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RESEARCH OF METAL OF THE DIES FOR PUNCHING AND CUTTING DEPOSITED BY TUNGSTENFREE HIGH SPEED STEEL TYPE (FCADW-SS 100H4M5F2 (ZR)

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Type codes:

SSFCW – *self-shielding flux-cored wire*
HFC *– high-frequency current*
CTPI *– cyclic thermal power impact*
FCADW-SS – *flux-cored arc deposition wire – self-shielding*
HFCQ – *high-frequency current quenching*

Summary. *An economic technological mode of dies production according to the scheme: mold surfacing - annealing - mechanical processing - quenching – tempering. The results of research of applying of self-shielding flux-cored wire type (FCADW-SS 100H4M5F2 (Zr)) for punching and trimming dies tool. Punches that surfaced by self-shielding flux-cored wire (FCADW-SS 100H4M5F2 (Zr)) have the hardness within 62-63 HRC after quenching and tempering. Wear resistance of the deposited stamping tool exceeds by 3,5-4 times than the resistance of tool of У8А (U8A) steel and by 1,5-2 times than the resistance of punches of I2XM (12HM) or 9XM (9HM) steels, that have the hardness 58 HRC. Established that the flux-cored wire (FCADW-SS 100H4M5F2 (Zr)) allows to ensures high technical and economic impact and achieve economies of expensive high alloying tungsten and tungsten-molybdenum high-speed steels.*

Key words: *die tool for cold metal processing, arc deposition, flux-cored wire, optimum mode of heat treatment, technical and economic effect, saving tungsten and tungsten-molybdenum steels.*

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Problem statement. Pressure metal treatment is one of the most economic and high productive processes of express operation in mechanic engineering. Working die parts (punches, matrixes) come under the load impact of high stress concentration on cutting edges or work surface. Consequently, to support normal conditions for fool performance, specified requirements are applied to material of punches and matrixes to be of high hardness and wear resistance at enough impact resistance, ability to hold necessary shape of edges for a long period. Material of die tool and its thermal treatment are chosen according to loads appearing in the process of die tool operation. Producing die tools for cold metal processing, carbon steel У8А, У10А or alloyed steel 12XM, 9XM are frequently used. Big quantity of carbides (till 15%) in these types of steel supports high wear resistance but causes decrease of impact resistance [1 – 5].

Die efficiency is characterized by working parts resistance to full wear. Resistance of punching and piercing dies depends on thickness and type of die material, its mechanic characteristics, perimeter and cutting configuration, shape of edges of punches and matrixes, gap setting between punch and matrix etc. The right choice of material for working parts of separating dies and modes of their thermal treatment has the biggest influence on resistance of dies. Working parts of separating dies go wrong because of intensive wear and exhausting damage of metal of edge. Working parts, being sharpened 20 – 25 times on front surface for renewal of geometry of edge, are taken out of service [2, 6].

Insufficient high exploitation resistance of die tool causes the loss of expensive instrumental steel. Since dies are quite expensive and compound instruments, in most cases, they are renewed by the resurface welding [6, 7].

So, increase of resistance of die tool for cold metal processing, punching and die forging of metal is actual task.

Review of recent investigations and papers. In spite of the actuality of resurface welding in forgings and die production, the quantity of research papers either national or foreign in the sphere of development of theoretical and technological bases of resurface welding of dies and instruments is not sufficient. Relatively small volume of scientific data in this sphere shows about the complexity of investigations of physical and chemical processes arising in alloys at cyclic thermal power impact (CTPI) during increase of temperature causing their wear. Surfacing of pressing tool is problematic because time of contact of its working surface with hot deformed metal (stamping, pressing, calibration, stitching, and extrusion) is increased comparatively with forging and hammer dies, and its wear is intensified. Pressing comes with impacts excluding danger of fragile damage and allows using different industrial chrome and tungsten types of instrumental surfacing alloys for dies surfacing. However, at intensive CTPI and peak maximal temperature up to 1100 °C and higher even better heatproof materials on the base of nickel and cobalt are not sufficient [1, 2, 7].

Considerable reserves in increasing of resource of die instrument for deforming metals are built in technological possibilities of surfacing using wear-resistant alloys. In recent decades I. Pokhodnya, V. Pidhayetskyy, N. Potapov, L. Moysov and other scholars developed new generation of highly effective surfacing covered electrodes (L/ Luzhanskyy, I. Yavdoshchin, A. Marchenko and others), flux-cored wires and tapes (V. Shlyepakov, O. Kakovkin, D. Baranov, L. Leshchynskyy, S. Hulakov and others), grained metal powder (H. Hladkyy, N. Rohov, A. Som and others). These high quality materials increased the quality of deposited metal and productivity of its coating on different details.

Foreign scholars made a great contribution to die and metallurgical instruments, they are: E. Pease, P. Murray, D. Andrews, K. Bransali, P. Crook and A. Dilawary (England), L. Friedman, A. Hickl, C. Evans, P. Johnson (USA), O. Knotek (Germany), M. Druetta (France), K. Madey (Poland) and many others [1].

Surfacing carbonfree disperse hard alloys for production of dies of cutting elements, guillotine-type knifes such as alloys of the system Fe-Co-Mo and Fe-Co-W with additional alloyed parts are famous.

Taking into consideration flux-cored wire, its core composition is famous: 15% Co; 15% Mo; 9% Ni; 4% FeNb; 1,0% Al + Mg; another Fe allowing to get the layer of high-quality disperse hard deposited metal and because of high level of wire alloying, it was recommended to use for surfacing under the layer of flux [2].

Suggested core composition of flux-cored wire caused rise in price of surfacing instrument and complication of surfacing technology, so, it was necessary to study surfacing materials of less quantity of Co and Mo and to increase operational characteristics of surfacing instrument owing to carbide strengthening.

Research objective. The aim of the research is to investigate mechanic peculiarities and phase composition of the studied steel 100Х4М5Ф2(Zr) after surfacing, annealing, quenching and tempering. To find possibilities of use of surfacing of piercing and trimming dies of self-shielding flux-cored wire SSFCW-100Х4М5Ф2(Zr), developed at the Department of Equipment and Technologies of Welding Production in Donbas State Machine-Building Academy and intended for surfacing of die instrument using tangstenfree high speed steel.

Problem statement. To support satisfactory stability of die instrument for cold metal processing, it is necessary to investigate the effectiveness of use for surfacing of piercing and trimming dies of self-shielding flux-cored wire SSFCW-100X4M5Φ2(Zr), which is used for surfacing of die instrument using tangstenfree high speed steel. To study surfacing technology and mode of thermal treatment of deposited metal for getting wear-resistant bimetal layer of high toughness, strength and plastic matrix. It is necessary to investigate the influence of alloying on the mechanism of composite strengthening. To study mechanic characteristics and phase composition of the tested steel after annealing, quenching and tempering. To develop rational parameters of thermal treatment and define optimal intervals alloying using chrome, molybdenum and vanadium to get high technical and economic effect economizing in expensive high alloyed tungsten and molybdenum high speed steel and increase of operating capacity of surfacing die instrument owing to combination of qualitative composition, structure and thermal treatment of deposited metal.

Research results. In spite of Fe-Co-Mo steel, the deposited metal by self-shielding flux-cored wire 100X4M5Φ2(Zr) does not contain many expensive and deficit W and Co [2]

At the same time, heat resistance of deposited metal by self-shielding flux-cored wire, studied after four hours heating up to 625 °C and cooling down to normal temperature is like high speed steel P18 being 58 – 62 HRC.

However, the mode of thermal treatment used for die tool surfaced by flux-cored wire 100X4M5Φ2(Zr), that is quenching from 1200-1220°C and drawing at 560 – 570°C, which support to get the highest hardness within 64 – 66 HRC and red-hardness (58 – 62 HRC) for punching and piercing dies at impact load can be useless.

For separating dies, as it was stated above, hardness within 61-62 HRC should be considered the most optimal one. Besides, surfaced material of such hardness should have high impact hardness and the most optimal structure. To get optimal meanings of hardness, impact hardness and structure of deposited metal are investigated additionally after different modes of thermal heating [8, 9].

Investigation of hardness and impact hardness of the metal surfaced by flux-cored wire 100X4M5Φ2(Zr) was done with the temperature of quenching and tempering. To produce samples of plates made from steel Ст3 80×150×12 mm in size, multilayered surfacing 22 – 25 mm of height was done. After surfacing and annealing, the base metal is sheared off and surfaced metal is shared off in 6-8 mm from the side of the base metal. The superficial layer of surfacing is shared off in 4 – 5 mm.

Received plates of deposited metal 150x80x11mm in size were cut into samples 11 mm in size. Samples 11x11 mm in section were made using allowance for further polishing. Quenching of samples were made at 1100, 1150, 1200 i 1260°C, and tempering at 520, 560, 580, 600°C.

The value of impact hardness was defined at impact bend of samples of standard sizes, being 10×10 mm in section and 55 mm long without cut on copra of 100 i 50 Н·m impact energy. Having received data in the value of impact hardness, we can make the following conclusions: 1) the metal has the highest impact hardness in the range of 0.46-1.46 MJ/m^2 after quenching from 1100°C at all tested modes of tempering, that is after heating up to 520, 560, 580 i 600°C; 2) on the second place, there are samples of 1200°C and the same modes of tempering according to the meanings of impact hardness. The value of impact hardness at this mode of thermal treatment is 0.7-0.90 MJ/m^2; 3) the samples being quenched from 1200°C have impact hardness 0.37 – 0.7 and 0.31 – 0.97 MJ/m^2. Consequently, to get maximal impact hardness, deposited metal should be quenched from 1100°C and tempered at 520 or 560°C. After such mode of thermal treatment, the hardness of deposited metal is 61-62 HRC, and impact hardness is 0.65-0.75 MJ/m^2, being optimal for separating dies.

The value of hardness of deposited metal in the range 61-62 HRC can be received under different conditions of thermal treatment. Hence, having done quenching at higher temperature in the range 1280-1300°C, higher temperature of tempering should be within 600-625°C. At lower temperature of quenching, correspondingly lower tempering should be.

To define these temperatures at samples made from steel 45 about 50 mm in diameter surfaced by flux-cored wire SSFCW-100Х4М5Ф2(Zr) surfacing in five layers was done. To measure the hardness of deposited metal at starting condition, the surface of surfacing was polished 1-2 mm deep, and then samples were under annealing and quenching. Quenching was done at 950 1000, 1100, 1150, 1200 and 1260 °C, and tempering at 200, 400, 520, 560, 580 і 600°C. Quenching at more than 1200°C is irrational because of flashing of crystal boundary.

Measuring of the hardness of deposited samples was done either after quenching or after each mode of tempering. At initial condition the hardness of deposited metal is 58-62 HRC. After annealing at 780 °C during 5 hours, its hardness falls down to 30 HRC. After quenching at 950 and 1000°C and tempering even at 200°C the hardness of deposited metal is not higher than 56 – 57 HRC. At higher tempering, the hardness falls down. During quenching from 1100°C and tempering at 200 – 400°C, the hardness of deposited metal is 60 – 61 HRC, and at 520°C it rises up to 61 – 62 HRC (second hardness). The value of this hardness remains stable after tempering at 580°C. The deposited metal obtains the same hardness at 1200°C and during tempering at 520°C. The lowest temperature of quenching is 1100°C at which after tempering at 520°C, the hardness of deposited metal is 60 – 62 HRC.

To receive the hardness of deposited metal in the range of 60 – 62 HRC and its maximal impact hardness (0.65 – 0.75 J/cm^2), deposited metal is necessary to be quenched at temperature not lower than 1100 °C and be tempered at 520°C, it was necessary to investigate the structure of the deposited metal after the defined mode of thermal treatment. To make a comparison, the structure of the deposited metal was studied at з 1200°C and the tempered one at 520°C. Microstructure of the deposited metal was investigated at upper and lower layers close to the base metal.

Except investigation of the structure of the deposited metal, the investigation of the structure of the base metal made from steel 40X used as the base at surfacing of dies for cold processing was made.

The duration of heating at quenching has a significant influence on size of grain of deposited metal. Therefore, samples from which sections were made for micro investigations during heating in salt bath for quenching at two modes: 2 and 5 minutes. The first mode two minutes in length was taken as optimal one with 10-12 seconds to one millimeter of thickness of deposited metal what is 10 mm. The second mode five minutes in length was taken in 2.5 overestimated comparatively with the optimal one.

To make sections for steel 40X 15 mm in thickness, multilayered surfacing in 10-12 mm in thickness was done using flux-cored wire SSFCW-100Х4М5Ф2(Zr) 3 mm in diameter. Then deposited samples were under annealing at 780 °C during 5 hours and further cut into separate templates 12 mm in thickness.

Heating at quenching of samples was made in salt bath $BaCl_2$ at 1100 and 1200°C and during 2 and 5 minutes holding. Cooling at quenching was done in oil and tempering after cooling at 520°C in electrical stove 5 hours holding.

Samples being thermally processed at defined mode were being grinded, polished, nitric acid etched and photographed using optical microscope at increase in 400 times. The results of micro investigations of samples were shown in Figure 1.

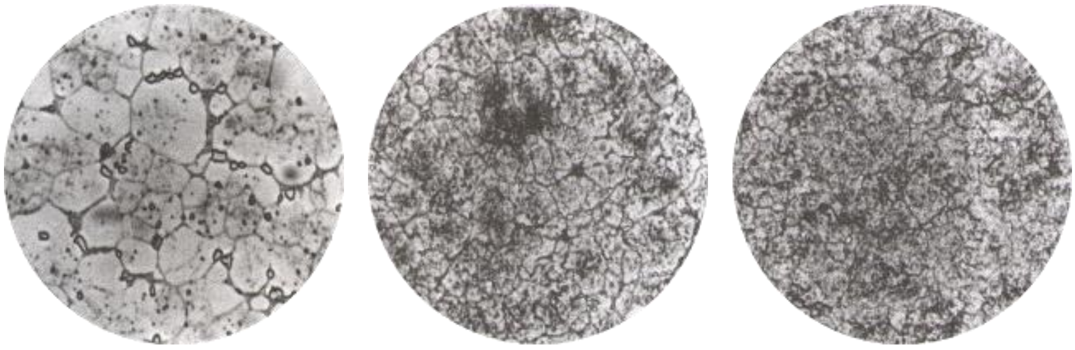

Figure 1. The microstructure of the base metal and deposited steel type 100X4M5Ф2(Zr) (FCADW-SS 100H4M5F2(Zr)) after the final heat treatment: a) base metal; b) deposited metal after quenching from 1200°C and tempering at 520°C; c) deposited metal after quenching from 1100° C and tempering at 520°C

The structure of the deposited metal after annealing, quenching from 1100, 1200°C and tempering at 520°C is composed from tempering martensite, raw carbides and residual austenite. More small-grained structure and more small-acicular martensite has the metal being quenched from 1100°C, Figure 1, b. Overheat is typical for the structure of the base metal, Figure 1, b. Increased time of holding at heating for quenching from 2 to 5 minutes does not influence significantly on the increase of the grain.

For production testing, wear resistance of cold dies surfaced by self-shielding flux-cored wire type SSFCW-100X4M5Ф2(Zr) piercing die was chosen. Piercing die had four round punches using which on 250 ton press in steel samples (segments) 40X 7 mm in thickness holes almost 20 mm in diameter in four points are made simultaneously.

Using piercing punches made from the stated above steel before their broken-down because of blunt or loss of size, almost 2000 items of production were made.

During surfacing for punches as the base material steel 40X was used and working part was surfaced by flux-cored wire SSFCW100X4M5Ф2(Zr) shown in Figure 2.

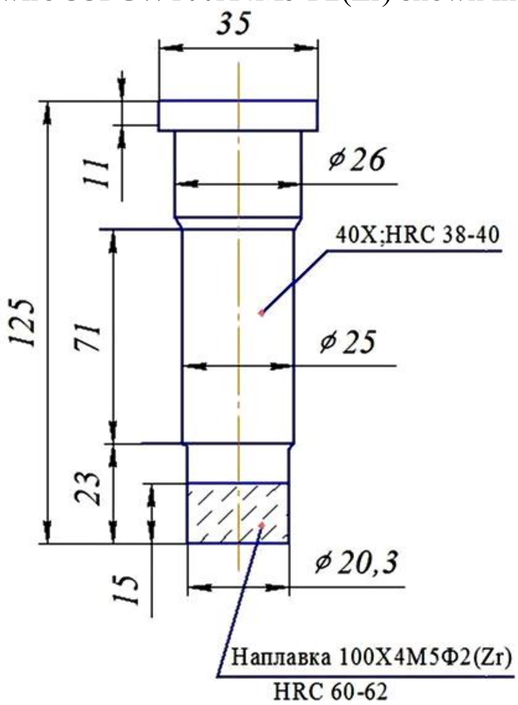

Figure 2. Surfaced punch for the punching holes

Surfaced punches were under annealing at 780°C with 5 hours holding, mechanic and thermal treatment and further grinding.

Production testing was done on punches for punching holes in segments made from steel 40X on 250 ton press.

Because of these punches were under big load, it was decided to use lower tempering at 300 and 400°C not to have insufficient hardness of the base metal made from steel 40X in range of 30-35 HRC. Besides, under production conditions it was decided to check chosen temperature of quenching 1100° C and to test some punches deposited from 1050 and 1200°C.

The hardness of the base metal after quenching from 1050-1200°C and tempering at 300-400 °C is satisfactory and ranges between 38-45 HRC. Nevertheless, the hardness of deposited metal in the range of 56-58 HRC is insufficient. To increase the hardness of the deposited metal, it is necessary to increase the temperature of tempering up to 500-520°C at which there is second disperse increase of hardness because of fall-out of second carbides.

Besides, at such temperature of tempering, there is the decrease of the hardness of the base metal almost to 30 HRC, being undesirable. So, it was decided to make additional tempering for deposited metal on high-frequency unit using short time heating up to 600-620°C, what was defined by brightness of heat. It allowed to increase the hardness of the deposited metal to 60-62 HRC.

After this, punches were under production testing on resistance. Their resistance was in 3.5 times higher than the resistance of the punches made from steel X12M which hardness is 58 HRC. As it was stated above, punches made from steel X12M before their blunt made holes in about 2000 points, and using deposited punches 700 holes were made. This testing ended.

Conclusions. The effect of alloying on the mechanism of the composite strengthening: the formation elastic and durable frame by eutectic solid components. As a result, the material combines wear and impact resistance. An economic technological mode of dies production according to the scheme: mold surfacing – annealing – mechanical processing – quenching – tempering. The results of research perspectives of applying of self-shielding flux-cored wire type SSFCW-100X4M5Ф2(Zr) (FCADW-SS 100H4M5F2(Zr)) for punching and trimming dies tool that provides of deposition a layer of tungstenfree high speed steel. Punches that surfaced by self-shielding flux-cored wire type SSFCW-100X4M5Ф2(Zr) (FCADW-SS 100H4M5F2(Zr)) have the hardness within 62-63 HRC after quenching and tempering. Wear resistance of the deposited stamping tool exceeds by 3.5-4 times than the resistance of tool made from steel У8А (U8A) and in 1.5-2 times than the resistance of punches of 12XM (12HM) or 9XM (9HM) steel, that have the hardness 58 HRC. For deposited metal hardness within 61-62 HRC and base metal of 40X (40H) steel within 33-35 HRC (using a 100-ton press) punches should be thermally processed, quenched with a temperature of 1100°C and tempered with a temperature of 520°C. The deposited punches should be quenching to obtain the hardness of deposited metal layer within 62-63 HRC and base metal within 38-45 HRC (using a 250-ton press). Quenching of deposited punches should be at heating with a temperature of 1100°C, and a double tempered: 1st - entire punch with a temperature of 400 ° C with an exposure of 1.5-2 hours and 2nd - short-term with HFCQ with a temperature of about 600-620°C only deposited parts. Because of the fact that the tempering on HFCQ could not guarantee the stable results of hardness of the blanking punches and piercing dies should continue researches other steel grades for the base metal and new heat treatment modes. Tests showed that the test sample of self-shielding flux-cored wire for deposition die tool could to increase its efficiency by connection of the qualitative composition, structures and heat treatment mode of the deposited metal. Established that the flux-cored wire SSFCW-100Х4М5Ф2(Zr) (FCADW-SS 100H4M5F2(Zr)) allows to ensures high technical and economic impact and achieve economies of expensive high alloying tungsten and tungsten-molybdenum high-speed steels.

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ДОСЛІДЖЕННЯ МЕТАЛУ ПРОБИВНИХ І ОБРІЗНИХ ШТАМПІВ НАПЛАВЛЕНОГО БЕЗВОЛЬФРАМОВОЮ ШВИДКОРІЗАЛЬНОЮ СТАЛЛЮ ТИПУ 100Х4М5Ф2(ZR)

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Резюме. *Запропоновано економічний технологічний спосіб виробництва штампів за такою схемою: наплавка в кристалізаторі – відпал – механічна обробка – загартування – відпуск. Представлено результати досліджень використання для наплавлення пробивних і обрізних штампів самозахисного порошкового дроту СПД-100Х4М5Ф2(Zr). Пуансони, наплавлені порошковим дротом СПД-100Х4М5Ф2 (Zr), мають після гарту і відпуску твердість у межах 62 – 63 HRC. Зносостійкість наплавленого штампувального інструменту в 3,5 – 4 рази перевищує стійкість інструменту зі сталі У8А, а також в 1,5 – 2 рази перевищує стійкість пуансонів зі сталей І2ХМ або 9ХМ, що мають твердість 58 HRC. Встановлено, що порошковий дріт СПД-100Х4М5Ф2(Zr) (FCADW-SS 100H4M5F2(Zr)) дозволяє забезпечити високий техніко-економічний ефект і досягти економії дорогих високолегованих вольфрамових і вольфрамо-молібденових швидкорізальних сталей.*

Ключові слова: *штамповий інструмент холодної обробки металу, дугове наплавлення, порошковий дріт, оптимальний режим термічної обробки, техніко-економічний ефект, економія вольфрамових і вольфрамово-молібденових сталей.*

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