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MODERNIZATION OF HEADS OF AUTOMATIC WELDING MACHINES FOR ORBITAL TIG-WELDING OF PIPELINES OF NPP POWER UNITS

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To the accuracy and reliability of actuating mechanisms of modern automatic machines for orbital (GTAW) welding of position joints of pipelines of NPP power units a number of specific requirements is made. In particular, they concern the largest diameters of faceplates of welding heads of such automatic machines, in which, as a rule, all or the most of those mechanisms are located. This paper describes the designs of actuating mechanisms of modern automatic machines for GTAW of position joints of NPP pipelines, designed at the Scientific and Engineering Center of welding and control in the field of nuclear energy. Designed were the mechanisms of clamping (fixation) of welding heads on a pipe being welded, the mechanism for arc length stabilization, the mechanism for rotation (rotator) of faceplate around the axis of pipes to be welded, the mechanism for automatic regulation of arc voltage, the mechanism for oscillation of nonconsumable electrode (across the weld) and the mechanism for filler wire feed. The results of industrial operation of some automatic machines for GTAW, designed at the Scientific and Engineering Center of welding and control in the field of nuclear energy, are presented, in which the described mechanisms are used. The aim of this work is to present the results of works carried out at the Scientific and Engineering Center of welding and control in the field of nuclear energy in the direction of creating components of automatic machines for GTAW of position joints of thin-walled pipelines of steels from austenite, pearlite classes, carbon steels and alloys of nonferrous metals (except aluminum and its alloys). 11 Ref., 2 Tables, 6 Figures.

Keywords: *automatic orbital arc welding, nonconsumable electrode, inert gases, welding head, faceplate, actuating mechanisms, faceplate rotator, nonconsumable electrode oscillator, filler wire*

One of the basic requirements to welding heads of automatic machines of a hinge type for GTAW is the minimum possible diameter of their rotating parts (faceplates), which is explained by the need in providing GTAW of position pipeline joints under the conditions of actual distances between the pipes existing at NPPs. Therefore, the creation of welding heads capable of operating in a wide range of outer diameters of welded pipelines is not possible, which demands dividing this range into subranges taking into account the diameters of pipelines used in the Ukrainian nuclear power industry.

The earlier investigations carried out at the Research and Design Institute of Installation Technology (NIKIMT) (Moscow) [1, 2] found that for welding of position joints of thin-walled pipelines (widely used during assembly, repair and modernization of NPP power units) applying the GTAW method, the most acceptable methods are autopressing, successive penetration or antipressing, which can significantly simplify the design of the corresponding welding equipment, including welding heads. The experience of NIKIMT and other organizations, which took into account the influence of the maximum permissible deviations of parameters of automatic arc orbital GTAW method of position pipe joints on the quality of welded joints [3, 4], served as the basis for designing domestic orbital automatic machines for GTAW and their mechanisms at the Scientific and Engineering Center of welding and control in the field of nuclear energy. It should be noted that in the direction of designing and manufacturing of orbital automatic

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Table 1. Some basic parameters and characteristics of welding heads in welding automatic machines for GTAW using the methods of auto-moulding, sequential penetration or anti-moulding

Number	Description of parameter, characteristics	Welding head (brand or designation and developer/manufacturer)			
		ADTs 627.03.00.000 (for welding in argon), Ukraine, Scientific and Engineering Center of welding and control in the field of nuclear energy	ADTs 627.03.00.000-01 (for welding in helium), Ukraine, Scientific and Engineering Center of welding and control in the field of nuclear energy	ADTs 625.03.00.000 (for welding in argon), Ukraine, Scientific and Engineering Center of welding and control in the field of nuclear energy	ADTs 626.03.00.000 (for welding in argon), Ukraine, Scientific and Engineering Center of welding and control in the field of nuclear energy
1	Minimum diameter of welded pipe, mm	7	7	18	42
2	Maximum diameter of welded pipe, mm	24	24	42	76
3	Maximum welding current, A	140	140	160	200
4	Range of welding speed control, m/h	0.42–48.80		1.9–33.5	4.0–39.6
5	Diameter of nonconsumable (tungsten) electrode, mm	1.6		2.0–3.0	
6	Radius of rotating parts, mm, not more than	50		70	86
7	Electrode cooling	Gas			
8	Arc voltage stabilization system	Mechanical coppier stabilizer (ALS)		Automatic arc voltage regulator (AAVR)	
9	Overall dimensions: length, mm, not more than width, mm, not more than height, mm, not more than	 110 285 280		 142 285 357	 178 330 357
10	Head mass (without communication cables and hoses), kg, not more than	3.00		3.50	4.30

Table 1. Cont.

Number	Description of parameter, characteristics	Welding head (brand or designation and developer/manufacturer)			
		ODA-1s (for welding in argon), Russia, NIKIMT	ODA-2s (for welding in argon), Russia, NIKIMT	ODA-3s (for welding in argon), Russia, NIKIMT	MU-IV 8/38 P (for welding in argon), France, Polysoude
1	Minimum diameter of welded pipe, mm	8	20	42	8
2	Maximum diameter of welded pipe, mm	26	42	76	38
3	Maximum welding current, A	100	160	200	180
4	Range of welding speed control, m/h	6.0–23.0	6.0–30.0		0.5–40.0
5	Diameter of nonconsumable (tungsten) electrode, mm	2.0–3.0		2.0–4.0	
6	Radius of rotating parts, mm, not more than	40	55	90	63
7	Electrode cooling	Water			
8	Arc voltage stabilization system	Mechanical copying stabilizer (ALS)	Automatic arc voltage regulator (AAVR)		
9	Overall dimensions: length, mm, not more than width, mm, not more than height, mm, not more than	 81 146 235	 100 180 250	 155 190 355	 112 152 282
10	Head mass (without communication cables and hoses), kg, not more than	3.70	5.70	11.70	3.25

machines for GTAW, considerable successes were achieved by such well-known companies as ARC MACHINES, INC and DIMETRICS, INC (USA), POLYSOUDE (France), ESAB (Sweden), SIEMENS and GES. M.B.H» (Germany), RTA (Italy), NIKIMT (Russia) and others.

Table 1 presents some of the basic comparative parameters and characteristics of welding heads designed and manufactured by different companies available at the market, which are widely used in Ukraine and Russia in the machines for GTAW of thin-walled metal pipelines of NPP power units applying autopressing, successive penetration or anti-pressing.

To the features of welding heads ADTs 627.03.00.000, ADTs 627.03.00. 000-01, ADTs 625.03.00.000 and ADTs 626.03.00.000 designed at the Scientific and Engineering Center for welding and control in the field of nuclear energy, which are applied for GTAW of thin-walled metal pipelines by the methods of auto-moulding, successive penetration or anti-moulding, one can attribute the possibility of using them to perform step-pulse welding and modulated current welding while maintaining a constant rotation speed of their faceplates (welding speed), which significantly extends the technological capabilities of designed domestic automatic machines for GTAW. Another feature of these welding heads is the ability to use the same control system with controllers of mechanism drives, which allows not only providing a preliminary setting and smooth regulation (programming) of the values of parameters of the welding cycles and modes, but also setting a number of fully circumferential arc passes (from 1 to 4), as well as reversing the direction of faceplates rotation after a certain number of such passes [5–9].

The welding head ADTs 627.03.00.000-01 is designed for operation in a controlled environment (mainly in helium) with an axis inclined by 15° (angular degrees) of a nonconsumable electrode relative to the vertical to a product being welded and differs from the welding head ADTs 627.03.00.000 only by an insulator through which the torch ADTs 627.03.02.000 with a nonconsumable electrode is mounted, a type of electric plugs and a gas fitting pipe of current and gas supply, which provides a connection of a head for its operation inside a sealed chamber with a controlled environment.

Figure 1 shows a general view of welding heads ADTs 627.03.00.000, ADTs 625.03.00.000 and ADTs 626.03.00.000. In more detail, the general view of welding heads ADTs 627.03.00.000 and ADTs 627.03.00.000-01 is shown in Figure 2. On the output gear of head reducer rotator *1*, faceplate *5* is mounted. On the faceplate, lever *2* of copying stabilizer, torch with nonconsumable electrode, the spatial position of which is fixed (including the «stickout») by means of flywheel *3*, copying scheme *8*, two supports *6* for laying current gas supply inlet and support *7* for its fixation («predeformation») are mounted. Lever *2* includes copying screw *8*, lever itself *9*, nut with flywheel *10* made of electrical insulation material, casing *11*, and also axis, sleeve and spring attached

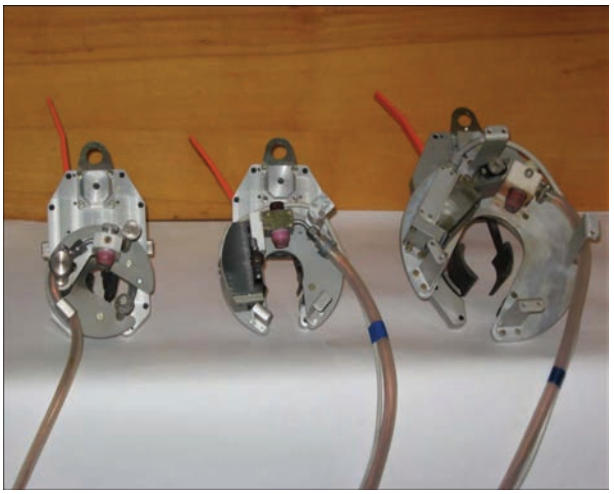

Figure 1. General view of welding heads ADTs 627.03.00.000, ADTs 625.03.00.000 and ADTs 626.03.00.000 on the side of their faceplates

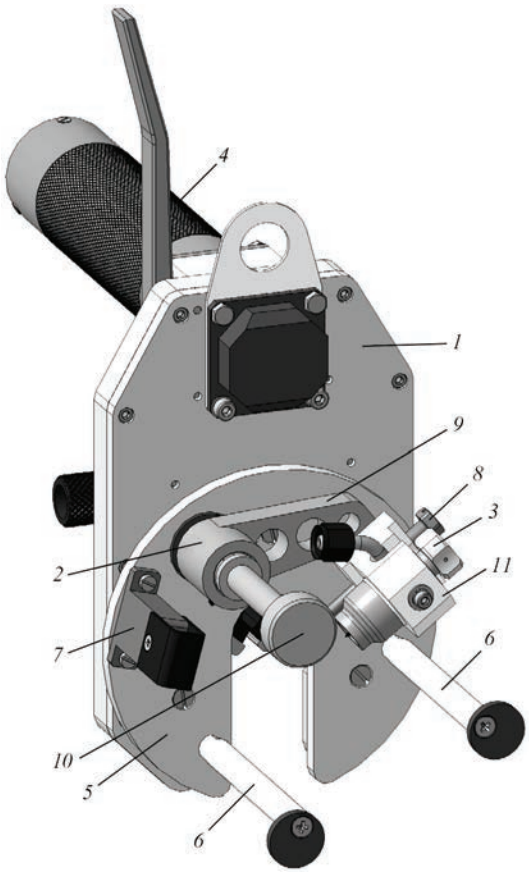

Figure 2. General view of welding head ADTs 627.03.00.000 (ADTs 627.03.00.000-01) on the side of faceplate (*4* — handle is hollow, other designations see in the text)

to faceplate and interacting with nut *10*. Casing *11* provides a fixation of torch with nonconsumable electrode in it and its electrical insulation from the potential of faceplate *5*, and, therefore, from the potential of a pipeline being welded. The axis included in lever *2* provides its rotation at a certain angle in the plane of faceplate *5*, which provides an additional convenience when performing the operations of setting the welding head ADTs 627.03.00.000 (ADTs 627.03.00.000-01) on a pipeline being welded and its removing from the pipeline, as well as during the adjustment and maintenance of torch with nonconsumable electrode. Nut *10* is designed to fix lever *2* in the working position or its release when it is necessary to perform its rotation. Copying screw *8* provides setting the length of an interelectrode gap (length of welding arc) required for welding process and its maintenance (by means of lever spring *2*) with an accuracy of not worse than ± 0.2 mm when faceplate *5* is rotated around the pipeline to be welded.

The mechanisms of rotation and clamping (fixing) of all welding heads designed at the Scientific and Engineering Center of welding and control in the field of nuclear energy, as well as AAVR head mechanisms are designed according to single unified schemes and for rotation mechanisms they differ only by the power of gear motor and reduction coefficient for each head

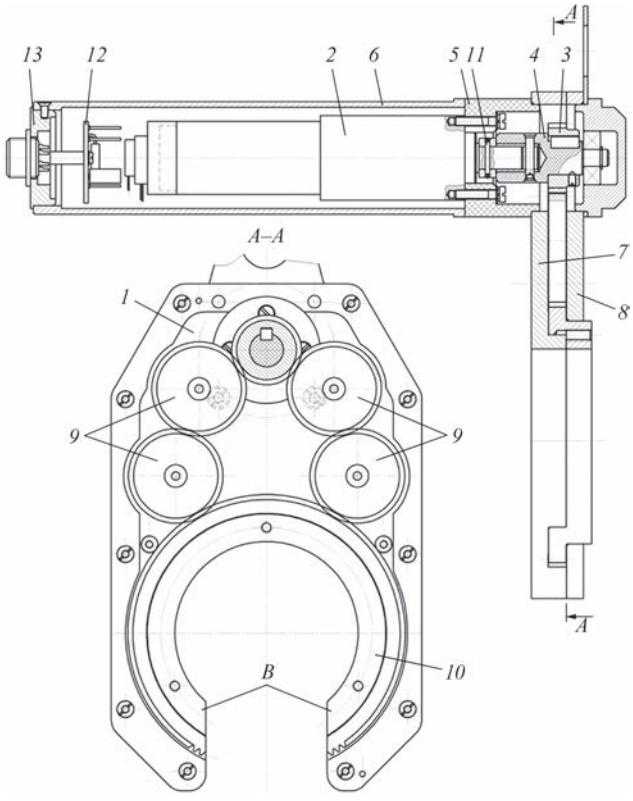

Figure 3. General view of rotator of all models of welding heads designed at the Scientific and Engineering Center of welding and control in the field of nuclear energy (on the side of their clamping mechanism (designations see in the text)

model, and for clamping (fixing) mechanisms on the pipe being welded they differ by the geometry and gripping area. The rotation mechanisms of a number of heads are driven with the help of unified adjustable reversive electric drives, produced on gear motors 2657 W 024 CR 30/1 of «Faul Haber» and encoders (speed sensors for shaft rotation of electric motors) of Kübler Company, generating 125 or 128 pulses per one full revolution of a motor shaft. The control of such drives is considered in detail in [8]. Figure 3 shows a general view of rotators of all head models designed at the Scientific and Engineering Center of welding and control in the field of nuclear energy. The transmission of a torque from the output shaft of gear motor of drive *2* to drive gear *3* of reducing gear *1* of welding head is carried out by means of shaft *4*. Protection of drive *2* from the effect of electrical potentials that may occur on the assemblies and parts of reducing gear *1* is provided both by means of shaft *4*, as well as by intermediate piece *5* made of an insulating material, and protection from the action of mechanical environmental factors is performed with the help of cylindrical handle *6*, in which, in addition to drive *2*, limiting filter *12* and plug *13* for connecting communication cable to rotator are located. Reducing gear *1* of the welding head includes casing *7*, cover *8* of the casing, set of gears *9* and output gear *10*. In order to provide mounting of welding heads on pipes of «infinite» length, casing *7*, cover *8* and output gear *10* and faceplate are made with a slot *B*. Output gear *10* of reducing gear *1* is meshed with two gears of the set of gears *9*, which provides a smooth and continuous rotation of output gear *10* regardless of its angular position relative to its two orthogonal axes (axes of the plane perpendicular to the longitudinal axis of a pipeline being welded). The other two gears of the set of gears *9* are meshed with drive gear *3*, mounted on shaft *4* by means of a key connection. Shaft *4* is manufactured in the form of a cylindrical body of revolution made of an insulating material, which is attached to the output shaft of drive *2* using the inner steel sleeve and pin *11*. Pin *11* protects drive *2* from exceeding the maximum allowable load value — when reaching or exceeding this value, pin *11* is cut off and should be replaced after eliminating the causes of excessive load. On output gear *10*, faceplate is installed.

Since during designing automatic machines ADTs 627 U3.1, ADTs 625 U3.1, ADTs 626 U3.1, ADTs 628 UKhL4, ADTs 629 UKhL4 and ADTs 630 UKhL4 for GTAW the most progressive world experience in this direction and technological capabilities of domestic production were taken into account, clamping (fixing) mechanisms designed at the Scientific and Engineer-

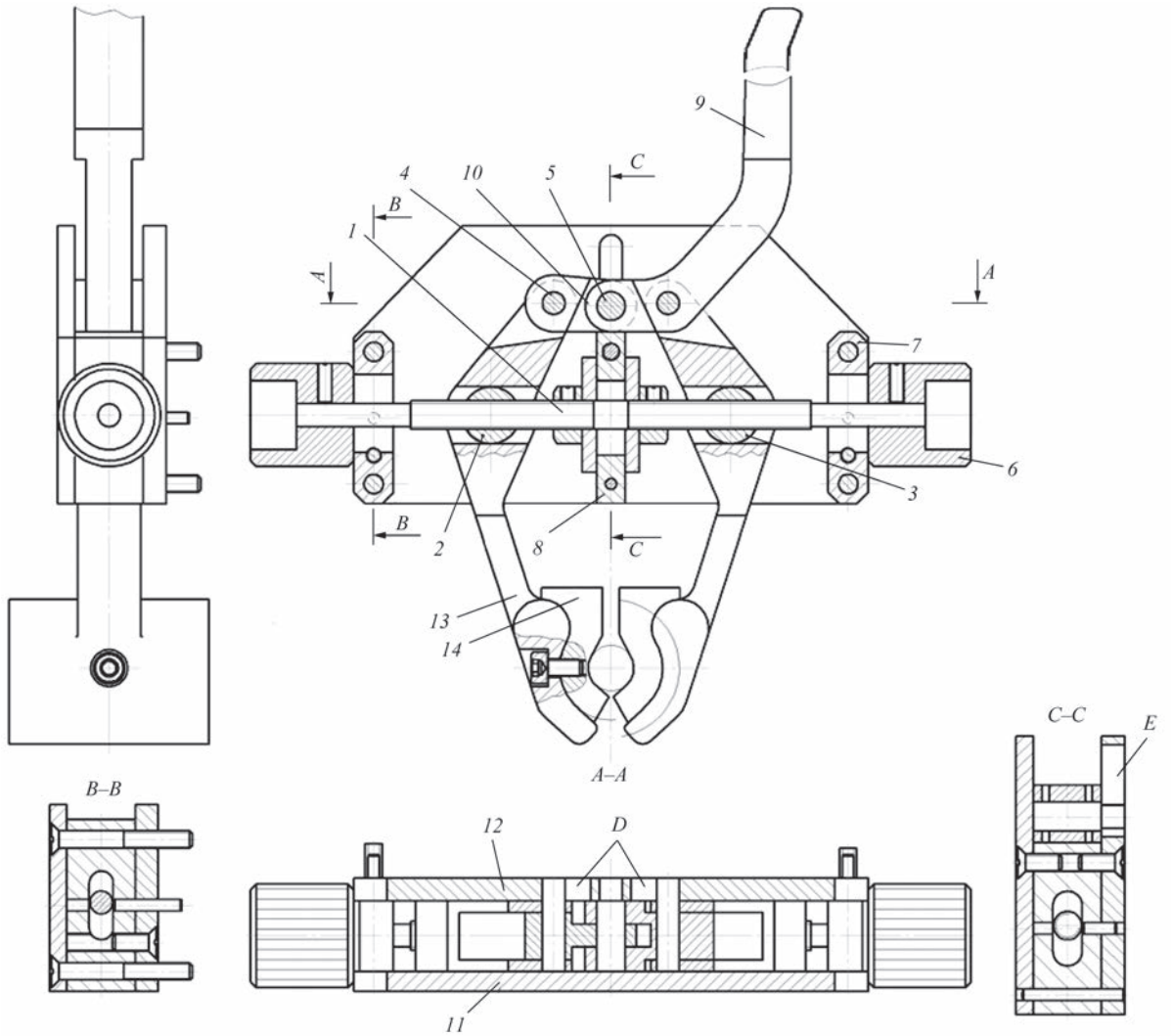

Figure 4. General view of clamping mechanism in all models of welding heads (designations see in the text) designed at the Scientific and Engineering Center of welding and control in the field of nuclear energy

ing Center of welding and control in the field of nuclear energy, welding heads on a pipe to be welded are in many respects resemble to the mechanisms of a similar purpose produced by Polysoude (France). The basis of this technical solution was the properties of a «breaking» lever. A general view of the mechanisms for clamping welding heads designed at the Scientific and Engineering Center of welding and control in the field of nuclear energy is shown in Figure 4. The clamping mechanism consists of screw *7*, nuts *2* and *3*, axes *4* and *5*, flywheels *6*, supports *7* and *8*, lever *9*, connecting rod *10*, cheeks *11* and *12*, grips *13* and inserts *14*. Screw *1* is made in the form of a pin, having a right-hand thread on a one end and a left-hand thread on the other. Nut *2* installed in one of the grips *13* also has a right-hand thread, and nut *3* installed in the other grip *13* has a left-hand thread. When screw *1* is rotated (using flywheels *6*), the grips *13* converge or diverge, depending on the direction of rotation of flywheels *6*. In addition, with the help of axes *4*, grips *13* are connected with lever *9*, which, in turn, is connected to connecting rod *10* with the help of axis *5*. Since two slots *D* and one slot *E* are provided in cheek *12*, when lever *9* is rotated, axes *4* acquire the ability to move in the slots *D*, and axis *5* — in the slot *E*. At the same time grips *13* are rotated around the nuts *2* and *3*. In one of the possible extreme positions of lever *9*, axes *4* will be shifted down (in the vertical direction) by 0.5 mm relative to axis *5*, as a result of which the clamping mechanism will come to a state, in which it turns out to be kinematically closed. Taking into account the design and kinematic diagram of the clamping mechanism for fixing the welding head on a pipeline to be welded, the head should be mounted on a pipeline to be welded, lever *9* of the clamping mechanism should be moved to the extreme left position and flywheels *6* should be half-way rotated in the direction providing bringing grips *13* into a contact with the outer surface of a pipeline to be welded, after which lever *9* is set to the extreme right position and flywheels 6 are turned in a half-turn in the direction that provides convergence of grips *13*, and lever *9* is

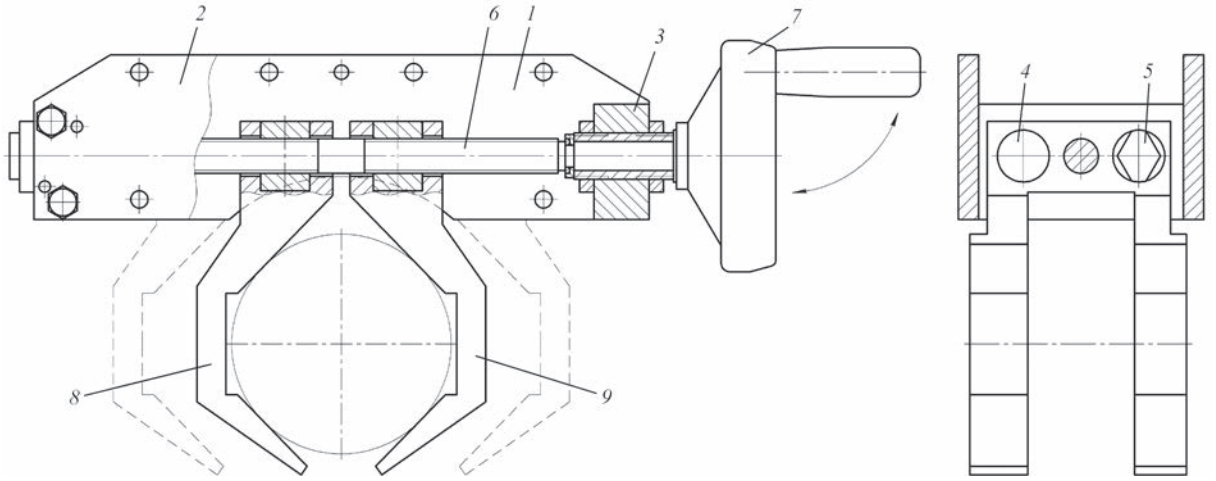

Figure 5. General view of alternative clamping mechanisms for all models of welding heads (designations see in the text) designed at the Scientific and Engineering Center of welding and control in the field of nuclear energy

moved (with a click) to the extreme left position. Then it is necessary to check the reliability of fixing of the welding head on a pipeline being welded and in case of insufficient clamping of the head, repeat all the operations of its fixing in the abovementioned sequence.

However, in the process of introduction and pilot operation of automatic machines ADTs 627 U3.1, ADTs 625 U3.1 and ADTs 626 U3.1 for GTAW, the disadvantages in the clamping mechanisms of welding heads were revealed, a general view of which is shown in Figure 4. The most significant drawbacks of such clamping mechanisms include the need for their preliminary adjustment on specimens, whose outer diameter is the same or very close to the outer diameter of a pipeline to be welded, high requirements to the absence of ovality of its outer surface, impossibility of achieving accuracy of alignment of the welding head on a pipeline being welded, which predetermine the necessity of using AAVR, the need in providing the smallest possible distance between the pipes to orient a certain spatial position of the welding head due to the presence of lever *9* in its clamping mechanism. The alternative clamping mechanisms, designed in 2017–2019 at the Scientific and Engineering Center of welding and control in the field of nuclear energy, the general view of which (typical) is shown in Figure 5, taking into account the experience of NIKIMT and other organizations, to a large extent are deprived of the noted drawbacks. As is seen from the Figure, the proposed clamping mechanism consists of two base plates *1* and *2*, separated by supports *3*. Along the guides *4* and *5*, one of which is made tetrahedral, by means of screw *6* having a right and left-hand thread on its own opposite ends and rotating by flywheel *7* with a throwing up handle, clamps (prisms) *8* and *9* can move in two opposite directions. One of the advantages of this technical solution is the preservation of the radii of rotating parts of welding heads, the values of which are given in Tables 1 and 2. To other advantages the fact should be attributed, that due to the exact performance of working surfaces of the clamps and their synchronous movement, converging and diverging, as well as the possibility of adjusting the position of the axis of the clamping mechanism relative to the axis of rotation of the welding head with a subsequent fixation of that position during its assembly, the proposed clamping mechanism provides an accurate alignment of the welding head on a pipe being welded. Moreover, there is no need in maintaining the set arc length in the welding process (for example, using the ALS or AAVR device).

At the same time, for regulating, presetting (programming) and automatic maintaining the arc voltage stable during welding in accordance with the set value and the selected algorithm of welding cycle in welding heads ADTs 625.03.00.000 and ADTs 626.03.00.000, the unified device AAVR is provided. The mechanism of this device represents a fixed casing, in which parallel to the plane of faceplates of the mentioned welding heads a low-power reversible direct current gear motor (for example, 1524 T 024 SR IE2 — 128 16/7 of «Faul Haber») is located. By means of a gear, output shaft of gear motor is connected with actuating screw installed in the fixed casing of the AAVR mechanism, which provides the conversion of the rotational motion of the shaft of the gear motor (in either of two possible directions) into the reciprocating motion of actuating screw, causing a corresponding linear movement of slider along the two fixed cylindrical guides. In its turn, through the metal bracket and insulator (made of electrical insulating material), slider is rigidly connected to the welding torch body, which makes it possible to move this torch along the axis that coincides with the axis of nonconsumable electrode installed in the torch in one of two possible directions. The choice of this direction during practicing of a pre-

determined welding cycle occurs automatically and depends on the sign of the error signal, determined by the mismatch of the actual and set (programmed) values of the arc voltage [4, 9]. To prevent damage of reducing gear of the AAVR mechanism when its slider is located in one of the extreme positions, actuating screw of this mechanism is equipped with a protective coupling. A detailed description of operation of the controller performing control of the operation of the AAVR device of welding heads ADTs 625.03.00.000 and ADTs 626.03.00.000 is given in [8].

The automatic machines ADTs 627 U3.1, ADTs 625 U3.1 and ADTs 626 U3.1 for GTAW of position joints of metal pipelines, containing the drives described above, not only successfully passed the complex technological and operational tests at the E.O. Paton Electric Welding Institute of the NAS of Ukraine and at the Scientific and Engineering Center of welding and control in the field of nuclear energy, but also passed the pilot tests at the Atomenergomash, the Design Bureau Atomprylad of the SE NNEC Energoatom and also at the TISER LLC. Moreover, the pilot models of automatic machines ADTs 627 U3.1 with welding heads ADTs 627. 03. 00. 000 and ADTs 627. 03. 00. 000-01 are in operation from 2010 to the present day. The results of pilot testing are positive. At present time, at the Scientific and Engineering Center of welding and control in the field of nuclear energy, the complex technological and operational tests of automatic machines ADTs 628 UKhL4, ADTs 629 UKhL4 and ADTs 630 UKhL4 for GTAW of position joints of metal pipelines with oscillations of nonconsumable electrode and mechanized filler wire feed are being completed.

The mechanisms of rotation and clamping of welding heads ADTs 628.03.00.000, ADTs 629.03.00.000 and ADTs 630.03.00.000 for GTAW are manufactured similarly to the same mechanisms of welding heads ADTs 627. 03. 00. 000, ADTs 627.03.00. 000-01, ADTs 625.03.00.000 and ADTs 626.03. 00. 000, while the rotation mechanisms of welding heads ADTs 628.03.00.000, ADTs 629.03.00.000 and ADTs 630.03.00.000 use the same limiting filters and the principles of design of reducing gears as in welding heads ADTs 627. 03. 00. 000, ADTs 627. 03. 00.000-01, ADTs 625. 03. 00. 000 and ADTs 626. 03. 00.000, and clamping mechanisms differ from the latter only by grips. A general view of a typical design of welding heads ADTs 628.03.00.000, ADTs 629.03.00.000 and ADTs 630.03.00.000 is shown in Figure 6. Table 2 shows some of the basic comparative parameters and characteristics of the heads, proposed by the market, which are used in machines for GTAW of metal pipelines with oscillations of nonconsumable electrode and filler wire feed designed and manufactured by different companies [6, 10, 11].

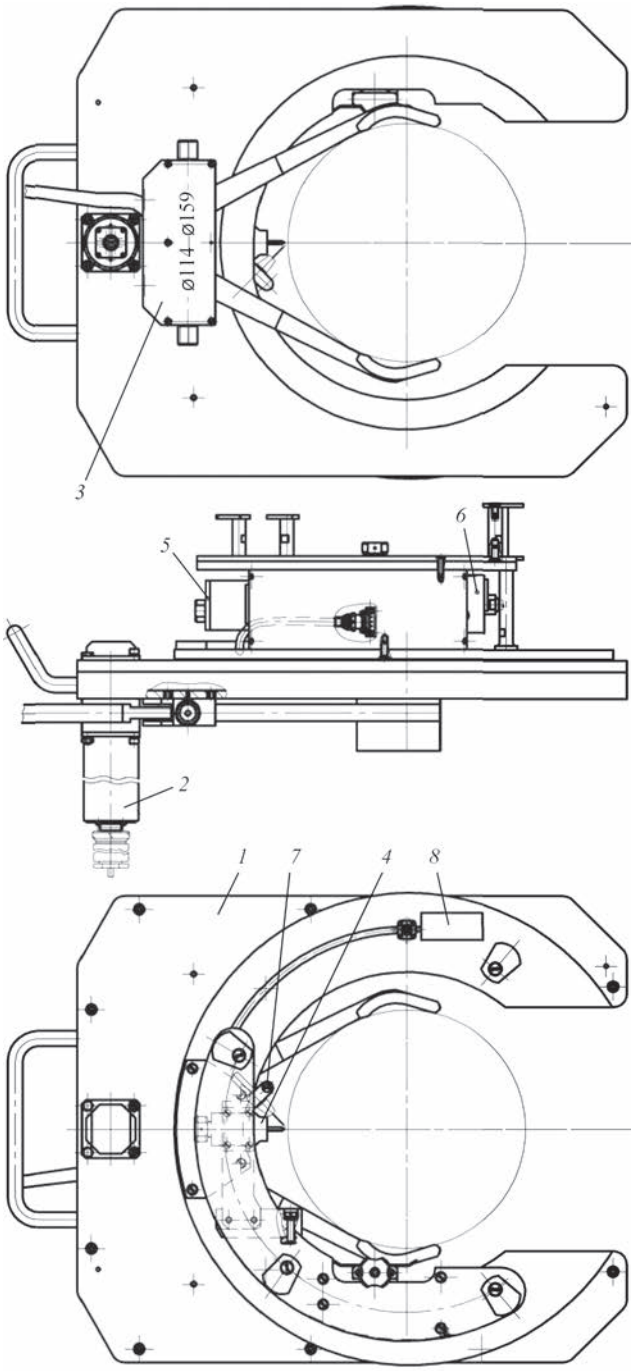

Figure 6. Typical general view of welding heads ADTs 628.03.00.000, ADTs 629.03.00.000 and ADTs 630.03.00.000: *1* — casing; *2* — rotation mechanism (rotator); *3* — mechanism for clamping (fixing) welding head on a pipe being welded; *4* — torch; *5* — AAVR mechanism; *6* — mechanism of transverse movement of nonconsumable electrode (oscillator); *7* — liner; *8* — sensor of spatial (angular) position of nonconsumable electrode

The feature of welding heads ADTs 627.03.0.000, ADTs 629.03.00.000 and ADTs 626.03.0.000 is that in addition to the actuating mechanisms mounted in the fixed casings of these heads and on their faceplates (torch,

Table 2. Some basic parameters and characteristics of welding heads in welding automatic machines for GTAW with the oscillations of nonconsumable electrode and filler wire feed

Number	Description of parameter, characteristic	Welding head (brand or designation and developer/manufacturer)			
		ADTs 628.03.00.000 (for welding in argon), Ukraine, Scientific and Engineering Center of welding and control in the field of nuclear energy	ADTs 629.03.00.000 (for welding in argon), Ukraine, Scientific and Engineering Center of welding and control in the field of nuclear energy	ADTs 630.03.00.000 (for welding in argon), Ukraine, Scientific and Engineering Center of welding and control in the field of nuclear energy	TAM-2 (for welding in argon), Russia, NIKIMT
1	Minimum diameter of welded pipe, mm	76	114	159	76
2	Maximum diameter of welded pipe, mm	114	159	219	133
3	Maximum welding current, A	250			
4	Range of welding speed control, m/h	1.7–27.0	0.95–13.50		3,0–14,0
5	Diameter of nonconsumable (tungsten) electrode, mm	3.0–4.0			2.0–4.0
6	Diameter of filler wire, mm	1,2; 1,4; 1,6			1,2; 1,4; 1,6; 2,0
7	Radius of rotating parts, mm, not more than	152.0	180.5	222	*R** + 130
8	Range of filler wire feed rate, m/h	4–55			10–50
9	Maximum radial movement of torch (nonconsumable electrode), mm	35.5		41.5	33.0
10	Maximum movement of torch (nonconsumable electrode) across the butt, mm	± 12	± 17		± 12
11	Cooling	Liquid (water)			
12	Overall dimensions: length, mm, not more than width, mm, not more than height, mm, not more than	 437 303 402	 480 350 475	 440 440 589	 275 340 450
13	Head mass (without communication cables and hoses), kg, not more than	13.5	16.0	22.0	29.0

AAVR mechanisms and mechanisms of transverse torch (nonconsumable electrode) movement, channel of filler wire feed), on each faceplate, the sensor of spatial position of electrode (accelerometer) is installed and rigidly fixed. The mechanisms for rotation of welding heads ADTs 628.03.00.000, ADTs 629.03.00.000 and ADTs 630.03.00.000 and their clamping mechanisms provide realization of the same options as the similar mechanisms of welding heads ADTs 627.03.00.000, ADTs 627.03.00.000-01, ADTs 625.03.00.000 and ADTs 626.03.00.000. In the mechanism of rotation of welding heads ADTs 628.03.00.000, ADTs 629.03.00.000 and ADTs 630.03.00.000, as the main components of the drive, the reverse gear motor 3257G 024 CR 32/3 of the Company «Faul Haber» and the encoder 05.2420.1211.0128 of the Company «Kübler» are used.

The design base of the torch of welding heads ADTs 628.03.00.000, ADTs 629.03.00.000 and ADTs 630.03.00.000 represents a rectangular metal body with two inner sealed cavities, one of which is intended for filling with cooling liquid (water) in order to realize its heat exchange with the mentioned casing, and the second is intended to function as a chamber of shielding (inert) gas entering the torch through the corresponding branch-pipe from the gas supply line of automatic machines for GTAW and flowing out of it through 10 holes with a diameter of 1.2 mm, which in combination with a gas filter, installed in the inner lower part of the torch body, provides a laminar flowing of shielding (inert) gas in the direction of welding zone through the ceramic torch nozzle.

The AAVR mechanism in welding heads ADTs 628.03.00.000, ADTs 629.03.00.000 and ADTs 630.03.00.000 is designed to provide maintaining the preset (programmed) length of welding arc and as to its design it is similar to the AAVR mechanism of welding heads ADTs 625.03.00.000 and ADTs 626.03.00.000. The peculiarity of the AAVR mech-

Table 2. Cont.

Number	Description of parameter, characteristic	Welding head (brand or designation and developer/manufacturer)		
		TAM-3 (for welding in argon), Russia, NIKIMT	MU-IV 76/195 P with built-in mechanism of filler wire feed (for welding in argon), France, Polysoude	MU-IV114/275 P with built-in mechanism of filler wire feed (for welding in argon), France, Polysoude
1	Minimum diameter of welded pipe, mm	133	76	114
2	Maximum diameter of welded pipe, mm	219	195	275
3	Maximum welding current, A	250		290
4	Range of welding speed control, m/h	3.0–14.00	0.5–20.0	
5	Diameter of nonconsumable (tungsten) electrode, mm	2.0–4.0	2.0–3.2	
6	Diameter of filler wire, mm	1,2; 1,4; 1,6; 2,0	0.8	
7	Radius of rotating parts, mm, not more than	R*+155	205	205
8	Range of filler wire feed rate, m/h	10–50	0.5–55	
9	Maximum radial movement of torch (nonconsumable electrode), mm	33.0	20	
10	Maximum movement of torch (nonconsumable electrode) across the butt, mm	± 12	± 15	
11	Cooling	Liquid (water)		
12	Overall dimensions: length, mm, not more than width, mm, not more than height, mm, not more than	90 520 550	500 410 500	616 500 530
13	Head mass (without communication cables and hoses), kg, not more than	35.0	32.0	35.0

Notes. 1. R* is the nominal outer radius of welded pipelines, mm.
2. Torches of welding heads of all the brands and developers/manufacturers mentioned in Table 2 are equipped with ceramic nozzles and gas lenses for forming laminar flow of inert gas or mixtures of gases coming out from them.

anism in welding heads ADTs 628.03.00.000, ADTs 629.03.00.000 and ADTs 630.03.00.000 consists in the fact that this mechanism is rigidly connected with the mechanism of transverse movement of the torch (nonconsumable electrode), intended for directing («aiming») of nonconsumable electrode to a welded butt and correcting the spatial position of this electrode across the mentioned butt joint, as well as for performing oscillations of nonconsumable electrode across the butt in accordance with the programmed values of the amplitude and oscillation frequency with electrode movements on the straight [4, 9]. As a drive in the AAVR mechanism of welding heads ADTs 628.03.00.000, ADTs 629.03.00.000 and ADTs 630.03.00.000, a reversive gear motor 2224 U 024 SR 20/1 of «Faul Haber» is used, and in the mechanism of transverse movement of nonconsumable electrode (oscillator mechanism) — the reversive gear motor 2642 W 024 CR of «Faul Haber» with a built-in encoder 05.24.20.1111.0128 of «Kübler» is used, which makes it possible not only to regulate the amplitude and frequency of electrode oscillations and to maintain their programmed values stable during the welding process, but also to automatically determine the moving direction of nonconsumable electrode.

As to their design, the mechanisms of AAVR and the oscillator of nonconsumable electrode in welding heads ADTs 628.03.00.000, ADTs 629.03.00.000 and ADTs 630.03.00.000 are combined in a one unit and in order to optimize the overall dimensions of these heads, the AAVR mechanism is installed perpendicular relative to the faceplate plane, and the oscillator mechanism is installed parallel to it.

The unit of the filler wire feed channel (liner unit) provides directing (feeding) of the filler wire to the zone of welding arc (weld pool zone), correcting the spatial position of filler wire relative to the nonconsumable torch electrode, changing and fixation of the spatial position of the liner when changing welding directions (directions of faceplate rotation).

The presence of a three-coordinate spatial position sensor (of accelerometer type) with electronic output installed on the faceplate of each of welding heads ADTs 628.03.00.000, ADTs 629.03.00.000 and ADTs

630.03.00.000 makes it possible to automatically determine the angular position of nonconsumable electrode in the plane (cross-section) of a welded butt relative to the gravity vector, which provides the performance of a programmed welding cycle regardless of the initial spatial position of nonconsumable electrode, and also obtaining a reliable information about its angular position for performance of welding cycle program in accordance with adequate control axes.

The mechanism for filler wire feed of welding heads ADTs 628.03.00.000, ADTs 629.03.00.000 and ADTs 630.03.00.000 is designed to provide movement of filler wire into the welding zone at a programmed speed and is made as a separate external unit, which allows using a standard reel for filler wire having a diameter of up to 300 mm. As a drive for this mechanism, DC electric motor was used, having a rated power of 100 W and a built-in encoder that generates 500 pulses per one full revolution of the output shaft of the electric motor. The main units of the filler wire feeding mechanism are two reducing gears and a standard four-roller clamping mechanism manufactured in Ukraine. The first among the reducing gears, which is a single-stage cylindrical one, provides the initial reduction with a ratio of 1: 3 and with the help of the second reducing gear of a worm type, a reduction with a ratio of 1:100 is carried out. The output shaft of the second reducing gear is connected to a four-roller clamping mechanism, in which by means of spring-loaded feeding rollers clamping to the filler wire and its direction into the feeding channel is provided. The feed rate is controlled by means of the filler wire feed drive controller, which is a part of the control system (CS) interface of the automatic machines ADTs 628 UKhL4, ADTs 629 UKhL4 and ADTs 630 UKhL4 for GTAW [8]. The controller generates a voltage at the motor armature and provides regulation and maintenance of a stable value of the programmed filler wire feed rate due to a feedback carried out by processing a sequence of pulses entering this controller from an information output of the optoelectric encoder built-in in the electric motor.

The water cooling system of welding heads ADTs 628.03.00.000, ADTs 629.03.00.000 and ADTs 630.03.00.000 is built on the principle of a closed liquid cooling system and is based on the use of autonomous water cooling units of domestic serial production designed to provide cooling and circulation of the working liquid in the cavities of torches with water cooling of machines for TIG welding at a welding current of up to 500 A.

The control of operation of the mechanisms and systems of automatic machines ADTs 628 UKhL4, ADTs 629 UKhL4 and ADTs 630 UKhL4, including the actuating mechanisms of welding heads ADTs 628.03.00.000, ADTs 629.03.00.000 and ADTs 630.03.00.000 is carried out by one and the same CS by means of its hardware and software. An obligatory component of CS is a standard personal computer. The software for GTAW automatic machines designed at the Scientific and Engineering Center of welding and control in the field of nuclear energy is based on the use of the integrated environment Lab VIEW and a personal computer with operating systems Windows XP-SP2 or Windows 7 either Windows 10.

Conclusions

1. Designing, manufacture, testing and results of pilot operation of experimental models of automatic machines ADTs 627 U3.1, ADTs 625 U3.1 and ADTs 626 U3.1 for orbital welding using nonconsumable electrode in inert gas or mixtures of gases (mainly by the methods of autopressing, successive penetration and antipressing) and designing, manufacture and testing of experimental models of automatic machines ADTs 628 UKhL4, ADTs 629 UKhL4 and ADTs 630 UKhL4 for orbital welding with oscillations of nonconsumable electrode and filler wire feed and the further development of the industrial manufacture of these machines and their components create all the necessary preconditions for equipping the assembly organizations, repair detachments and enterprises of power engineering and other sectors of the Ukrainian economy with domestic modern equipment, which makes it possible to realize both used as well as new technologies for automatic welding of position butt joints of thin-walled pipelines with a nominal outer diameter ranging from 7 to 76 mm, as well as pipelines with a nominal outer diameter ranging from 76 to 219 mm with a wall thickness of up to 12 mm and edges preparation from austenitic, pearlitic and martensitic classes of steels, high alloys, nonferrous metals and alloys (except aluminum and its alloys).

2. The presence of a personal computer in the CS of the developed automatic machines ADTs 628 UKhL4, ADTs 629 UKhL4 and ADTs 630 UKhL4 makes it possible not only to perform adaptive control of GTAW processes and equipment for its realization, but also to document the actual values of parameters of these processes and conditions of welding, to conduct their retrospective analysis and comparison with practiced computer models, to obtain initial information for carrying out reliable non-destructive testing, diagnostics and predictive calculations of reliability of welded position butt joints of pipelines.

3. The further development of domestic technologies for GTAW of position butt joints of pipelines

and equipment for their realization in the direction of increasing the level of automation approached to robotization is possible due to the modernization of some actuating mechanisms of welding heads for GTAW, use of video sensors, creation of a bank of typical welding conditions, advanced use of modern (for example, signal) microprocessors and nonvolatile memory.

4. The mechanisms of automatic machines for GTAW considered and described in this work can be successfully used in automatic welding machines and installations for producing rectilinear and curvilinear welds using nonconsumable electrode in the inert gas shielding and in mixtures of gases.

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