces with packing and fixing of details on massive metal pig-iron or corrosion-resistant steel equipment and new technology of heating in low-energy-consuming vacuum desktop furnaces with housing of details on BK-94-1 ceramics layer by layer, and also on lamellar heaters from the same ceramics. The scheme of details and samples adjustment at realization of experiences is given on fig. 1, while fig. 2 shows precision microvalve membranes made of 36НХТЮ alloy tape of 0,12 mm thickness by a method of magnetic-discharge stamping. Samples are placed on a polished BK-94-1 ceramics heating element before being carried in low-energy-consuming SNVL-0,8.0,5./9,5M furnace for ageing. The current-carrying contacts, the heating spiral geometry received by the method of current-carrying paste firing-on in ceramics and the membranes exposed to ageing in vacuum are visible on the picture received with x-ray unit and executed on PT-1 film.

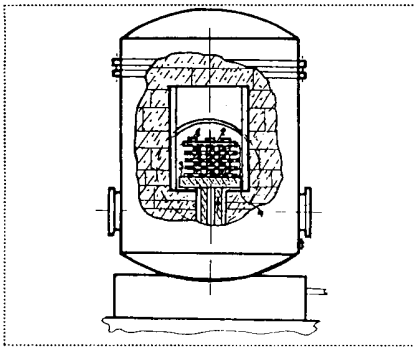


Fig 1. The scheme of 36НХТЮ alloy elements placing for ageing in BK-94-1 ceramic armature in low-energy consuming vacuum SNVL-0,8.0,5./9,5M furnace: 1 - elements: *2* - ceramic armature, *3* - a little table; *4* - current-carrying contacts.

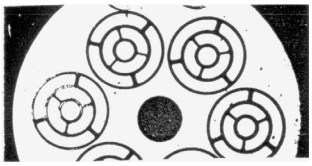


Fig. 2. 36НХТЮ alloy membranes at ageing in vacuum on ceramic heaters

All elements and samples used for researches of a microstructure, measurement of microhardness had been preliminary mechanically processed and membranes had been electropolished after cutting down, punching, forming. Vacuum ageing was carried out after measurement of initial hardness and non-flatness or deformations with respect to supporting base surfaces. Modes of thermal processing are given in tab. 2.

Таблица 2

Name, element manufacturing method	Temporary resistance (initial condition), MPa	Preparation for ageing on BK-94-1 ceramics; vacuum, Pa	Temperature, °C	Time, h	Cooling in furnace**
Membranes in diameter of 18 mm, tape of 0,12 mm; МИШ*	1220-1230	On heaters of 1,8 mm thickeness, 55 mm diameter; 13,3	640 660	4-5	SNVL-0.8.0,5./9,5M, 20-30 °C/from to 300 °C

* magnetic-discharge stamping on MIU-30 unit.

** Further cooling down to 60 °C in a furnace any way.

During microhardness measurement at 0,5 and 1,0 N loadings by PMT-Z device and hardness measurement by Vickers at 10 and 30 N loadings it was established, that vacuum ageing at 640-700°C temperatures for 2-4 hours practically provides precipitation hardening of elements made from 0,10-0,60 mm thickness tapes to the maximal hardness. At a rise in temperature of ageing up to 720-750 °C, insignificant decrease of hardness by 10~15% from the limit value, achievable for the given condition of whortleberry hardening at rolling of 36НХТЮ alloy, is observed in limits of heat range of the chemical compound.

On fig. 3, the change of microhardness and hardness by Vickers for two tapes with respect to a temperature of ageing is shown, given placing the samples on aluminum oxide vacuum-tight ceramic РК-94-1 plates. The values of microhardness measured at loadings of 0,5 and 1.0 N on membranes are by 20-25 units higher, than those at hardness measurement by Vickers at 10 N loading, that is connected to features of the microstructure of thin 36НХТЮ alloy tapes with a various degree of drawing. Integral values of hardness by Vickers allow to estimate a degree of ageing of thin-tape elements more objectively. Moreover, the influence of the structural factor on an estimation of hardness after vacuum ageing is simultaneously excluded.

The microstructure of the valve membrane made from 36НХТЮ alloy after ageing at 640 °C in vacuum in ceramic fixtures is shown on fig.4. In tab. 3 The results of hardness and nonflatness measurements of triple-leafed openwork membranes, as well as the values of microhardness of membranes after ageing SSHOL-, СНВЛ-, СНОЛ-, СНОЛ-ВНЦ furnaces by the new developed technologies are presented in table 3..

Таблица 3

Membrane material, thickness of a tape, mm	Roughness of a surface (before ageing) Ra a micron	Vaccum ageing method*	Micro-hardness	Non-flatness by membranes internal / external Micron
36НХТ10, 0,11	0.16-0,20	Metal fitting-out, печь СГВ furnace. 660 °C. 4 h	488-502	1-2 / 3-5
36НХТЮ, 0,12	0,12-0,20	On polished ceramics without heaters. СНВЛ furnace, 640 °C, 4 h	492	Отс. / 2-3
36НХТЮ, 0,12	0.20-0,32	On ceramic heaters, СНВЛ furnace, 660 °C, 2 h	480-501	Отс. / 1-2

*Installation of fixtures with samples:
in SGV-2.4/1 5-M2 furnace in the metal adaptation with wedge predeformation;
in SNVL-0,8.0,5/9,5M furnace between ceramic plates or heaters freely, without loading.

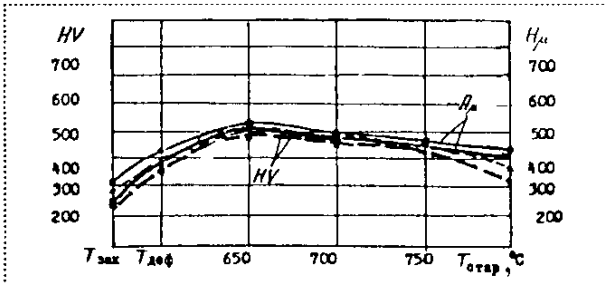
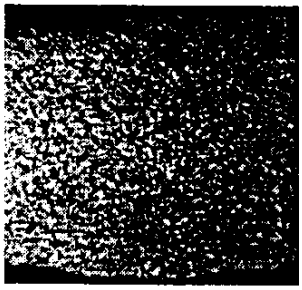


Fig. 3. Microhardness (Hμ) and hardness by Vickers HV change of elements made from 36НХТЮ tapes with respect to temperature of ageing in vacuum for 4 hours.

During the life-time resource tests of membranes in structure of PSS microvalves of EPT it was established, that fatigue strength of membranes after ageing in vacuum in ceramic heaters was not worse, than at ageing in metal adaptations in SGV furnaces. The number of cycles before destruction of crosspieces of membranes was 10^7-10^8 but with more stable tightness of valve seal for membranes aged in ceramic adaptations, in comparison to the ones processed using existing technology, that is connected to decrease of both thermal and structural deformation and better preservation of geometry of membranes.

Their pilot-scale production in EDB «FAKEL» has allowed to improve quality and reliability of products at a reduction of 30-35 % of power-consuming and labor expenditures of thermal processing given the conditions of small-scale production. /7/



Rice 4. Microstructure of membranes made from 36НХТЮ tape after vacuum ageing in SNVL-0,8.0,5./9,5M furnace on ceramic fixtures at 640°C (x100)

The list of the literature

1. Rahshtadt A.G. Spring steels and alloys. M.: Metallurgy. 1982.400p.
2. Rahshtadt A.G., Hovova O.M., Zhigalina O.M. The research of structure and properties of 36НХТЮ alloy after high-speed hardening//МиТОМ. 1996. N5. P. 2-7.
3. Precision alloys: The reference-book / Under edition. B.V.Molotilova. M.: Metallurgy. 1983. 439 p.
4. Slomjanskij G.A. Materials for elements and assemblies of aircraft instruments. M.: Mechanical engineering. 1964. 324 p.
5. Tarasov A.N., Panfilov V.A. The way of processing and manufacturing of curvilinear reflectors from 36НХТЮ//Pat. Of Russian Federation_N 2 052 512. БИ _N2.1996.
6. Tarasov A.N., Bober A.S. The way of thermal processing of elastic elements//Pat. The Russian Federation _2 093 589. БИ _N29. 1997.
7. A.N.Tarasov, V.A.Panfilov, A.G.Njatin. Feature of designing and vacuum thermal processing of elements of small-sized electromagnetic valves//Works of XXX Ural seminar " Heterogeneous structures". Ekaterinburg 2000. p 275-280