Analytical instrument engineering and technology

Аналитическое приборостроение и технологии

UDC 62-214.2
https://doi.org/10.32362/2500-316X-2022-10-2-35-42

RESEARCH ARTICLE

Application of an integrated method to improve the quality of manufacturing parts of electronic warfare devices

Anton V. Kryukov @

MIREA – Russian Technological University, Moscow, 119454 Russia
@ Corresponding author, e-mail: minyyc@yandex.ru

Abstract

Objectives. The development of technological methods with the purpose of increasing the structural strength of defense engineering products can be carried out by creating new methods for obtaining and processing parts or improving traditional methods based on an integrated (synergistic) approach. The article presents a complex method for surface treatment of parts and assessment of the hardness and surface roughness of the initial workpiece from alloys of the Al–Mg system to improve the quality of manufacturing the module cases of the *MSP-418K* product related to electronic warfare devices.

Methods. This approach consists in the vision of a metallic material as a system subjected to a chain of technological impacts in the process of chemical, thermodynamic, and mechanical interaction of its components. The workpieces were obtained by metal pressure treatment according to various schemes and temperature conditions Then they were processed with a blade tool using a dynamometer. The resulting cut was examined using a metallographic method along the entire end face from the outer surface to the center of the sample of workpieces.

Results. Experiments were carried out for the case of Al–Mg alloys. It made it possible to reveal the relationship between the parameters of the change in the structure of the material being processed and the stability of the cutting process, as well as the quality of the surface during finishing turning.

Conclusions. The proposed technological solutions based on a synergistic approach provided a balanced improvement in material parameters by eliminating the shortcomings of the original semi-finished product. The obtained experimental data allowed concluding the deformation of workpieces according to complex schemes at low temperature has a beneficial effect on the machinability of the metal material, ordering the structure and improving the quality of the surface of the parts. Using a synergistic approach, it became possible to correct the poor technological heredity of material properties obtained in previous operations: the surface quality of the workpieces due to the continuity of the processed material and the strength properties of parts for critical and especially critical purposes were improved. The existing technological process for manufacturing the "petal" part was changed in practice using an integrated method, which made it possible to improve its technological and technical characteristics.

Keywords: machinability, annealing, surface quality, cutting tool load, material structure, hot-rolled plates, extruded bar

• **Submitted:** 11.11.2021 • **Revised:** 08.12.2021 • **Accepted:** 01.03.2022

For citation: Kryukov A.V. Application of an integrated method to improve the quality of manufacturing parts of electronic warfare devices. *Russ. Technol. J.* 2022;10(2):35–42. https://doi.org/10.32362/2500-316X-2022-10-2-35-42

Financial disclosure: The author has no a financial or property interest in any material or method mentioned.

The author declares no conflicts of interest.

НАУЧНАЯ СТАТЬЯ

Применение комплексного метода для улучшения качества изготовления деталей приборов радиоэлектронной борьбы

А.В. Крюков @

ЦНИРТИ им. академика А.И. Берга, Москва, 107078 Россия
@ *Автор для переписки, e-mail: minyyc@yandex.ru*

Резюме
Цель. Разработка технологических приемов, направленных на повышение конструктивной прочности изделий оборонного машиностроения, может осуществляться с помощью создания новых способов получения и обработки деталей или улучшения традиционных приемов на основе комплексного (синергетического) подхода. В статье приводится комплексный метод обработки поверхности деталей, оценки твердости и шероховатости поверхности исходной заготовки из сплавов системы Al-Mg для улучшения качества изготовления корпусов модулей изделия МСП-418К, относящегося к приборам систем радиоэлектронной борьбы.
Методы. Данный подход заключался в видении металлического материала как системы, подвергаемой цепочке технологических воздействий в химическом, термодинамическом и механическом взаимодействии своих составляющих. Заготовки получали методом обработки металла давлением по различным схемам и в различных температурных режимах, затем обрабатывали их лезвийным инструментом с использованием динамометра и исследовали полученный рез металлографическим способом по всему торцу от наружного диаметра к центру образца.
Результаты. На примере Al-Mg сплавов проведены эксперименты, позволившие обнаружить зависимость между параметрами изменения структуры обрабатываемого материала и стабильностью процесса обработки резанием, а также качеством поверхности при чистовом точении детали.
Выводы. Предложенные технологические решения на основе синергетического подхода обеспечили сбалансированное улучшение параметров материала за счет устранения недостатков исходного полуфабриката. На основании полученных опытных данных сделан вывод о том, что проводимая деформация заготовок по сложным схемам при пониженной температуре благотворно влияет на обрабатываемость металлического материала, упорядочивание структуры и повышает качество поверхности деталей. При применении синергетического подхода есть возможность исправить плохую технологическую наследственность свойств материалов, полученную на предыдущих операциях; повысить качество поверхности заготовок за счет сплошности обрабатываемого материала; улучшить прочностные свойства деталей ответственного и особо ответственного назначения. Благодаря полученным результатам на практике подвергнут изменению существующий технологический процесс изготовления детали «лепесток», который позволил улучшить ее технологические и технические характеристики.

Ключевые слова: обрабатываемость, отжиг, качество поверхности, нагрузка на режущий инструмент, структура материала, горячекатаные плиты, прессованный пруток

• **Поступила:** 11.11.2021 • **Доработана:** 08.12.2021 • **Принята к опубликованию:** 01.03.2022

Для цитирования: Крюков А.В. Применение комплексного метода для улучшения качества изготовления деталей приборов радиоэлектронной борьбы. *Russ. Technol. J.* 2022;10(2):35–42. https://doi.org/10.32362/2500-316X-2022-10-2-35-42

Прозрачность финансовой деятельности: Автор не имеет финансовой заинтересованности в представленных материалах или методах.

Автор заявляет об отсутствии конфликта интересов.

INTRODUCTION

Electronic warfare (EW) is an armed struggle during which an effect of electromagnetic interference (EMI), also called radio-frequency interference (RFI), or jamming on the electronic means of enemy control, communication, and reconnaissance systems. Electronic warfare products are used to protect electronic equipment from exposure to powerful electromagnetic and acoustic radiation, as well as high-precision weapons equipped with passive homing devices for RFI sources. The use of selectively directed weapons against radioelectronic means (REM), as a rule, does not lead to catastrophic destruction and irreparable losses [1]. Such weapons deprive electronic devices of the possibility of normal, regular functioning. One of these products is the small jamming station *MSP-418K* (Fig. 1).

FIBER OPTIC WDM MULTIPLEXERS/DEMULTIPLEXERS WITH LOW FLEXURAL LOSS FACTOR

The station is designed to equip targets, aviation decoys, individual and individual-mutual protection of small-sized aircraft, for example, the *MiG29* and *MiG31* by creating deliberate active jamming of radioelectronic weapons controls (REWC), included in antiaircraft missile, antiaircraft artillery and aviation and missile systems. This station belongs to the means of radioelectronic countermeasures (REC) of the fifth generation, as it enables significant expansion of the combat capabilities of aviation.

The station ensures the simultaneous creation of deliberate targeted active interference to at least four REWCs, including homing radio heads (HRH), with their carrier frequencies separated by more than 100 MHz. Sensitivity in the operating frequency range at the input for a pulsed signal is no more than 51 dB W; for a continuous signal, a quasi-continuous signal, and a long (pulse) signal—no more than 68 dB W. The mass of the product is no more than 170 kg, the operating frequency range is from 4 to 18 GHz.

The *MSP-418K* station consists of several units, two switches *PK-1-2*, a set of cable assemblies *KKS L-281*, a set of low-frequency bundles *KNChZh L-281-1*, a set of attenuators *Kat L-281-1*, two sets of mounting parts *KMCh L-281-1*, as well as *KMCh*(*U*) *L-281-1*.

The product *L-281-1* is developed based on digital signal processing using digital radio frequency memory

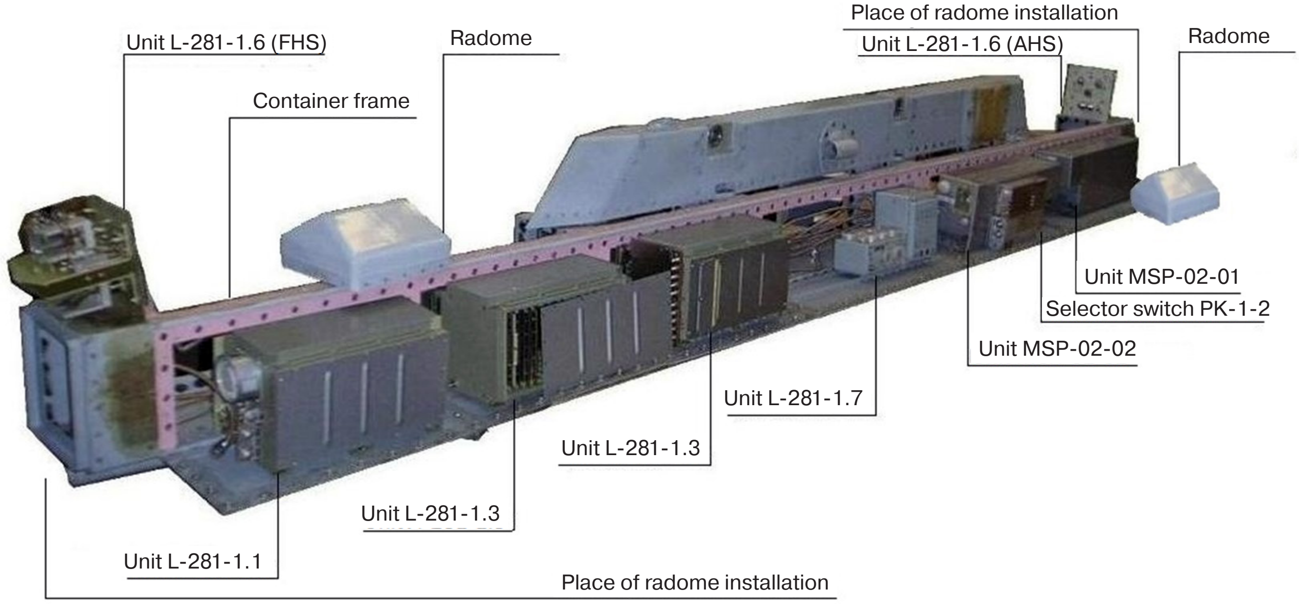


Fig. 1. Design of the small jamming station *MSP-418K*

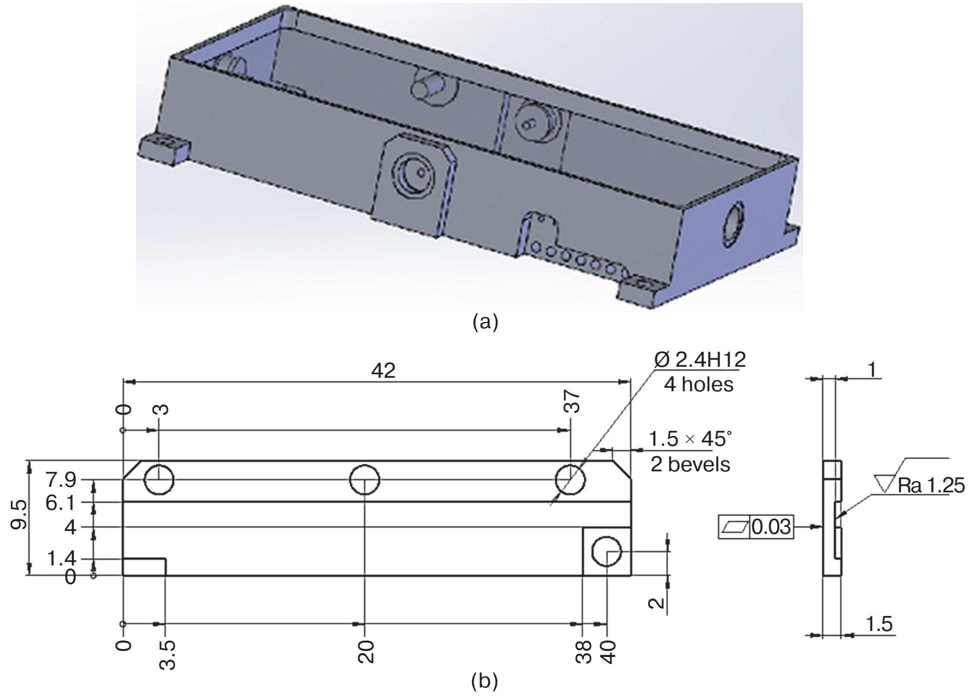


Fig. 2. Case model (a) and frame drawing (b) from steel *MD-40*

technology and is designed to counteract the REWC, operating in pulsed, continuous, pulse-Doppler, and long-pulse modes[1]. The station units include various standardized modules, which consist of a body and electronic filling, as well as typical standardized microassembly parts (Fig. 2).

These parts belong to the class of critical and especially critical applications. They provide vacuum tightness and geometric accuracy over the full-service life. At the same time, despite many years of manufacturing practice, a general cause of electrical breakdown and failure of their electronic filling are failures of the vacuum sealing of cases and failures of the geometry of microassembly parts [2].

The housings of microassemblies are made from hot-rolled plates based on aluminum alloys of the Al–Mg system (Fig. 3a). Their use is justified by the simplicity of the technological process[2, 3]. This does not take into account the high level of internal stresses in the material obtained during rolling (Fig. 3b), which are the higher, the greater the thickness of the plate [2, 3]. In addition, "lines" of intermetallic phases Mg_2Al_3 and Mg_5Al_{18} are formed in the structure of hot-rolled plates, and their appearance is especially pronounced in the zones of localization of deformations and discontinuity of their rates (Fig. 3c) [4].

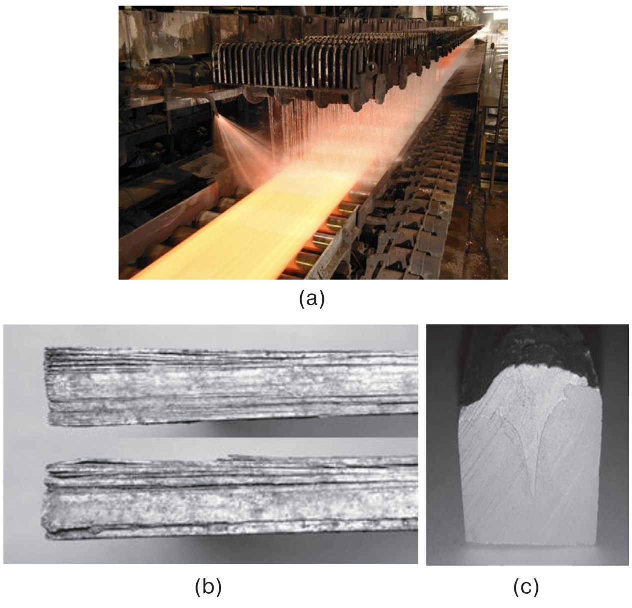


Fig. 3. The process of manufacturing microassembly cases from hot-rolled aluminum alloys of the Al–Mg system (a); result of plate delamination due to intergranular corrosion (b); a defect in the materials of the hot-rolled plate (c)

The loss of tightness of microassembly housings, as industrial practice shows [5], occurs due to "leakage through the material" of the housing (Fig. 4a),

[1] Compact JAMMER MSP-418K. *Zhurnal oboronno-promyshlennogo kompleksa*. 18.08.2009. URL: http://bastion-karpenko.ru/compact-jammer-msp-418k/. Accessed November 10, 2021 (in Russ.).

[2] GOST 17232–99. Aluminium and aluminium alloys plates. Specifications. Moscow: Izd. standartov; 2000. 10 p. (in Russ.).

[3] GOST 4784–97. Aluminium and wrought aluminium alloys. Grades. Moscow: Izd. standartov; 2001. 12 p. Edited (in Russ.).

(a) (b) (c)

Fig. 4. Types of damage to the surface of the housings due to "leakage through the material" of the housing (a); delamination of the coating of the base material (b) and "leakage along cracks" (c)

delamination of the coating from the base material (Fig. 4b) or "leakage along cracks" formed during the chemical nickel-plating of the body and cover of the microassembly before soldering (Fig. 4c). A number of works are devoted to this problem, for example, [6, 7], but they do not take into account the influence of the structure and properties of the material of these cases.

The article [7] considers a method for improving the quality of finished units' parts in the *MSP-418K* product by introducing an additional technological operation to optimize the structure of the starting material in the manufacture of radioelectronic warfare parts. This makes it possible to exclude the invariance of hereditary factors obtained in previous technological operations[4].

With an increase in the grain size, the tendency of the metallic material to destruction increases due to phase separation and thermal diffusion of the melt substances that leads to an increase in the number of defects and impurities displaced from the volume. Plastic deformation during rolling makes it possible to resist this process [8]. Workpieces that have undergone additional deformation are usually characterized by increased strength properties of the material. Depending on the requirements for the material of the workpiece, one of the recommended forging schemes is assigned and the temperature of heating the material before forging is selected.

MATERIALS AND METHODS

In the case of aluminum alloys of the Al–Mg system, experiments on using a complex technological process for manufacturing electronic warfare parts were conducted. The technological process includes forging the original bar workpieces according to various schemes of the All-Russian Research Institute of Aviation Materials, *VIAM* (State Scientific Center of the Russian Federation) [9, 10] and temperature parameters; stabilizing annealing of three forgings at 320°C in comparison with three forgings carried out at a temperature of 420°C for 1 h, followed by air cooling of each batch of forgings; processing of samples on a screw-cutting lathe; dynamometric and metallographic studies to measure the hardness and roughness of the treated surfaces of the samples.

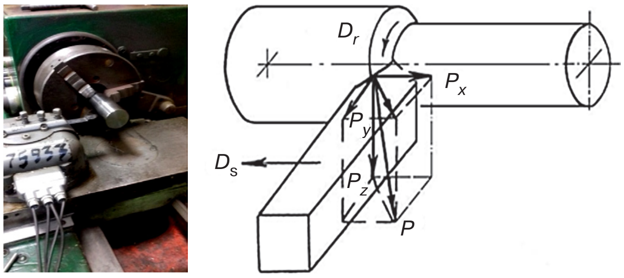
The manufacture of a part under different temperatures is necessary for increasing the strength properties of the material [11]. The number of defects and impurities in the initial material increases with the increase of grain size. Grain crushing during the forging process reduces the content of grain boundary impurities, making the material of the part more uniform and balanced in properties.

The temperature for stabilized annealing was chosen in accordance with *VIAM* recommendations. The recommended forging temperatures are 350–430°C [12]. However, based on previous studies, it was decided in the experiment to set the forging temperature at the upper and lower values: 420°C and 320°C, respectively.

The studies were performed with six forgings (samples No. 1–6) with dimensions Ø70 × 140 mm; the results were compared with the original material of the workpiece (pressed rod) with dimensions Ø70 × 120 mm, (sample No. 0). The permissible degree of deformation during forging on the "hammer" of forging and pressing equipment was 50% [11]. In an electric muffle furnace (SNOL), the workpiece (samples No. 1–3) was heated to a temperature of 420°C, and samples Nos. 4–6 were heated to a temperature of 320°C. The draft was up to 60 mm.

After stabilized annealing, the samples were machined on a *16K20* screw-cutting lathe using a dynamometer (Fig. 5a). Figure 5b shows that when turning along the generatrix (diameter) and along the end face of experimental samples, the load force on the cutting tool (cutter) is distributed over three coordinates: P_x is the feed force, P_y is the radial force, and P_z is the cutting force [7].

[4] Kovka i shtampovka deformiruemykh alyuminievykh splavov: Proizv. Instruktsiya (Forging and stamping of wrought aluminum alloys: Prod. Instruction) PI 1.2.085–78. [Approved VIAM]. 01.09.1978. 17 p. (in Russ.).



(a) (b)

Fig. 5. General view of the *16K20* screw-cutting lathe with an automated dynamometer *UDM 600* (a); schematic description of the distribution of the load force on the cutter during the processing of samples on a screw-cutting lathe (b)

RESULTS AND DISCUSSION

The dynamometric method of research showed that the distribution of load forces in the cutting tool (cutter) during the treatment of samples in three coordinates corresponds to their classical relationship: the value of the feed force P_x varies from ⅛ to ¼, and the radial force P_y—from ¼ to ½ of the cutting, P_z. Comparison of experimental, mechanically turned samples (Fig. 6a) with the original bar (Fig. 6b) showed that when machined samples with the same oriented structure in the material are obtained by forging operations, it is possible to ensure the lowest roughness of the machined surface. This is because a more effective dynamic damping of vibrations during cutting is achieved by a large dissipative resistance force of the material of the workpiece with a texture of the deformed metal oriented in different directions.

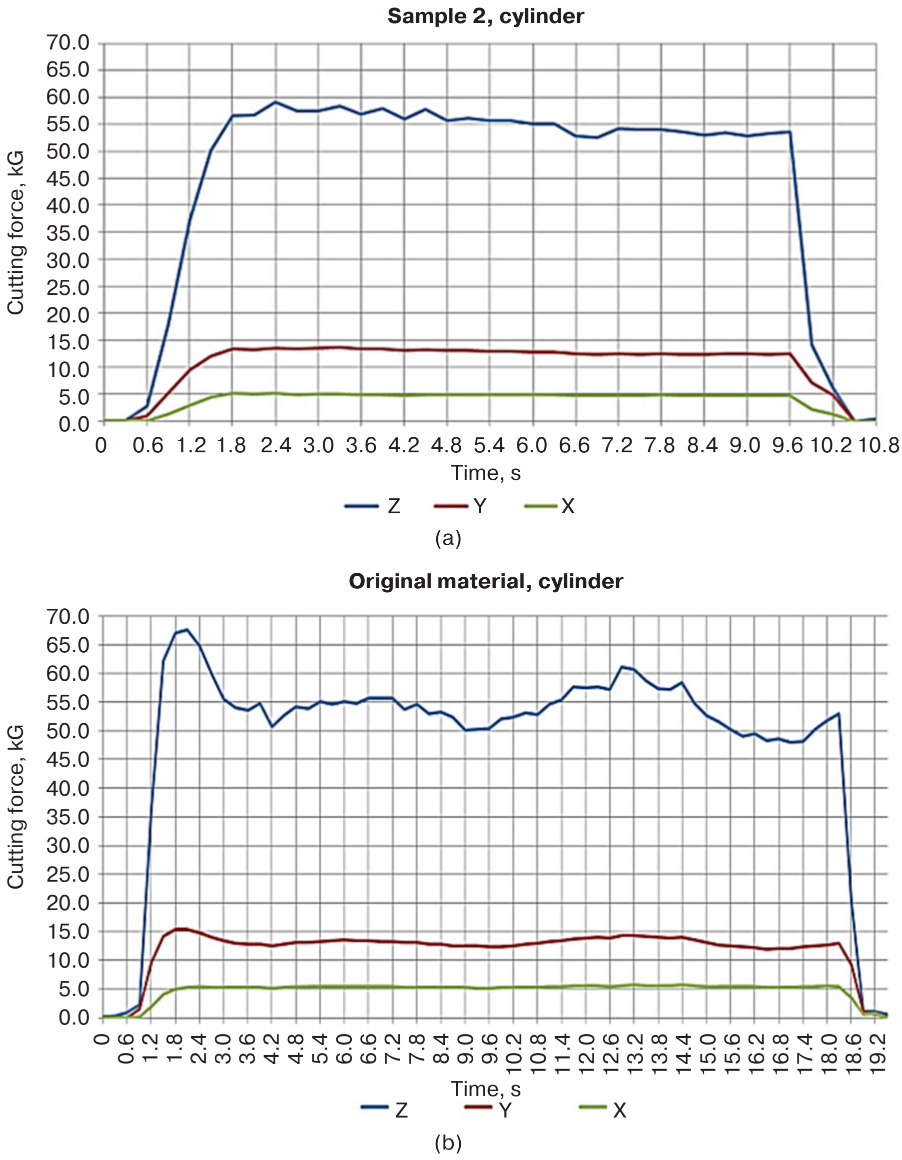
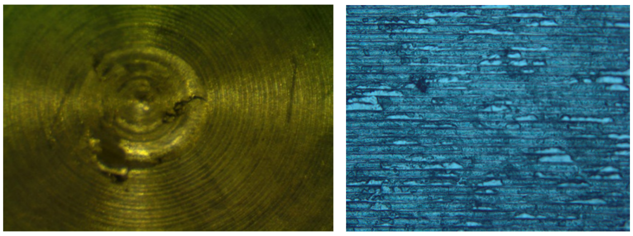


Fig. 6. The surface roughness distribution of the experimental forgings (a) and the original billet (b)

A comparison of the microstructure and roughness (texture) of the surface of the original workpiece showed that the coincidence of the grain size and the magnitude of the force of removal and feed of the tool leads to tearing in the material of the original workpiece and sticking of the material to the cutter (Fig. 7a). In this case, pull-out usually occurs at the triple junctions of grains, where there are places of accumulation of impurity phases [13].



(a) (b)

Fig. 7. The surface of the original workpiece with material tearing out during turning and machining and chips on its surface (a); the surface obtained after forging with interlayers of inclusions (b)

At the same time, an increase in the density and hardness of the material of workpieces facilitates chip flow and improves the quality of their surface after turning (Fig. 7b). Elongated non-metallic inclusions located along the cut boundaries are weakly bound to the metal matrix or differ sharply from it in terms of elastic characteristics. Microscopic metal discontinuities near the boundaries of non-metallic inclusions are located differently in relation to the external force applied during the turning process. All these imperfections (interlayers of inclusions) enhance the dissipation of vibration energy during the turning and machining of experimental samples after forging.

We can draw some conclusions analyzing the magnitude and nature of the loads on the cutter during turning along the generatrix and along the end of the original bar and experimental forgings, as well as the roughness (texture) of the machined surface and the hardness of the material of the machined workpieces at various points.

First, the load force on the cutter increases with an increase in the forging and a decrease in the deformation temperature. In this case, the force becomes kinematic (uniform) in comparison with the machining of the original material of the workpiece.

Secondly, forging according to complex schemes at low temperatures not only improves the characteristics of the vacuum tightness and corrosion resistance of the metal material, but also reduces the roughness of the machined surface of the samples. On the contrary, the smaller the deformation reduction achieved, the larger the grain of the material and the chains of intermetallic phases, as well as the softer the sample material and the rougher its surface after machining with a blade tool on a screw-cutting lathe.

CONCLUSIONS

The paper presents a complex method for improving the quality of manufacturing electronic warfare parts based on alloys of the Al–Mg system. Machining the workpiece under conditions providing its uniform deformation makes it possible to obtain a balanced set of technological and special properties. Good machinability and surface quality of workpieces by cutting are achieved via increased hardness of the material of the workpiece, and at the same time via critically important for a number of parts increased resistance of the material to development of corrosion processes and its vacuum tightness.

Manufacturing the microassembly body from a workpiece obtained according to the complex forging scheme ensures uniform deposition of a nickel coating with a minimum level of tensile stresses formed in the surface layer of the workpiece material.

REFERENCES

1. Dobykin V.D., Kupriyanov A.I., Ponomarev V.G., Shustov L.N. *Silovoe porazhenie radioelektronnykh sistem* (*Force defeat of radio-electronic systems*). Moscow: Vuzovskaya kniga; 2007. P. 10–16 (in Russ.).
2. Khadi O.Sh., Litvinov A.N. Simulation of the stress-strain state of microassembly housings during their manufacture and operation. In: *Dynamics and strength*. Proceedings. Moscow: Ross. Akad. Nauk; 2013. P. 3–26 (in Russ.).
3. Golovkin P.A., Fesenko S.A., Kryukov A.V. Deformation mechanism control as a tool to improve the quality of titanium alloy forgings. In: *Progressive developments of scientists – new products of rocket and space technology*. Collection of scientific papers; 2013. P. 189–194 (in Russ.).

СПИСОК ЛИТЕРАТУРЫ

1. Добыкин В.Д., Куприянов А.И., Пономарев В.Г., Шустов Л.Н. *Силовое поражение радиоэлектронных систем*. М.: Вузовская книга; 2007. С. 10–16.
2. Хади О.Ш., Литвинов А.Н. Моделирование напряженно-деформированного состояния корпусов микросборок в процессе их изготовления и эксплуатации. В сб.: *Динамика и прочность*. Избранные труды Всеросс. научн. конф. по проблемам науки и технологий. М.: РАН; 2013. С. 3–26.
3. Головкин П.А., Фесенко С.А., Крюков А.В. Управлением механизмами деформации как инструмент повышения качества поковок из титановых сплавов. В сб.: *Прогрессивные разработки ученых – новым изделиям ракетно-космической техники*. Сб. научн. трудов. 2013. С. 189–194.

4. Stepanov V.G., Klestov M.I. *Poverkhnostnoe uprochnenie korpusnykh konstruktsii* (*Surface hardening of hull structures*). Leningrad: Sudostroenie; 1977. 197 p. (in Russ.).
5. Dal'skii A.M., Bazrov B.M., Vasil'ev A.S. *Tekhnologicheskaya nasledstvennost' v mashinostroitel'nom proizvodstve* (*Technological heredity in machine-building production*). Moscow: MAI; 2000. 360 p. (in Russ.). ISBN 5-7035-2322-2
6. Gorenskii B.M., Lapina L.A., Lyubanova A.Sh., et al. *Modelirovanie protsessov i ob"ektov v metallurgii* (*Modeling of processes and objects in metallurgy*). Krasnoyarsk: Siberian Federal University; 2008. 145 p. (in Russ.). ISBN 978-5-7638-1266-4
7. Litvinov A.N., Khadi O.Sh. Estimation of the accuracy of an approximate method for determining the allowable pressure for microassembly bodies. In: *Actual problems of modern mechanical engineering.* Proceedings of the Intern. scientific and practical. conf. Tomsk: Tomsk. politekh. inst.; 2014. P. 191–194 (in Russ.).
8. Kishkina S.I., Fridlyander I.N. (sci. eds.). *Aviatsionnye materialy*: spravochnik v 9 t. T. 4. *Alyuminievye i berillievye splavy*. Chast' 1. *Deformiruemye alyuminievye splavy i splavy na osnove berilliya* (*Aviation materials*: a reference book in 9 v. V. 4. *Aluminum and beryllium alloys*. Part 1: *Wrought aluminum alloys and beryllium-based alloys*). Moscow: VIAM; 1982. 628 p. (in Russ.).
9. Amosov I.S., Skragan V.A. *Tochnost', vibratsii i chistota poverkhnosti pri tokarnoi obrabotke* (*Accuracy, vibration and surface finish in turning*). Anserov M.A. (Ed.). Leningrad: Mashgiz; 1958. 91 p. (in Russ.).
10. Teleshov V.V., Churyumov A.Yu. Analysis of the influence of the characteristics of a two-phase matrix structure on the fracture toughness of wrought aluminum alloys. *Tekhnologiya legkikh splavov = Technology of Light Alloys*. 2012;2:22–40 (in Russ.).
11. Golovkin P.A. Improving the microassamblies cases quality of the electronic microwave devices be using forging operations. *Tekhnologiya mashinostroeniya*. 2020;9:5–7 (in Russ.).
12. Kryukov A.V., Volkov A.V., Golovkin P.A., Galkin V.I. Improving the quality of microwave electron microwave instruments – detailed at optimization of structural changes. *Vestnik RAEN = Bulletin of the Russian Academy of Natural Sciences*. 2019;19(3):36–41 (in Russ.).
13. Verbovoi F.P., Kalugin A.A., et al. Dependence of the quality of forgings from the $AlMg_6$ alloy on the initial billet and the magnitude of the deformation during forging. *Alyuminievye splavy i spetsial'nye materialy* (*Aluminum alloys and special materials*). *Sb. trudov. VIAM = Proceedings of VIAM*. 1975. V. 9.

4. Степанов В.Г., Клестов М.И. *Поверхностное упрочнение корпусных конструкций*. Л.: Судостроение; 1977. 197 с.
5. Дальский А.М., Базров Б.М., Васильев А.С. *Технологическая наследственность в машиностроительном производстве*. М.: Изд-во МАИ; 2000. 360 с. ISBN 5-7035-2322-2
6. Горенский Б.М., Лапина Л.А., Любанова А.Ш. и др. *Моделирование процессов и объектов в металлургии*. Красноярск: Сибирский федеральный университет; 2008. 145 с. ISBN 978-5-7638-1266-4
7. Литвинов А.Н., Хади О.Ш. Оценка точности приближенного метода определения допустимого давления для корпусов микросборок. В сб.: *Актуальные проблемы современного машиностроения*. Сборник трудов Междунар. научно-практ. конф. 11–12 декабря 2014 г. Юргинский технологический институт. Томск: Изд-во Томского политехнического университета; 2014. С. 191–194.
8. Кишкина С.И., Фридляндер И.Н. (науч. ред.). *Авиационные материалы*: справочник в 9 т. Т. 4. *Алюминиевые и бериллиевые сплавы*. Часть 1. *Деформируемые алюминиевые сплавы и сплавы на основе бериллия,* Кн. 1. М.: ВИАМ; 1982. 628 с.
9. Амосов И.С., Скраган В.А. *Точность, вибрации и чистота поверхности при токарной обработке*; под общ. ред. М.А. Ансерова. Л.: Машгиз; 1958. 91 с.
10. Телешов В.В., Чурюмов А.Ю. Анализ влияния характеристик двухфазной матричной структуры на вязкость разрушения деформируемых алюминиевых сплавов. *Технология легких сплавов*. 2012;2:22–40.
11. Головкин П.А. Повышение качества корпусов микросборок электронных СВЧ-приборов с использованием ковочных операций. *Технология машиностроения*. 2020;9:5–7.
12. Крюков А.В., Волков А.В., Головкин П.А., Галкин В.И. Повышение качества корпусов микросборок электронных СВЧ-приборов за счет оптимизации структурных изменений. *Вестник РАЕН*. 2019;19(3):36–41.
13. Вербовой Ф.П., Калугин А.А. и др. Зависимость качества поковок из сплава $AlMg_6$ от исходной заготовки и величины деформации при ковке. *Алюминиевые сплавы и специальные материалы. Сб. трудов. ВИАМ*. 1975. Вып. 9.

About the author

Anton V. Kryukov, Process Engineer, Academician A.I. Berg Central Research and Development Institute (20-9, Novaya Basmannaya ul., Moscow, 107078 Russia). E-mail: minyyc@yandex.ru. https://orcid.org/0000-0001-9840-1408

Об авторе

Крюков Антон Вячеславович, инженер-технолог, АО «ЦНИРТИ им. академика А.И. Берга» (107078, Россия, Москва, ул. Новая Басманная, д. 20, стр. 9). E-mail: minyyc@yandex.ru. https://orcid.org/0000-0001-9840-1408

Translated by E. Shklovskii
Edited for English language and spelling by Q. Scribner, Awatera