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# STRENGTHENING OF EXPANDERS FOR TUBE PROFILE PRESSES FOR THE PRODUCTION OF CORROSION-RESISTANT TUBES BY LIQUID CARBONITRIDING

*L.M. Deyneko[1], L.S. Kryvchyk[1], V.L. Pinchuk[1], O.S. Baskevych[1]*
*A.V. Panchenko[2], A.O. Taranenko[1]*
*[1]Ukrainian State University of Science and Technology, Dnipro, Ukraine*
*[2]Sumy State University, Sumy, Ukraine*
*E-mail: udunt@diit.edu.ua; info@sumdu.edu.ua*

In the creation of competitive products at the stage of technological development, one of the most important tasks of applied science is the development of new materials for advanced products and technologies for their strengthening. One of the types of hot metal deformation is hot pressing. It is widely used for the manufacture of products from many steels and alloys that are difficult to deform. With the development of production in various industries, a large number of varieties of the pressing process have emerged, and the number of alloys being pressed has sharply increased. Another most important advantage of pressed products is that they can be made in such a complex configuration that cannot be obtained by other methods of pressure processing or even cutting. The most widespread application of pressing is for the production of tubes from low-plasticity steels and alloys. The quality of tubes obtained by pressing is largely determined by the durability of the tool [1]. Blanks made of high-alloy steels are subjected to through drilling before pressing and, in some cases, expansion. The expansion process is used in the production of tubes from high-alloy steels because piercing them is difficult and leads to increased wall thickness variation. The expansion of the blank is carried out by an expander, with a piercing needle coaxially fixed at the front end of the expander, the length of which is 1.2–3.0 times the length of the drilled blank. Steels for hot pressing tools have prolonged contact with hot metal, and the working tool operates under conditions of high temperatures, intense sliding speeds, and significant specific pressure, which necessitates the use of high-alloy heat-resistant tool steels with increased toughness and strength as the material [2]. The article proposes and justifies the use of liquid carbonitriding after quenching and tempering of tool die steel 4X4VMFS for the manufacture of expanders for tube profile presses with the aim of increasing the strength, wear resistance, and operational durability of tube pressing tools for the production of tubes from corrosion-resistant high-alloy steels.

## INTRODUCTION

The production of steel tubes by pressing is carried out on tube pressing units with a vertical mechanical press (VMP) or a horizontal hydraulic press (HHP). Hydraulic presses can be of vertical and horizontal design. On a horizontal hydraulic press, only the operation of pressing tubes from sleeves obtained by piercing on vertical presses or drilling and subsequent expansion is performed. The process of tube manufacturing includes two operations: piercing the blank and pressing the sleeve into a tube. These operations can be performed separately in two sequentially installed presses – piercing and tube profile or combined in one press [3].

Expansion allows the use of longer blanks than in piercing (the ratio of the length of the blank to its diameter in expansion can reach 10–11, while in piercing it does not exceed 6–8), which increases the productivity of presses, but increases the labor intensity of production due to the introduction of the operation of through-hole drilling in the blank. For the expansion of drilled sleeves, mandrels of a special shape are used, one of which is shown in Fig. 1.

The surface of the pressing tool experiences specific pressure, the level of which approaches the strength limit of the material from which the tool is made. The following parameters of the temperature regime of the tool operation have the greatest influence on the state of the working surface:

– the temperature of the working surface, which determines the mechanical fluctuations of the temperature on the surface, causing the processes of thermal fatigue and tempering;

– the depth of temperature penetration, when the tool deforms under the influence of external loads. When pressing steels, the surface of expanders can heat up to 800…850 °C, and the zone of maximum strengthening is located at a depth of 2…9 mm. After such heating, three main zones are formed in the metal cross-section;

– the surface zone, which is slightly etched, where secondary hardening occurs, and its hardness is higher than the initial one, i.e., in the working layer of the matrix, carbides dissolve more intensively, and in the structure of the secondary hardened layer with pronounced needle-like structure, the second phase is absent;

– the zone of increased etching, where the temperature is higher than the tempering temperature but below the critical one;

– the zone of the base metal, not subjected to temperature influence. Various methods are used to reduce the depth of weakening: the use of heat-resistant steels, changing the pressing speed, selecting lubricants, strengthening the working surface, etc. [4].

Operating conditions of expanders: heating the blank before piercing, installing the expander on the needle, piercing the blank. The durability of the expander is 100 cycles.

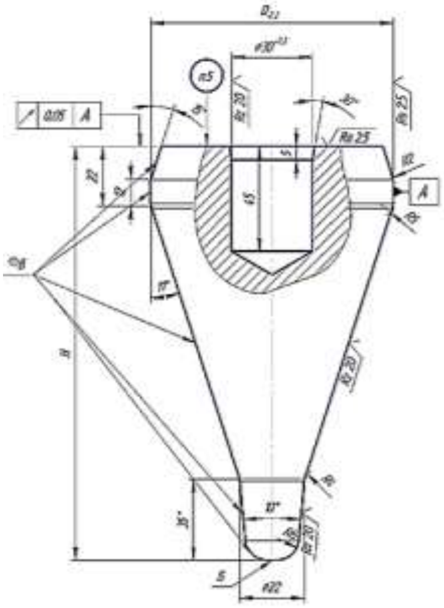

*Fig. 1. Expander for pressing corrosion-resistant tubes*

Types of failures:

– deformation of the outer surface;

– cracking;

– longitudinal holes.

One of the main reasons for the failure of expanders is the development of thermomechanical fatigue processes, which lead to the appearance of a network of “tempering” cracks (Fig. 2).

Taking into account the operating conditions, the following requirements are imposed on the material: high heat resistance; toughness; high tempering resistance; wear resistance; heat resistance; high thermal conductivity [5].

Therefore, die steels must have:

– high heat resistance, ensuring the necessary resistance to plastic deformation of the working surface of the die when heated. It is characterized by the temperature at which the yield strength remains not lower than 900…1000 MPa, since specific loads during hot stamping reach 800…900 MPa, as well as by the heating temperature after which the steel retains a hardness of HRC 40–50;

– high resistance to tempering; it is better the higher the toughness and thermal conductivity;

– resistance to interaction with the material, as well as scale resistance.

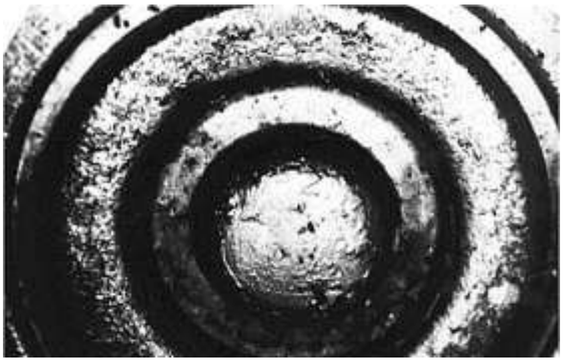

*Fig. 2. Surface of tempering cracks [4]*

The heat resistance of die steels is created by complex alloying with chromium, molybdenum, tungsten, and vanadium [6]. The chemical composition and purpose of the main grades of die steels are regulated by DSTU 3953-2000.

Steel 4X4VMFS (DI-22) is a steel of increased heat resistance and toughness. It is the most widely used steel for most hot deformation tools, die-casting molds, and tube pressing tools for horizontal presses (matrix rings of complex matrices, mandrels, expanders, bushings). Its distinctive feature is the increased content of carbide-forming elements (chromium, molybdenum, tungsten, vanadium). Due to this, steel 4X4VMFS (DI-22) has higher heat resistance, strength at operating temperatures, than steels 5XNM and X40CrMoV5-1 [7].

The hardening temperatures of heat-resistant steels are chosen based on the conditions for obtaining the highest hardness while maintaining a sufficiently fine austenite grain, which ensures a better combination of operational properties. The chemical composition of the steel is given in Table 1.

Table 1

Chemical composition of steel 4X4VMFS, % by weight (DSTU 3953-2000), AISI 4140 (USA)

| C | Si | Mn | Cr | V | Mo | W | Ni | Cu | S | P |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | no more | | | | |
| 0.37 | 0.6 | 0.20 | 3.2 | 0.6 | 1.20 | 0.8 | 0.6 | 0.30 | 0.03 | 0.03 |

Foreign analogs of steel 4X4VMFS are steels 30WCrV17-2, 45WCrV7, X30WCrV5-3, X30WCrV9-3, X40CrMoV5-1 (DIN, WNr – Germany), SKD62 (JIS – Japan), H12, T20812 (USA). The distinctive feature of steel 4Х4ВМФС compared to moderately heat-resistant steels is the increased content of carbide-forming elements (chromium, molybdenum, tungsten, vanadium) at 0.3…0.4% C. Due to this, it has approximately equal values of toughness, but higher heat resistance, strength at operating temperatures, and wear resistance than 5XHM, 5XH [8].

To obtain higher resistance to wear and deformation, the tool is hardened from elevated temperatures to obtain austenite grain No. 7, 8 in the metal of the tool. The recommended hardness values after hardening and tempering of the steel are given in Table 2.

Table 2

Recommended hardness values after hardening and tempering of tools made of steel 4X4VMFS

| Steel | Hardening | | Tempering vacation, °C | | Heat resistance, HRC, °C |
|---|---|---|---|---|---|
| | | | 1 | 2 | |
| | Heating temperature, °C | Hardness, HRC | 620…630 | 640…650 | |
| 4X4VMFS | 1070…1080 | 55–60 | 48…50 | 44…46 | 660 |

The traditional modern technology for strengthening pressing and stamping tools made of semi-heat-resistant die steels is high-temperature hardening with tempering. The goal of the final heat treatment is to obtain an optimal combination of basic properties in the finished tool: hardness, strength, wear resistance, toughness, and heat resistance.

Hardening is carried out to dissolve a significant part of the carbides and obtain high-alloy martensite. Therefore, the hardening temperatures are elevated and are limited only by the need to maintain fine grain and sufficient toughness [9].

For heating under hardening and tempering, salt baths are most often used. The widespread use of salt baths in various heat treatment operations is explained by the advantages that molten salts have compared to other heating and cooling media. These include high speed and uniformity of heating, high accuracy of temperature control, and protection of the surface from direct exposure to air. The heating rate in salt baths is 4–5 times higher than in flame furnaces. Molten salts protect the tool from direct exposure to air oxygen and reliably protect them from oxidation. When deoxidizers are introduced into the composition of salts during heating in baths, decarburization of the surface layers of the metal of the tool can be avoided [10].

In salt baths, chlorides of sodium, potassium, and barium are most often used, and as deoxidizers – borax, ferrosilicon, silica, magnesium fluoride, etc.

Preheating the tool to 800… 850 °C during heating for hardening is necessary to prevent cracking due to the low thermal conductivity of die steels. Preliminary heating in a bath of composition $BaCl_2$ – 70%; KCl – 27%, $MgF_2$ – 3…5%.

The preheating temperature is $850^0$C, holding time is calculated as 30 s per 1 mm of the maximum cross-section of the tool plus 1.5…2 min for temperature equalization across the cross-section. Cooling from austenitizing temperatures is carried out in oil M3 – M16 with heating to 50…70 °C or in a polymer medium. Tempering is carried out in salt baths: medium-temperature salt composition: KCl – 50%, $Na_2CO_3$ – 50% or low-temperature composition NaOH – 100%; double tempering. The temperature of the first tempering is 620…630 °C. Holding time is not less than 30 min; cooling in air; the temperature of the second tempering is 560…580 °C. Holding time is not less than 30 min. Cooling in oil M3 – M16, with heating to 50…70 °C. After grinding, the tool is tempered at 140…160 °C for 2…3 h with cooling in oil M3 – M16. The structure of the steel after hardening and tempering is tempered martensite – alloyed α-solid solution, rich in carbon and alloying elements [11]. In the general mass of the structure, there are inclusions of special carbides that did not dissolve in austenite during heating for hardening (Fig. 3).

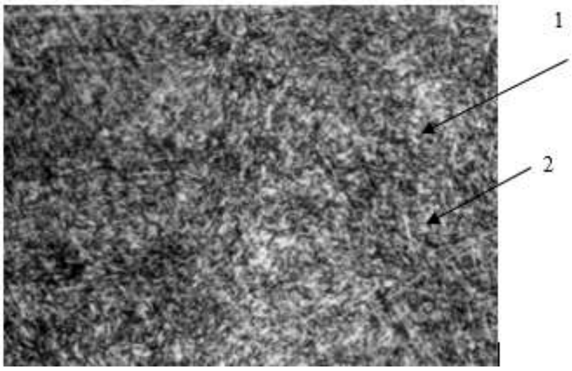

*Fig. 3. Microstructure of steel 4X4VMFS after hardening from 1070 °C and tempering at 620…630 °C (1st tempering), 560…580 °C (2nd tempering) (tempered martensite (1) and carbides (2), × 500*

The mechanical properties of the tool metal are given in Table 3.

The most effective method of strengthening pressing and stamping tools is their chemical-thermal treatment. For this, the most effective process is considered to be nitriding, when the predominant type of tool wear is the tempering of the surface layer of the metal under conditions of cyclic thermal and force influence [12].

Table 3

Mechanical properties of steel 4X4VMFS at T=20 °C

| Assortment | $\sigma_в$, МПа | $\sigma_T$, МПа | $\delta_5$, % | ψ, % | KCU, кДж/м$^2$ | Heat treatment |
|---|---|---|---|---|---|---|
| Sort | 1700 | 1500 | – | – | 440 | Hardening 1070…1080 °C, oil,<br>1 vacation 620…630 °C, 2 vacation 560…580 °C |

The essence of the liquid carbonitriding process is that the tool, after conventional heat treatment (for example, hardening and tempering), final machining to working dimensions (grinding, polishing, etc.), is subjected to heating for surface saturation with nitrogen and carbon in an active bath at the optimal temperature for each type of product and with different holding times at the specified temperature. This process is widely known worldwide under the general name – salt bath ferritic nitrocarburizing. According to RD 50 – 186 – 80, carbonitriding is also called liquid nitriding, and the diffusion layer obtained on the surface of the metal product has an identical structure and composition. Therefore, the complex of physical and mechanical properties of the products is identical, both in gas (traditional well-known process) and in liquid carbonitriding. However, carbonitriding in molten salts has a number of advantages over traditional gas nitriding, which is usually carried out in an ammonia environment. Due to this, this nitriding method has gained wide popularity in Europe, America, and around the world [13].

The method of carbonitriding consists of saturating the surface of products with nitrogen and carbon in a synthesized melt of potassium dicyandiamide and potash salts at a temperature of 540…580 °C. In terms of energy consumption and technical results, this method is significantly better than such surface strengthening methods as gas nitriding, cyaniding, boriding, laser hardening, etc. [14]. The main advantages of carbonitriding include the short duration of the process, simplicity of equipment (low-temperature furnace, made in the form of a bath), universality of this method of chemical-thermal treatment, and low processing cost. Compared to solid and gas cyaniding processes, it should also be noted that there is less deformation of products during carbonitriding due to the reduced processing temperature. The process is carried out at a temperature of 540…600 °C, holding time of 4…6 h, layer thickness of 0.12…0.4 mm [15]. The process consists of the diffusion saturation of the tool surface with nitrogen and carbon simultaneously. To impart corrosion properties to carbonitrided products, it is recommended to carry out the oxidation process in a nitrite-alkaline melt at 350…400 °C. The method of carbonitriding followed by oxidation has been named the "NOC process" (low-temperature oxycarbonitriding) [16]. After carbonitriding, a strengthened layer is formed on the surface of the tool, consisting of several zones (the upper layer is ε-carbonitride of the $Fe_3(NC)$ type, below which is the γ′-phase zone of the $Fe_4(NC)$ type, below which is the diffusion zone (heterophase layer), which consists of a solid solution of carbon and nitrogen in iron with inclusions of carbonitride phases, the hardness of which is significantly higher (Fig. 4) than the hardness of the core [17].

Nitrogen and carbon present in the carbonitrided layer slow down the processes of transformation of solid solutions and coagulation of carbonitride phases, as a result of which the high hardness of the carbonitrided layer is maintained up to temperatures above 650 °C, and the intensive cooling of the tool after each pressing cycle contributes to the preservation of the carbonitrided layer and its properties during further operation [18].

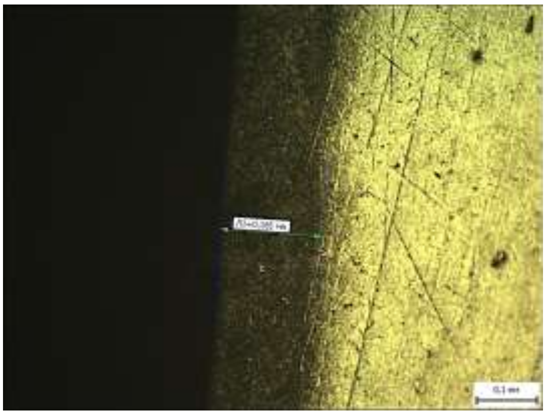

*Fig. 4. Macrostructure of the cross-section of steel 4X4VMFS after carbonitriding, × 500*

The sequence of operations during carbonitriding: preliminary preparation – cleaning, washing, degreasing; heating the parts to a temperature of 350…400 °C; then carbonitriding is carried out (570…590 °C) in a melt of cyanate and carbonate salts of alkali metals, cooling in air to 350…400 °C, oxidation in an alkaline melt at 350…400 °C for 0.5 h, and subsequent cooling in air to room temperature [19].

The graph of the carbonitriding mode is shown in Fig. 5.

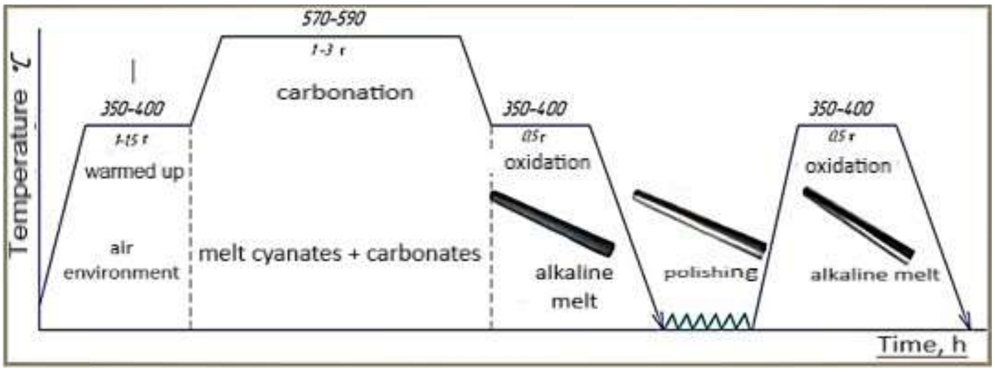

*Fig. 5. Graph of the carbonitriding mode [20]*

The purpose of this work is to study the structure and properties of steel 4X4VMFS after combined heat treatment, which consists of hardening with double tempering followed by liquid carbonitriding (combined with the third tempering).

## RESEARCH METHODOLOGY

In the work, expanders of a tube pressing unit with a force of 16 MN in the amount of 3 (three) pieces made of steel 4X4VMFS with a diameter of 120 mm and a length of 195 mm were subjected to hardening with two tempers for strengthening and subsequent liquid carbonitriding.

The most reliable assessment of the results of chemical-thermal treatment is provided by metallographic studies, which allow obtaining information about the thickness and structure of the obtained surface layer on the surface of the parts. Usually, for metallographic studies, sections are etched with natal – 2…4% alcohol solution of nitric acid. Metallographic studies of sections were also carried out using an Axiovert 200 MAT microscope, the hardness of the surface of the samples after chemical-thermal treatment was measured using a microhardness tester (microscope) – type PMT-3 at a load of 200 g, as well as on a Vickers hardness tester at a load of 5 kg [21].

After carbonitriding, X-ray phase analysis of the carbonitrided layer of the samples was also carried out, and a graph of the microhardness distribution of the layer along its depth was constructed.

X-ray phase analysis was carried out on an X-ray diffractometer DRON-3 in monochromatized Co-Kα radiation (λ=0,179 nm). Identification of compounds (phases) was carried out by comparing interplanar distances (d, nm) and relative intensities (I rel-I/I0) of the experimental curve with the data of the electronic file PCPDFWIN. Shooting was carried out at angles of 10…90 degrees. Phase analysis – step 0.1 degrees. Duration 5 s. Structural analysis – step 0.01 degrees. Duration 5 s.

2Q – scanning angle, position of the maximum in degrees;

I abs – absolute value of intensity at 2Q;

I rel – axial value of intensity at 2Q;

D, A – interplanar distance in nanometers;

$L_{1,2}$ – crystallite sizes according to the Seljakov-Scherrer formula

$$L_{HKL} = \frac{0.94\lambda}{\beta Cos\theta_{HKL}}, \qquad (1)$$

L – crystallite sizes and the degree of microstresses were calculated from two lines and by solving a system of equations:

$$L_{HKL} = \frac{0.94\lambda}{\beta Cos\theta_{HKL}}, \qquad (2)$$

$$\frac{\Delta d}{d} = \frac{\Delta a}{a} = \frac{\beta}{4tg\theta_{HKL}} = M, \qquad (3)$$

Dhkl – dislocation density in the direction of the plane (hkl) [22].

The tabular values of the ferrite lattice parameters a=0,287 nm are given in Table 4.

Table 4

Tabular values of ferrite lattice parameters a=0,287 nm

| Зразок | a, nm | $L_{110}$, nm | $L_{220}$, nm | L, nm | M,% $x10^{-3}$% | $D_{110}$, A $x10^{10}$ $cm^{-2}$ | $D_{220}$, A $x10^{10}$ $cm^{-2}$ |
|---|---|---|---|---|---|---|---|
| 1 | 0.28701 | 86.9 | 66.0 | 129.3 | 1.63 | 10.53 | 66.74 |
| 2 | 0.28706 | 80.8 | 56.5 | 120.4 | 1.98 | 12.19 | 91.08 |
| 3 | 0.28732 | 68.0 | 54.8 | 101.1 | 1.85 | 17.19 | 96.41 |
| 4 | 0.28701 | 84.7 | 61.4 | 126.1 | 1.78 | 11.10 | 76.99 |
| 5 | 0.28719 | 76.2 | 50.8 | 112.1 | 2.24 | 14.07 | 112.64 |
| 6 | 0.28751 | 71.4 | 49.8 | 106.4 | 2.25 | 15.59 | 117.14 |

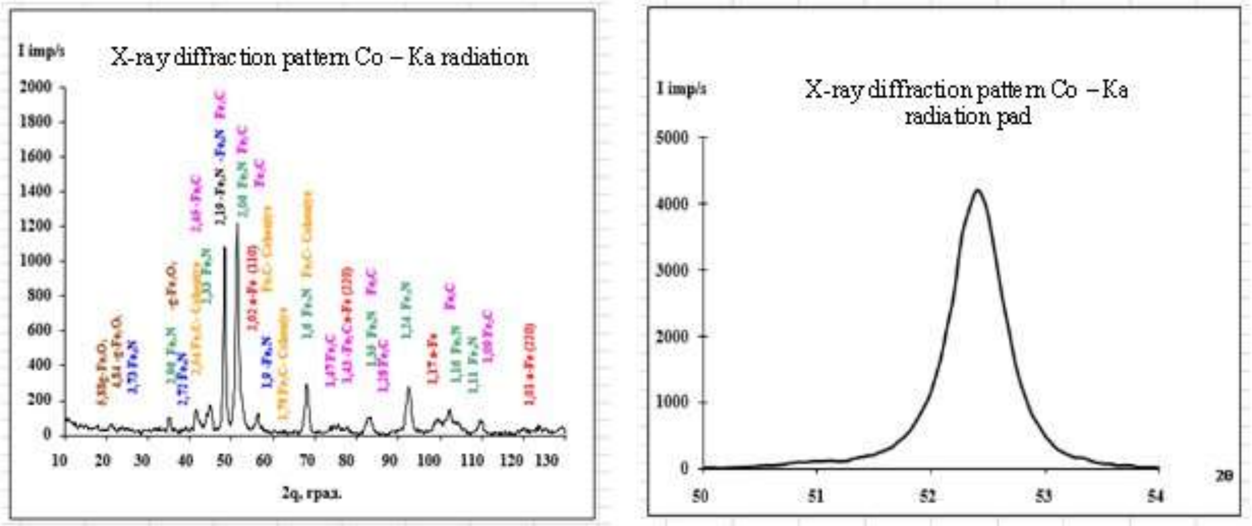

*Fig. 6. Diffraction patterns of samples after hardening with tempering and carbonitriding*

The diffraction patterns of the samples after hardening with tempering and carbonitriding are shown in Fig. 6.

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The results of microhardness measurements of samples of die steel for the manufacture of expanders for tube profile presses after hardening with tempering and carbonitriding are shown in Table 5.

Table 5

Results of microhardness measurements of samples of die steel 4X4VMFS for the manufacture of expanders for tube profile presses after hardening with tempering and carbonitriding

| Sample No | Zone distance from surface, μm | Print diameter, μm | Average imprint diameter, μm | Load, g | Average microhardness value, MPa | Average microhardness value, kg/mm$^2$ |
|---|---|---|---|---|---|---|
| 1 | center | 82 | – | 200 | – | – |
| 2 | center | 83 | – | 200 | – | – |
| 3 | center | 82 | 25.36 | 200 | 5660.4 | 577.6 |
| 4 | 50 | 56 | – | 200 | – | – |
| 6 | 50 | 57 | 17.25 | 200 | 12235.6 | 1248.5 |
| 7 | 100 | 66 | – | 200 | – | – |
| 8 | 100 | 70 | – | 200 | – | – |
| 9 | 100 | 58 | – | 200 | – | – |
| 10 | 100 | 60 | 19.56 | 200 | 9516.0 | 971 |
| 11 | 200 | 88 | – | 200 | – | – |
| 12 | 200 | 86 | – | 200 | – | – |
| 13 | 200 | 87 | 26.8 | 200 | 5069.5 | 517.3 |
| 14 | 300 | 86 | – | 200 | – | – |
| 15 | 300 | 86 | – | 200 | – | – |
| 16 | 300 | 87 | 26.59 | 200 | 5148.1 | 525.3 |
| 17 | 400 | 87 | – | 200 | – | – |
| 18 | 400 | 86 | – | 200 | – | – |
| 19 | 400 | 88 | 26.8 | 200 | 5069.5 | 517.3 |

The graph of the change in microhardness of the carbonitrided layer of steel 4X4VMFS presented in Fig. 7, reflects the nature and degree of change in the structural-phase composition along the depth from the surface of the sample after carbonitriding.

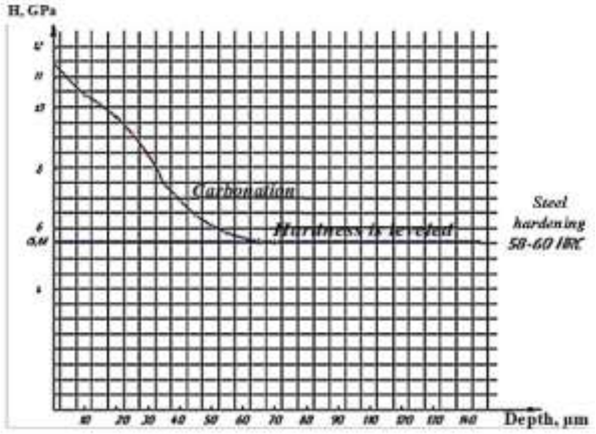

*Fig. 7. Hardness of expanders made of tool steel 4X4VMFS after carbonitriding [23–26]*

As the results of microhardness measurements of experimental samples show, the hardness on the surface reaches 9000…12500 MPa due to the formation of a strengthened layer on the surface of the tool, consisting of several zones (the upper layer is ε-carbonitride of the $Fe_3(NC)$ type, below which is the γ′-phase zone of the $Fe_4(NC)$ type, below which is the diffusion zone (heterophase layer), which consists of a solid solution of carbon and nitrogen in iron with inclusions of carbonitride phases, the hardness of which is significantly higher than the hardness of the core. Nitrogen and carbon present in the carbonitrided layer slow down the processes of transformation of solid solutions and coagulation of carbonitride phases, as a result of which the high hardness of the carbonitrided layer is maintained up to temperatures above 600 °C [27–29].

*Fig. 8. Technological line of carbonitriding at "TOV KARBAZ"*

The surface layer is a carbonitride phase, in which inclusions of a complex cubic carbide $(Fe, W, Cr, V)_6C$ are located [30]. Below the carbonitride layer is a zone of complex heterophase structure, and further a light zone, where carbonitride inclusions are almost not visible.

## RESULTS OF THE RESEARCH AND THEIR DISCUSSION

To standardize the carbonitriding process at "TOV KARBAZ", own technical conditions TU U 25.6-32646974-001:2019 "Carbonitriding of metal surfaces in salt melts" were developed and implemented, approved by the State Standard of Ukraine. The carbonitriding line of the enterprise is shown in Fig. 8.

In factory conditions, the traditional technology of thermal strengthening of expanders is hardening followed by double or triple tempering to obtain a hardness of 48 – 50 HRC. The proposed technology of thermal strengthening excludes the third tempering and additionally uses carbonitriding of the tool with the aim of changing the structure and properties of the surface layer, increasing the strength, wear and heat resistance of the steel by forming stable carbides during heating [31].

As a result, the steel acquires high surface hardness HV 9500 – 12500, which does not change when heated to 600…650 °C, high wear resistance, high endurance limit, corrosion resistance [32, 33].

Testing of the tool after strengthening treatment was carried out at the pressing section of TOV “VO OSKAR” (Dnipro) (Fig. 9).

*Fig. 9. Testing of tube tool at TOV “VO OSKAR” (Dnipro)*

The purpose of the testing: to evaluate the feasibility of conducting carbonitriding of thermally strengthened expanders with the aim of improving their operational durability, hardness, heat resistance, endurance.

Test results: if the durability of expanders made of steel 4X4VMFS after conventional thermal strengthening is 80 – 100 pressings, then expanders additionally subjected to chemical-thermal treatment (carbonitriding) showed a durability of 120 – 140 pressings due to higher hardness, heat resistance, formation of a special structure on the surface as a result of chemical-thermal treatment [34].

## CONCLUSIONS

1. The method of the proposed chemical-thermal treatment provides opportunities to increase the service life of tube pressing tools. For expanders of tube profile presses made of steel 4X4VMFS after the implementation of complex treatment using carbonitriding, which is recommended for the treatment of products of significant sizes, the hardness of the surface layer increases to the level of 9500…12500 MPa, and the operational durability of the tool is 1.3–1.5 times, which is ensured by the formation of a strengthened layer on the surface of the tool, consisting of several zones (the upper layer is ε-carbonitride of the $Fe_3(NC)$ type, below which is the γ′-phase zone of the $Fe_4(NC)$ type, below which is the diffusion zone (heterophase layer), which consists of a solid solution of carbon and nitrogen in α-iron with inclusions of carbonitride phases of alloying elements (W, Cr, Mo, V), the hardness of which is significantly higher than the hardness of the core. Nitrogen and carbon present in the carbonitrided layer slow down the processes of transformation of solid solutions and coagulation of carbonitride phases, as a result of which the high hardness of the carbonitrided layer is maintained up to temperatures above 650 °C, which was confirmed by the results of metallographic, X-ray structural studies and studies of mechanical properties and the results of industrial testing of the experimental tool.

2. Conducting chemical-thermal treatment after hardening with tempering of expanders made of tool steel 4X4VMFS (carbonitriding) significantly increases the operational properties of the tool and its service life by 30…40%, as well as the quality of its surface, which significantly increases the quality of the internal surface of tubes made of high-alloy steels.

3. The advantage of this technology is the high speed of saturation, uniformity of heating and saturation in the melt, increased wear resistance and corrosion resistance of the surface, reduction of the friction coefficient by 1.5–5 times, environmental friendliness and non-toxicity of cyanate salts.

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# ЗМІЦНЕННЯ ЕКСПАНДЕРІВ ТРУБОПРОФІЛЬНИХ ПРЕСІВ ДЛЯ ВИРОБНИЦТВА КОРОЗІЙНО-СТІЙКИХ ТРУБ РІДИННОЮ КАРБОНІТРАЦІЄЮ

***Л.М. Дейнеко, Л.С. Кривчик, В.Л. Пінчук, О.С. Баскевич, А.В. Панченко, А.О. Тараненко***

На етапі розвитку техніки однією з найважливіших завдань прикладної науки є розробка нових матеріалів для перспективних виробів і технологій їх зміцнення. Одним із видів гарячого деформування є гаряче пресування. Його широко використовують для виготовлення виробів із усіх сталей і сплавів, які важко деформуються. У зв'язку з розвитком енергетики та електротехнічної промисловості, бурхливим зростанням авіа- і суднобудування з'явилася велика кількість різновидів процесу пресування, різко зросла кількість сплавів, що пресуються. Ще одна найважливіша перевага пресованих виробів полягає у тому, що їх можна зробити такої складної конфігурації, яку іншими способами обробки, тиском або навіть різанням, отримати неможливо. Найширше застосування пресування отримало для виробництва труб з низькопластичних сталей і сплавів. Якість труб, отриманих пресуванням, визначається значною мірою стійкістю інструмента [1]. Заготовку з високолегованих сталей перед пресуванням піддають крізному свердлуванню і, у ряді випадків, експандуванню. Процес експандування застосовують при виробництві труб з високолегованих сталей, оскільки прошивка їх утруднена і призводить до підвищеної різностінності. Експандування заготовки здійснюють експандером, при цьому на передньому кінці експандера співвісно закріплена прошивна голка довжиною, що становить 1,2–3,0 довжини свердління заготовки. Сталі для штампів гарячого пресування мають тривалий контакт із гарячим металом, робочий інструмент працює в умовах високих температур, інтенсивних швидкостей ковзання і значного питомого тиску, що зумовлює необхідність використати як матеріал високолеговані теплостійкі інструментальні сталі, що володіють підвищеною в’язкістю і міцністю [2]. У статті запропоновано, обґрунтовано використання рідинної карбонітрації після загартування з відпуском інструментальної штампової сталі 4Х4ВМФС для виготовлення експандерів трубопрофільних пресів з метою підвищення міцності, зносостійкості, експлуатаційної стійкості трубопресового інструмента для виробництва труб з корозійно-стійких високолегованих сталей.