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WELDING

Practical workbook

ЗВАРЮВАННЯ

Навчальний посібник до лабораторного практикуму

Kharkov “KHAI” 2007
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In the workbook are submitted different types of welding, operational procedure and technical data of welding equipment, as well as heat generation, chemical and metallurgical processes, which influence to joint formation. Specific welding in aviation industry are describe: argon arc welding of aluminum and titanium alloys, as well as spot and seam resistance welding, microplasma welding, est.

The workbook is intended for domestic and foreign students who are taking course “Welding in aviation” in English.

Викладено різні способи зварювання, опис лабораторних робіт і характеристик зварювальних машин, а також процеси тепловиділення, хімічні, металургійні процеси, що впливають на утворення сполук. Розглянуто специфіку зварювання в авіаційній промисловості: дугове зварювання у середовищі аргону алюмінієвих і титанових сплавів, а також точкове, роликове, плазмове та ін.

Для вітчизняних та іноземних студентів, що вивчають на англійській мові курс „Зварювання в авіації”.

Fig. 24. Tab.10. Bibliography 5
Іл. 24. Табл.10. Бібліогр.: 5 назв

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Laboratory work № 1

RESISTANCE SPOT WELDING

The aims of the work are:

1. To study the structure and operational principles of the machine *MT-1606* and the process of resistance spot welding,
2. To tune the machine, weld the specimens, test their strength and select the optimal welding mode,
3. To draft the report.

Description of the machine *MT–1606*

Technical data of the machine

The *MT–1606* machine is designed for spot welding of structural and high-alloyed steels, titanium alloys from 0.8 up to 6.5 mm thick, as well as for welding of some copper alloys (as brass, bronzes, etc.) up to 1.2 mm thickness. Maximum power of the machine is 95 kW, rated welding current is 16 kA, maximum number of spots per minute is 200.

The machine's electrical circuit

The electrical circuit (figure 1.1) consists of the following parts:

1. Fuse switch (*FS*) (switches off the machine if it is overheated).
2. Welding transformer (*TR*) (used for voltage lowering to 2.9…5.7 V). The primary winding of the transformer consists of a set of bobbins for welding current adjustment. Secondary winding consists of one coil (one wap). From secondary winding current is supplied to electrode holders and electrodes through a powerful copper bus.
3. Power level switching unit (*PLSU*) (used for welding current changing.) Sections of the transformer's primary winding are switched off or on by switching keys.
4. Contactor (used as a snap-action switch to switch off the current in the primary winding). Contactor consists of two thyristors *T1* и *T2*.
5. Hydraulic valve (*HV*) (installed in contactor circuit to prevent switching the machine on without water cooling).
6. Welding timer (*WT*) (provides for automatic control of the machine). It is an electronic-relay device to switch on and off the electromagnetic pneumatic valve and contactor in definite sequence. This ensures that the parts are pressed together, the welding current is switched on and off, and upper electrode goes up at the right moment.
7. Pedal button (*PB*) (intended for starting up)

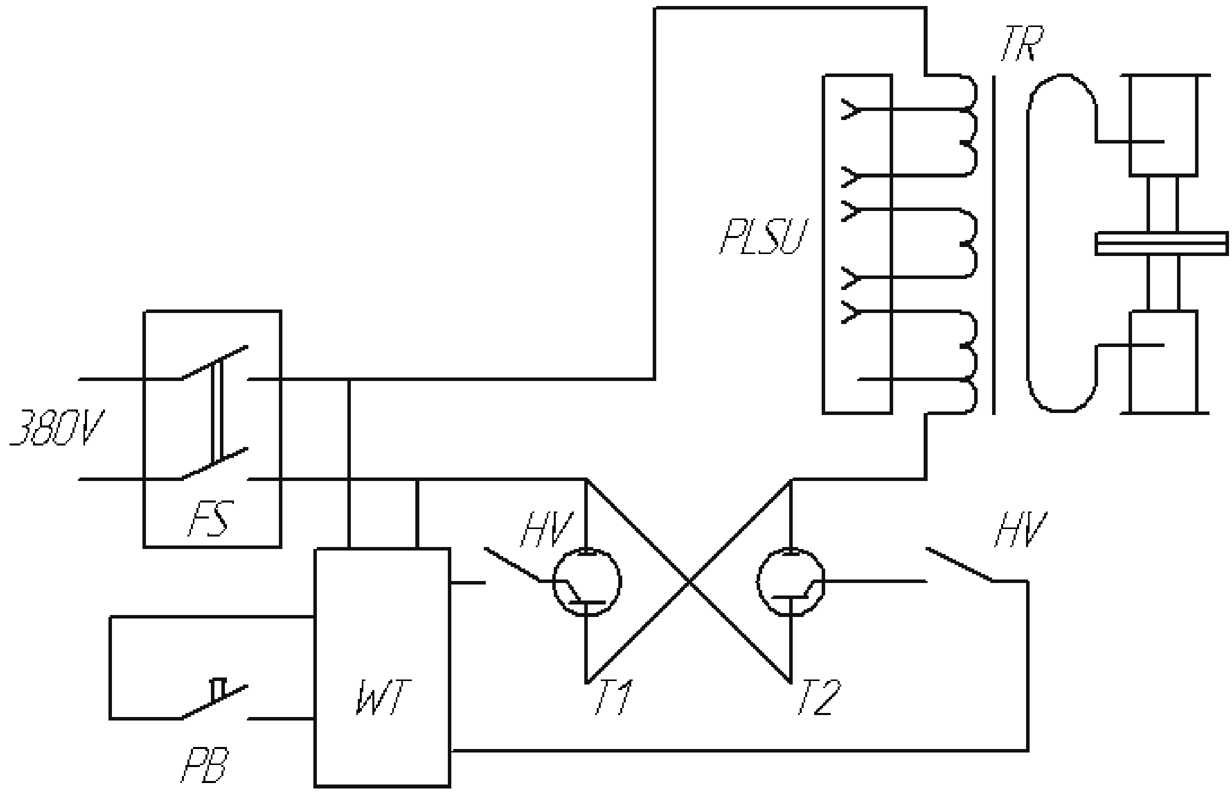


Figure 1.1 - The electrical circuit of the machine *MT-1606*

Pneumatic system of the machine

Pneumatic system (figure 1.2) is used for pressing welded parts together. It includes cylinder with two plungers inside, electromagnetic pneumatic valve *2*, oil atomizer *3*, pressure regulator *4*, drive valve *5*, two throttling valves *1*, air filter *6*, and communicating hoses.

From air supply net air passes through the filter and gets to the pressure regulator. Using the pressure regulator the working air pressure is set. Pressure is monitored by a manometer. From the pressure regulator air goes to the electromagnetic pneumatic valve and then (depending on valve's handle position) gets either in the under chamber of cylinder, lifting the under plunger up to the upper plunger, or in the middle chamber (through the upper hose and the upper plunger rod), pushing the under plunger down and pressing the parts.

Oil atomizer supplies oil for moving parts. Moving air carries oil away from the oil atomizer and lubricates pneumatic valve, cylinder and plungers.

Upper plunger position control valve is used for air inflating or bleeding from the upper chamber of the cylinder. While the air is bleeding the upper plunger is moving up to cylinder head and the electrodes move apart to the maximum distance.

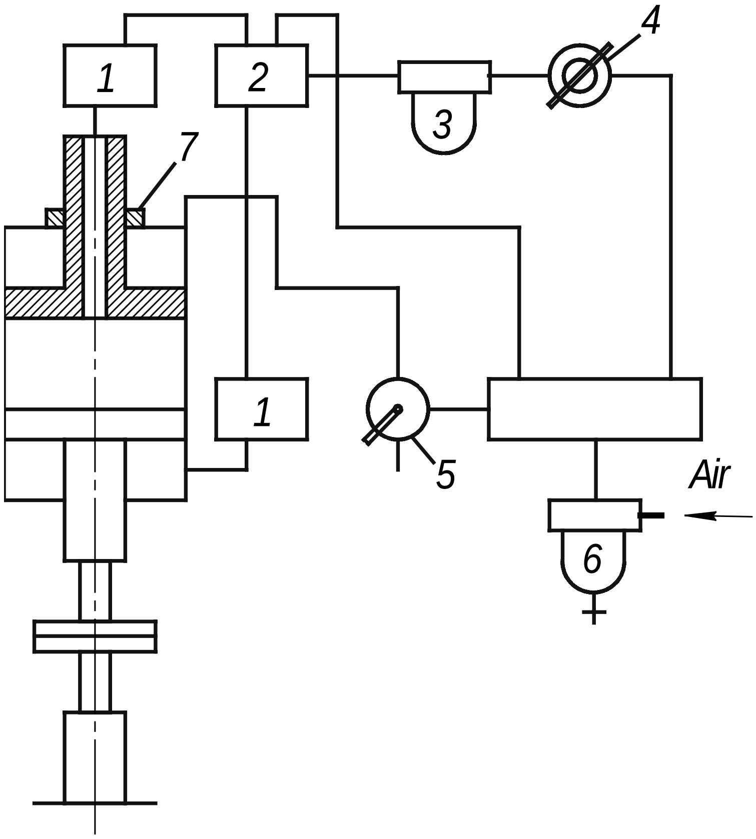


Figure 1.2 - Pneumatic system of the machine *MT-1606*

The throttling valve adjusts speed of air feeding to the cylinder's chambers. So, it controls traverse speed of under plunger.

Upper electrode holder is connected with the under plunger. The under electrode holder and the electrode are immovable.

The cooling of the machine

In the machine *MT–1606* the stream of water cools some parts of transformer's secondary winding, electrode holders of electrodes and thyristors. Water from water-supply network goes throughout rubber hoses to the parts which need cooling. Directed to cool thyristors, water passes through hydraulic valve. If the water supply is cut off, the hydraulic valve turns off the thyristors and the welding current won't switch on.

Working procedure within the machine:

Spot welding is executed by joint action pressure and heating. The parts are heated by current flowing through them.

The welder places the parts between electrodes and presses the *PB*, which switches the welding timer on. While operational, the welding timer activates electromagnetic pneumatic valve, which feeds air in the middle chamber of cylinder, so the under plunger, slider, upper electrode holder and electrode go down and press the parts. Pressing force should be strong enough to ensure good contact between the parts and the electrodes.

In some time (squeezing time) what is needed for pressing force stabilization, the welding timer activates the thyristors. It causes welding current in the column of metal which is gripped between the electrodes. The quantity of heat, which is released in the column of metal, depends on welding current strength, resistance of the column of metal and time of welding current.

The surface of welded parts is cooled strongly in the area under water-cooled copper electrodes. The heat sinks into the electrodes which results in the following thermal state. The maximum temperature is halfway between the electrodes, where the metal melts and forms a so-called welding nugget. Molten metal nugget is kept from run-out by the dense ring of surrounding metal heated up to plastic state. On the expiry of welding time the current is switched off. After this the parts are kept under pressure for some time (holding time) without welding current, it is necessary for solidification of the molten metal. When holding is over the welding timer breaks supply circuit of electromagnetic pneumatic valve, slide valve change it's position and air goes to the under chamber of the cylinder. Under plunger moves up and releases the welded parts. The electrodes will be separate during the pause time for parts changing. Then cycle of welding will repeat.

Thus **the generic welding cycle for a spot consists of squeezing, welding, holding and pause**.

For one spot welding you need to press the pedal button for a second and set it free. The switch during this time should be in the position of simple cycle («Одиночный цикл»). While working with a high quantity of spots you may use the position of automatic work («Автоматическая работа»). In this case the pedal button should be pressed permanently. The machine will repeat the welding cycle automatically.

Machine adjustments for specific behavior:

The main parameters of spot welding process are welding current I_w, welding time t_w, electrode pressing force P, electrode contact spot diameter d.

Depending upon the specified material and sheet thickness these parameters could be calculated approximately, but experimental selection is more accurate. At the same time quality weld nugget should have definite diameter d_n and height h_n (figure 1.3). In this case the joint strength will be ensured.

The other parameters of welded spot which also matter sometimes are: the indentation ***c***, value of joint opening ***a***, width of yielded region ***δ***. If yielded region is very small or overheated then melted metal could flow out and thus spitting will occur. It results in the increase in indentation significantly and in decrease of the strength of joint.

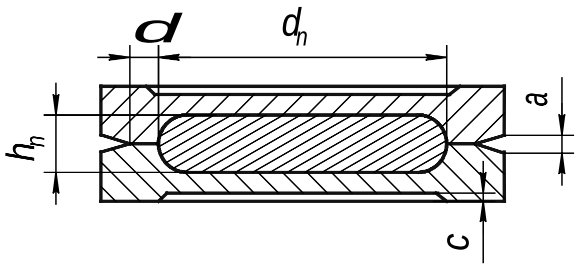


Figure 1.3 - Weld cross-section and its typical dimensions

Machine adjustments consist of picking and setting up the:
1. Power level (determines current strength),
2. Pressing force of parts,
3. Upper electrode stroke;
4. Holding time, welding time, forging time, pause.

Power level and pressing force are selected depending on thickness and type of welded material. Power level is set by three switch keys (right side within machine). Pressing force is set by the screw of air regulator and is controlled by manometer. The dependence of electrode pressing force of pressure in manometer and dependence of power level on switch keys position are in the table on the right side of the machine.

Upper electrode stroke is selected depending on configuration of welded units and parts and is set by the nut, screwed on upper plunger rod. While turning the stroke you need to turn valve handle to the left. Turn it to the right later.

Times for holding, welding, forging and pause are set by the switches of welding timer (right side under frame). Switch scale calibration is in the periods of alternating current with 50 hertz frequency (duration of one period is 0.02 sec).

The switches in the left column have increments of one period (1…9) and in the right column have increments of 10 periods (0…90). Time of each operation is adjusted within the limits of 1…198 periods, i.e. within the limits of 0.02…3.96 sec, with 0.02 sec step.

Procedure to start working with the machine:

After the machine is turned for correct welding conditions you may involve the machine into work (after getting permission from a instructor). For this purpose you need to:
1. Switch the knife-switch and the circuit breaker on;
2. Supply air into the machine (switch the compressor on, rise pressure up to 6 atm and open the valve at air-intake filter of the machine);

3. Take out one of the key of power level switch;
4. Press the pedal button and test the machine working without welding current;
5. Set the switch key into previous place.
After this the machine is ready for welding.

Content of the report

1. The electrical circuit of the machine *MT-1606* and its main elements.
2. The pneumatic system of the machine *MT-1606* and its main elements.
3. The protocol of welding and strength testing in accordance with a form of the table 1.1.

Table 1.1 - Protocol of sample testing

Exp. num.	Material - Sheet thickness, mm - Type of joint - single-spot, lap Electrode contact spot diameter, mm -					
	Pressure, atm	Pressing force, P, kN	Power level	Welding time, t, sec	Distractive force, P, kN	Nature of destruction
1						
…						

4. The graph of dependence P = f(t).
5. The selection and grounds for optimal welding conditions.

Check questions

1. Where the heat is released under spot welding?
2. What are the characteristic dimensions of welding spot?
3. What does the cycle consist of?
4. What are the main parameters of spot welding mode?
5. How can one avoid empty-out of molten metal, not decreasing the strength of welded spot.
6. How can one change the parameters of welding mode if the thickness of welded sheets has increased?
7. What do we need the squeezing for?
8. What is the purpose of some units of electric circuit?
9. Indicate the purpose of some units of pneumatic system.
10. How can one adjust spot machine for max welding current (to do it practically)?
11. What is the min. value of welding time which may be set on the machine?

Laboratory work №2

RESISTANCE BUTT WELDING AND SOLDERING

The aims of the work are:
1. To know the technique of resistance butt welding and soldering.
2. To know the particulars of MC-301 and order of its preparation for work to weld or to solder.
3. Welding and soldering some specimens, test its strength, make the conclusion about weld quality, pick up the optimal welding conditions.
4. Drawing up the report.

Process of butt welding

Resistance butt welding is based on metal heating up by electric current passing and deforming (yielding) it by mechanical force for metal bond ensuring in all surface of welding.

Butt welding is performed on special machines in two ways - by resistance and by flashing action.

Resistance butt welding:

This method is used for low-carbon and low-alloyed steels, that don`t make a refractory skin during heating. Parts preparation for welding consists in fine edge fitting and its careful trimming from dross and rust.

The elements to be welded are placed between the copper posts of the machine and are pressed together with force P, so as to improve the contact (figure 2.1, a). Then the welding current is switched on, the transient resistance decreases and does not influence the heating process. Most of the heat is involved on the metal's own resistance.

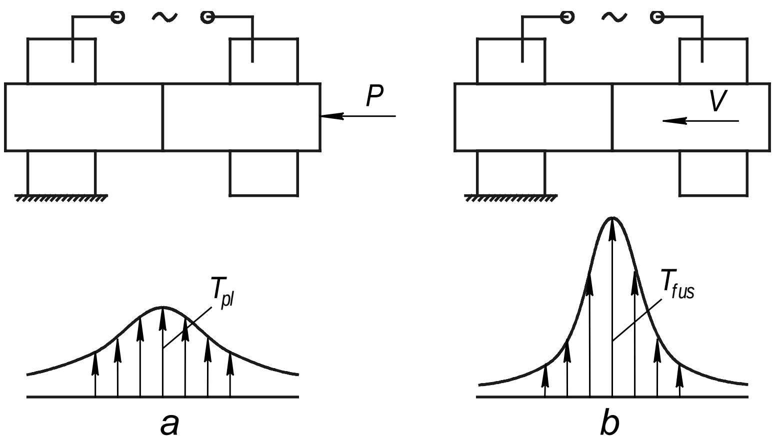


Figure 2.1 - Butt welding:
a – resistance butt welding, b – flash butt welding

The parts between the copper posts are not heated evenly. The maximum temperature does not depend on the joints position, it is in the zone, which is equidistant to both copper electrodes, and nearer to the electrodes, the lower the temperature because of intensive heat sink. Faying surfaces of parts shall be in the maximum temperature zone.

Metal heats up to the plastic state in the butt zone, after that the pressing force $\boldsymbol{P_p}$ deforms the weldments with defined upset distance $\Delta \boldsymbol{L}$.

The main parameters of upset welding are:- welding current $\boldsymbol{I_w}$, welding time $\boldsymbol{t_w}$, initial squeezing force $\boldsymbol{P}$, pressing force $\boldsymbol{P_p}$, upset distance $\Delta \boldsymbol{L}$, distance between clamps $\boldsymbol{L}$.

Flash butt welding

This technique is suitable for welding low carbon and low alloyed steels, copper and aluminum alloys, high alloyed and special steels, some dissimilar metals.

Under the influence of flash welding (figure 2.1, b) the parts are in contact without pressure. In this case the heat generation is increased at the zone of contact resistance. This results in temperature rise in the contact surface, where metal fuses intensively and splashes out. To restore the contact between parts they are brought together with the feeding speed equal to burn off rate. When the current is switched off the welding zone is deformed by upset force $\boldsymbol{P}$. At that fused metal flows out and it results in good conditions for getting into contact with pure (un-oxidized) metal and it's bonding the flaying surfaces all around.

The main parameters of flash welding are: welding current $\boldsymbol{I_w}$, feeding speed $\boldsymbol{V}$, burn-off distance $\Delta \boldsymbol{L_{оп}}$, burn-off time $\boldsymbol{t}$, upsetting force $\boldsymbol{P_{ups}}$, upset distance $\Delta \boldsymbol{L}$.

Butt resistance welding machine MC-301

The machine is designed for upset welding of structural and highly-alloyed steels, some non-ferrous metals and alloys. Resistance brazing may be also performed at this machine.

Technical data of the machine

1. Nominal power – 5 kW
2. Supply voltage – 380 V.
3. Cross-section welded: steel – 35…50 mm^2
   copper alloys – 8…20 mm^2.
4. Maximum of squeezing force – 5000 N.
5. Number of power level – 6.
6. Secondary voltage – 1…1.8 V.
7. Welding current – 6.8…12.2 kA.

Structure and electric circuit of the MC-301 machine

Shell-type welding transformer *TR* with power level switches *PS1* and *PS2* (figure 2.2) is mounted in the top half of the case.

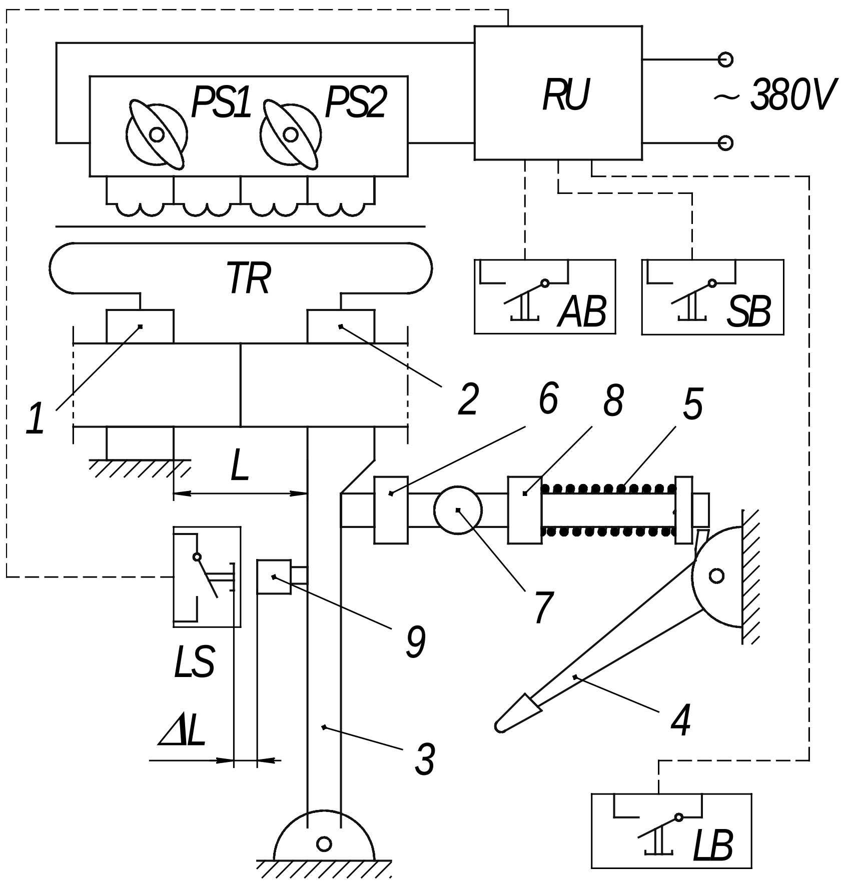


Figure 2.2 - Electric circuit of the *MC-301* machine

The relay unit *RU* is located in the bottom right of the machine. Stop button *SB* and button for annealing *AB*, and shears for cutting of weldments are mounted on the welder's front side.

The immovable lever-eccentric clamp *1* is mounted on the upper plate of the welder's case. The movable clamp *2* is mounted on the rocking lever *3*; its eccentric axle is fastened in orifices on the front and rear plates of the case.

The weldments are squeezed with the pressing force $\boldsymbol{P_p}$ when the arm *4* is pulled to the farthest position. Its crankshaft squeezes the spring *5* and passes the force to the movable clamp *2* via screw *6* with a spherical joint *7*. Pressing force can be adjusted by a nut *8* which tightens the spring *5*. Initial distance between clamps *L* is adjusted by the screw *6*. Push bar *9* is placed on the movable clamp; it can be used for adjustment of the upset distance ***ΔL***.

When the start button *LB* is pressed, the *RU* turns on and electric current is supplied to the primary winding of welding transformer.

When the adjusted upset distance is reached, a push bar *9* pushes the limit stop and breaks the supply circuit; the relay contactor switches the welding current off. It can be also switched off manually by the *SB*.

The *AB* button shall be pressed to anneal the parts; it switches on the *RU*. In this case the current are switched on only for a time while the button is pressed.

Depending on the grade of material and cross-section area of weldments, adjustment of the machine for resistance upset welding consists of setting up the following parameters:

Power level;
Pressing force P_p;
Upset distance ΔL;
Distance between clamps L.

The order of operations in the resistance welding

1. Set up the required welding parameters.
2. Push the arm to the farthest position.
3. Mount the weldments in clamps without a gap.
4. Pull the arm to the farthest position.
5. Define the position of the movable clamp by a ruler placed on the top of the machine's case.
6. Switch the welding current on by pressing *LB*; make the required welds.
7. Check the upset distance by the ruler.
8. Release the article from the clamps.

The process of metal brazing and soldering

The process of soldering includes such main operations: preparation of soldering surfaces, their mounting, soldering and the following treatment of the article.

Liquid solder wets the solid metal well if its surface is purely clean. That is why the soldering zone is mechanically and chemically cleaned; during the soldering process fluxes are used, they additionally clean the metal surface from oxide and adipose coatings and also protect the metal from oxidizing during the heating. Flux must have a sufficient cast ability at the soldering temperature (T_s), should be easily removed after soldering and should not cause a corrosion.

Both purity metals and alloys can be used as a solder. The latter should have a melting temperature (T_m) that is less than T_m of the soldering metal ($T_{m.\ solder} = T_{m.\ metal}$ – 50…100°C); the solder should wet the metal well and fill gaps, and it also should be corrosion-proof. Coefficients of thermal expansion of solder and soldering metal should be approximately equal. High-temperature copper, silver and nickel solders, and low-temperature stannic, lead, zinc and other low-melting solders gained ground.

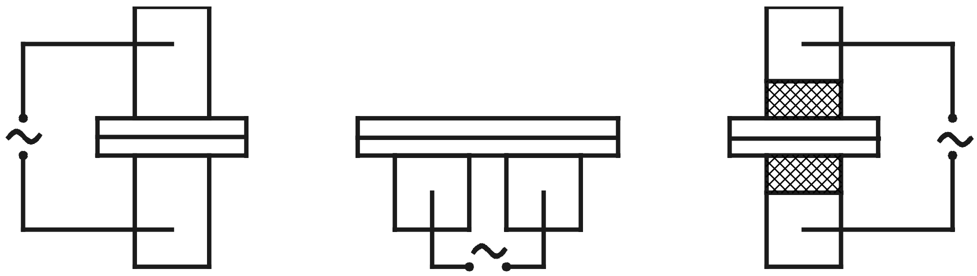
Soldering conditions include heating conditions, hold time at the temperature of T_s, conditions of cooling. Usually T_s is greater than T_m of a solder: $T_s = T_{m.\ solder} + 30\ldots50°C$. During the hold time the solder must melt, fill gaps and make fillets. Conditions of cooling should not permit the intensive oxidizing of metal and formation of thermal stress cracks. Soldered joint porosities which appear if the cooling of the solder is fast are also undesirable.

During the soldering the heating of parts can be general or local. General heating is used for soldering of relatively small articles. Heating can be performed by gas and plasma burners, soldering irons, different stoves, salt baths. Inductive, radiation, resistance and other methods can be used.

The resistance brazing of metals

Under resistance brazing the joining area are heated due to the heat evolved in parts through which current flows. For resistance brazing resistance welding machines are usually used. In this case joining zone may be heated in different ways, such as:

1. Current flows through both of parts, which are placed between the electrodes (figure 2.3a)
2. Current flows through one of the parts, another are heated due to heat conductivity (figure 2.3b).
3. Current flows through the coil plates placed between the electrodes and the article. Current heats the coil plates and the joining area are heated due to heat conductivity (figure 2.3c)



a b c

Figure 2.3 – Techniques of resistance brazing

The operational procedure on the machine

In this work the sample brazing is performed on the machine *MC-301*.

1. Set the desired power level.
2. Cover the ends of the parts to be welded and solder plate with flux.
3. Fix the parts in clamps within the gap between 1,5…2 mm.
4. Place solder plate to the gap and grip it by lever.
5. Switch the current on by pressing *LB* and after complete fusion of solder switch the current off by pressing *SB*. Do not allow the overheating of the metal.
6. Release the article from the fixture.

The content of report

1. The figures of resistance butt welding and flash butt welding.
2. Main parameters of the both resistance butt welding and flash butt welding.
3. The protocol for testing welded and brazed samples in the form of table 2.1.

Table 2.1 - Protocol of sample testing

<table>
<tr><td colspan="4">Material –
Cross-section area of the sample -</td><td colspan="4">Brazier –
Flux -</td></tr>
<tr><td rowspan="2">Num. of exp.</td><td rowspan="2">Type of process</td><td colspan="3">Mode of welding or brazing</td><td rowspan="2">Time of welding, sec</td><td rowspan="2">Distractive force, kN</td><td rowspan="2">Nature of distraction</td></tr>
<tr><td>Pressing force, kN</td><td>Power level</td><td>Upset distance, mm</td></tr>
<tr><td>1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>…</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

4. The selection of optimal modes of welding and brazing and the analysis of results obtained.

Check questions

1. Release of heat under butt welding.
2. Operation procedure under butt resistance welding and flash welding.
3. Main parameters of resistance butt welding and flash butt welding.
4. Nature of temperature distribution within the heated zone under resistance butt welding and flash butt welding.
5. List the main assembled units of the gear of machine pressing and indicate their destination.
6. List the main units of electric circuit of the machine *MC-301* and indicate their destination.
7. Technological procedure of metal brazing.
8. Main parameters of resistance brazing mode.
9. Technique of heating under resistance brazing.
10. Resistance brazing operational procedure on the machine *MC-301*.

Laboratory work № 3

Machine submerged welding

<u>The aims of the work are:</u>

1. To know the technological process of machine submerged welding and the particulars of the machine *A1416*.
2. To tune the machine for required welding conditions, weld the specimens, measure hardness of weld, base metal and heat affected zone. To conclude the quality of the weld made.
3. Prepare the report.

Process of machine submerged welding:

This process (figure 3.1) uses welding arc, which is completely hidden under the special loose powder called flux.

The flux includes ionizing, deoxidizing, alloying, slag-making and other components. As bonding agent they use liquid glass (alkali silicate).

The electrode wire *1* is fed into welding zone. The arc is covered by flux *2* which is fed from storage bin. The flux is melt and surely hide arc. Wire *1* and some base metal is fused. As the arc moves away the fluid metal *6* is solidified and weld *4* is formed. The shell *3* made of consolidated welding flux, which shields the weld till it becomes cool.

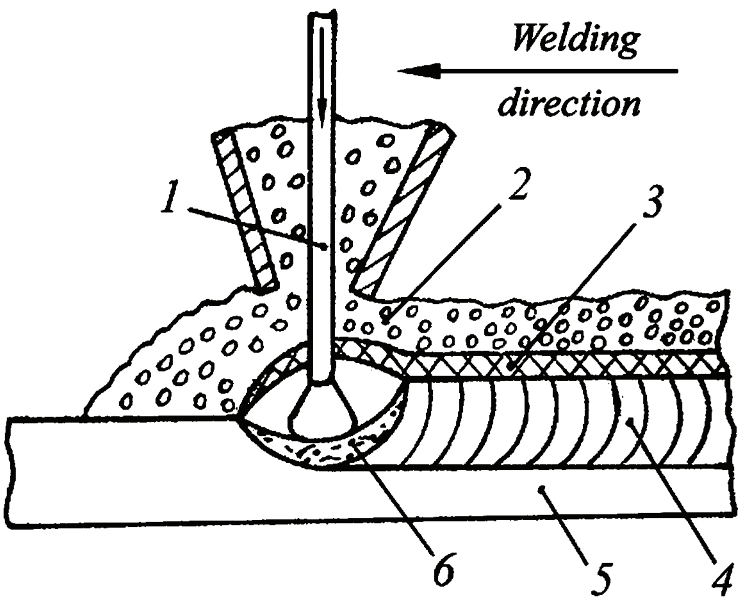


Figure 3.1 - Graph of submerged arc welding process flow

The machine submerged arc welding has much more efficiency than manual arc welding. Automatic machine welding is characterized by high quality and very good conditions of work.

Nowadays they use the machines working with constant feeding rate of fillet wire. In this case operating mode ought to select in such a way as to secure equality between wire fusion rate and feeding rate. Short circuits are not allowed and arc length should be constant. To ensure this the welding source must have high short-circuit current, i.e. output characteristic of power source must be flat slope. Such type of output characteristic guarantees that in case of the arc length decrease the welding current will have a considerable increase in number ΔI (figure 3.2), the electrode will be fused faster and the arc length will restore up to its previous value. The effect of the arc length restoration is called “arc self regulation”.

Main parameters of automatic welding are:

1. Welding current I_a (It determines the depth of penetration).
2. Arc voltage U_a (It determines weld width).
3. Electrode wire feed speed V_f.
4. Electrode wire diameter.
5. Speed of welding V_w.

All operational parameters of welding are interdependent. The change of one of them will change other parameters (one or more) or else the quality of bead will become worse.

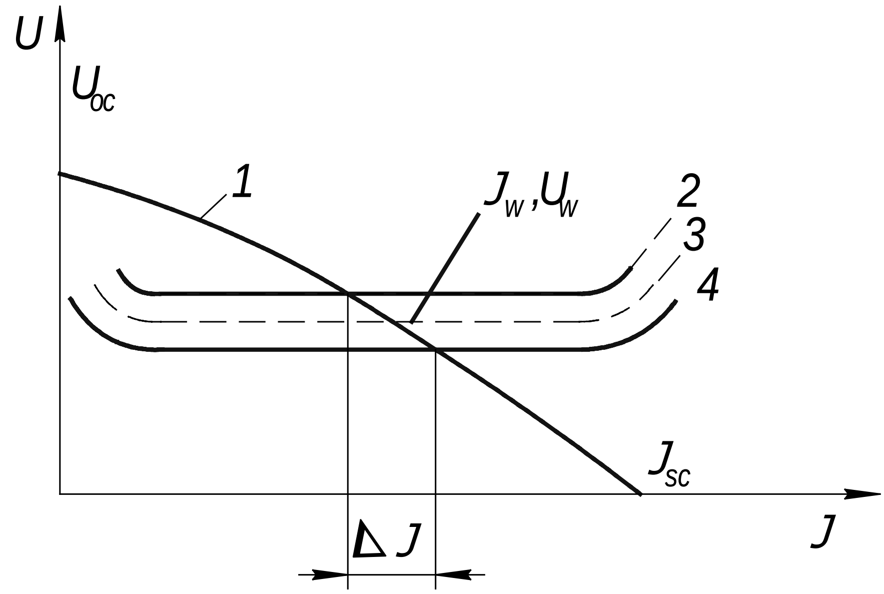


Figure 3.2 - Slopes of welding source and arc:
1- slope of welding source; 2 – voltage-ampere characteristic of arc at normal length; 3 – at short length

A1416 head for automatic submerged arc welding

Welding gun *A1416* (figure 3.3) is designed for submerged welding to weld butt, corner and lap joints (linear or circular if diameter is large).

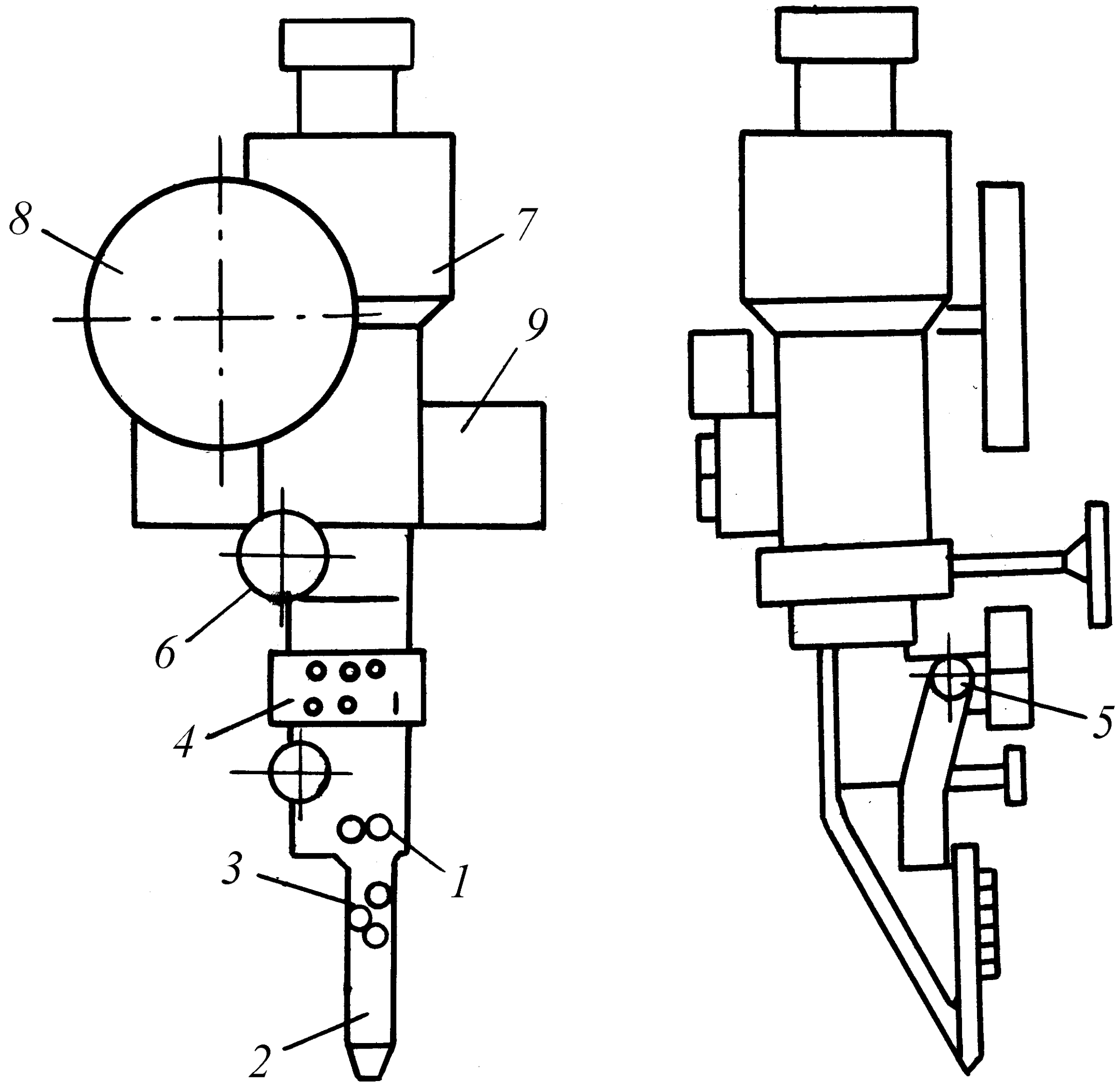


Figure 3.3 - Head *A1416* structure

Welding operational specification

1. Speed of welding – 0.2…2 m/min.
2. Filler wire feed speed – 0.5…6.0 m/min.
3. Diameter of filler wire – 2.5…6.0 mm.
4. Welding current – 200…1500 A.
5. Welded metal thickness – 5…25 mm.

A1416 head works on the principle of arc self regulation, i.e. with constant filler wire feed speed. It consists of the following main parts:

1. Welding head includes feed mechanism *1*, contact tube *2* used for electricity supplying to electrode wire, coil straightener *3* to straight wire, control panel *4* and hanger bracket with correcting mechanism *5*.
2. Set B, includes lifting mechanism *6*, flux distributing device *7* with aspirator and bobbin for electrode wire *8*.
3. Set C represent a monorail self-propelled truck *9* with separated electric drive. At truck measuring instrument (voltmeter and ampere meter) are mounted.
4. High power welding transformer intended for arc supply, for example, *CT-1000*, *CT-500*, est.

To switch on the transformer and engines of truck and feed wire device the contactor control apparatus is (set under welding desk).

Welding head adjusting

The adjusting consists of selecting and setting up the following parameters: welding current I; wire feed speed V_e; travel speed V_w, electrode out distance.

The current adjusting is performed with welding transformer. For this purpose *CT-500* front panel there are two handles, by means of which the magnetic shunt is moved. The current shall be evaluated approximately according to the scale pointer at front board of the transformer. Under welding you may get the accurate value of current by ampere meter.

Wire feeding speed and welding speed can be adjusted by changeable gear. Burn-off distance of electrode wire can be set up by flywheel of hoisting mechanism.

Methods for butt joint welding.

There are one side and double side butt welds. In case, when it is possible to turn the welded parts upside down, someone may use double side welding with weld penetration up to 60% the thickness of sheet at one pass (figure 3.4, a).

Under one side welding it is required to use backing, to avoid burn-through damage Copper removable backing (figure 3.4, b) is suitable for joints with small gap or without it, copper-flux backing (figure 3.4,d) for joints with large gap, in some cases non-removable steel backing (figure 3.4, c) is desired.

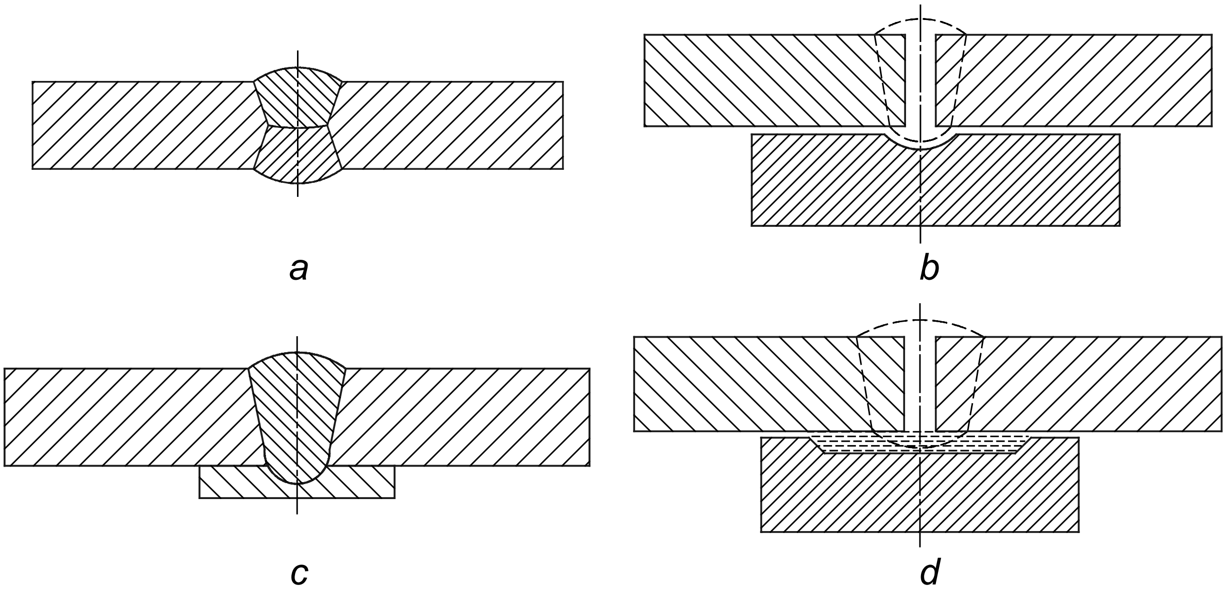


Figure 3.4 - Type of butt joints

Directions to practice welding

1. Clamp the parts. Check if the joint line and welding directions are in parallel. To do it you need to move welding head along the joint by buttons “Forward” and “Back”. Handle on self-propelled truck should be down.
2. Set up welding parameters: the current strength, welding speed, wire feeding rate (according to instructor’s directions).
3. Lead the welding head to weld beginning. Locate the contact wheels of welding head over welded parts to have the electrode out. The distance between contact wheels and welded parts should be the 20…25 mm length. Rest the electrode wire against the parts by buttons “Up” and “Down”. Switch on the automatic travel of head by changing handle position to the up.
4. Cover electrode and joint with flux, by opening sleeve valve at upper part of flux feeding sleeve. Flux layer thickness should be 40…60 mm.
5. Press the button “Start” to start welding.
6. Controlling weld, stop welding. For this press the button “Stop-1” if the welding head coming to joint end, wait 1…2 second to seal the crater and press “Stop-2”.
7. Move the welding head off; clear away the flux, after cooling, chop the slag shell off.
8. Weld the back side according to the steps 2…7.
9. After welded article cooling, measure hardness of base metal, weld and heat affected zone.

Content of the report

1. Scheme of automatic under flux welding.
2. Main parameters of welding mode. Main assembles of *A1416* head.
3. Sketch of butt joints.
4. Protocol of welding parameters and conditions, testing results.

Table 3.1 – Protocol of welding conditions and testing results

Material and thickness	
Type of the joint	
Current, A	
Voltage, V	
Welding speed, m/h	
Wire feeding speed, m/h	
Flux	
Weld hardness, HRC	
Base metal hardness, HRC	
Heat affected zone hardness, HRC	
Weld appearance	

5. Conclusion on the quality of weld made.

Check questions

1. What components does a flux include?
2. What main units and gears do you know?
3. What main parameters of machine submerged arc welding do you know and how do they influence on the weld appearance?
4. How to tune the required speed of welding, wire feeding rate and welding current?
5. How can we increase weld bead width without changing quantity of overlapping metal?
6. Where is the current connected to electrode wire?
7. What is the weakest zone of the weld and why?
8. What slope of power source is preferable for submerged welding if electrode wire feeding rate is constant?

Laboratory work № 4

Manual arc welding with AC transformers

<u>The aims of the work are:</u>
1. To know the structure and operational principals of the transformer *ТД-500*;
2. To know practical welding;
3. To study the external characteristic of the transformer;
4. To prepare the report.

Welding transformers

Special power supply sources are used to sustain an electric arc while welding. Open circuit voltage of power sources for manual arc welding on the safety side shall be maximum 75 V for AC and 65 V for direct current. The slope shall be steep.

Special decreasing transformers are used as the source of AC. These transformers obtain steep slope by:
- Connecting an auxiliary throttle to transformer. The throttle is adjustable inductive resistance X_{thr}
- Using special structure of transformer itself, which ensures the increase of inner inductive resistance X_{tr}
- Changing the inductive resistance X_{thr} and X_{tr}, you can change slope the of power source and thus change the welding current.

The transformer ТД-500

Performances:

1. Power consumed	32 kW
2. Voltage of power source	220 or 380 V
3. Open circuit voltage:	
a) at range of high currents	60 V
b) at range of low currents	75 V
4. Rated current	500 A
5. Range of current regulation	90-650 A

The transformer *ТД-500* is a portable device built into one case with natural ventilation. It may be referred to as a transformer with elevated inner inductive resistance (increased dissipation). We can obtain elevated resistance thanks to the fact that primary and secondary winding are located on the transformer core at some distance between each other. The inductive resistance ***X*** is adjusted by changing the distance between primary and secondary winding.

The transformer consists of the following main units:

a) Magnetic core;
b) Primary and secondary winding;
c) Current soft regulation gear;
d) Current range switch;
e) Current indicator;
f) Filter for decreasing interferences under radioreceipt;
g) Case.

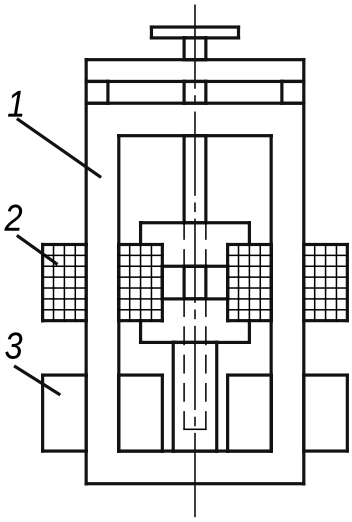


Figure 4.1 - Scheme of welding transformer *ТД-500*

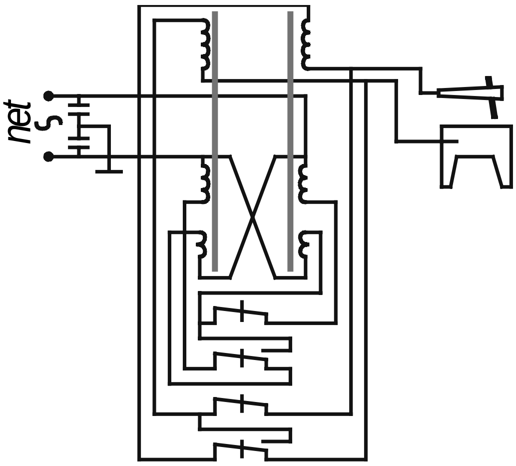


Figure 4.2 - Electric circuit of the transformer *ТД-500*

The magnetic circuit *1* is a core-type magnetic circuit. The bobbins of primary *3* and secondary winding *2* are placed on the core (see figure 4.1).

The secondary winding consists of two sections and the primary winding consists of four winding, two of which are the paramount with a great number of winds and the others are additional with a low numbers of winds. (see figure 4.2). The bobbins of secondary winding are movable and can move up or down to the bobbins of primary winding with the help of screw mechanism. This fact contributes to soft current regulation. When the bobbins approach each other the inductive resistance *X* decreases and the welding current increases.

When the secondary winding moves away from the primary winding, the inductive resistance increases and welding current decreases.

Furthermore current range regulation is possible by switching the bobbins order (current range switch). Parallel connection of bobbins gives low inductive resistance and the range of high currents and the subsequent connection gives high inductive resistance and the range of low current.

Under subsequent connection of sections (the range of low currents) the additional sections of primary winding are switched off and the open circuit voltage of transformer increases up to 75 V. This fact influences positively on stability of the arc at low currents.

The current indication mechanism is connected to movable winding by lever gear. The indices on its scale are approximate ones.

The transformer is equipped with the volumetric filter intended for deduction of radio interferences, which emerge while welding.

<u>The external characteristic of power supply source</u>

The external characteristic *1* is a dependence of voltage at out source fixture the current in outer circuit (under unchangeable adjustment of the source).

In condition of manual arc welding this characteristic shell be steep slope. Under manual arc welding the oscillations of electrode tip relatively the item are inevitable. In this connection the arc length changes within the limits 0…2 cm. When doing this the arc voltage $\boldsymbol{U_a}$ changes within the limits 20…40 V.

If steep slope the change of working current is insignificant. The arc is stable, the short circuit current a bit exceeds current, and the power source is not overloaded.

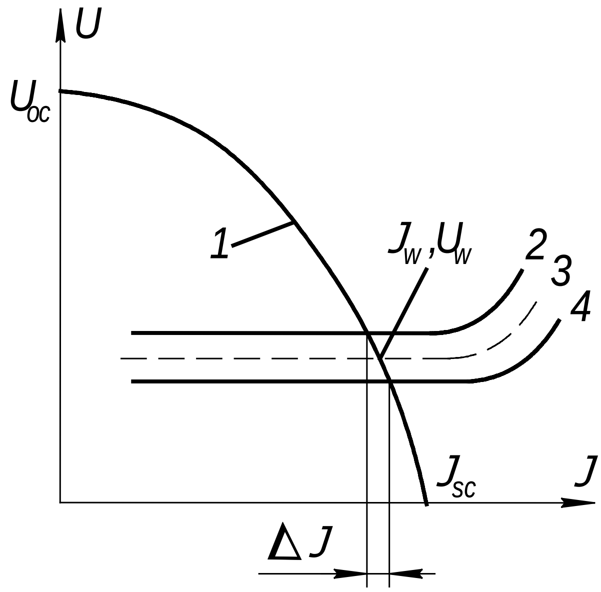


Figure 4.3 - The curves of power source and the electric arcs: 1- external characteristic slope of the power source; 2,3,4 –curves of volt-ampere characteristics various for arc length

Referring to the transformer, which supplies the electric arc, external characteristic is described by the equation in vector view

$$\overline{U_t} = \overline{U_a} = \overline{E_2} - \imath X_t \overline{I_t} \,, \qquad (1)$$

where $\overline{U_t}$ - voltage at out fixture of the transformer (output voltage), which is equal to arc voltage $\overline{U_a}$; $\overline{E_2}$ - electromotive force of secondary winding,

$\overline{I_t}$ - operational current, $\boldsymbol{X_t}$ - inner inductive resistance of transformer, ι - single vector.

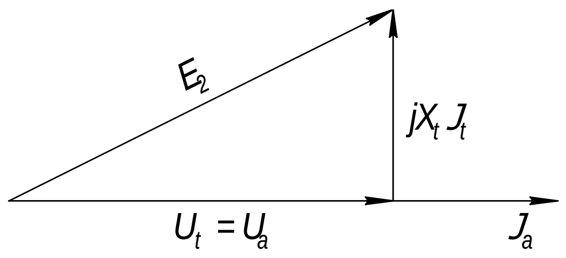


Figure 4.4 - Triangle of voltage

As the arc is an active loading, the arc voltage $\overline{U_a}$ and output voltage $\overline{U_t}$ coincide in phase with the arc current $\overline{I_a}$, and the voltage drop on the resistance $\boldsymbol{X_t}$ anticipates the current 90°.

The equation is shown graphically as a triangle of voltage (figure 4.4).

The equation of outer characteristic in scalar form shall have the following view

$$U_t = \sqrt{E_2^2 - X_t^2 I_t^2} \qquad (2)$$

In open circuit the current $\boldsymbol{I_t} = 0$, and $\boldsymbol{U_t} = \boldsymbol{E_2}$. In short circuit the voltage $\boldsymbol{U_t} = 0$, and the current

$$I_{sc} = \frac{E_2}{X_t} \qquad (3)$$

The current of short circuit may be changed by adjusting $\boldsymbol{E_2}$ and $\boldsymbol{X_t}$. In the transformer *ТД-500* when changing the distance between the bobbins only inductive resistance $\boldsymbol{X_t}$ is changed, but electromotive force $\boldsymbol{E_2}$ does not change practically. However, in switching the current range, the $\boldsymbol{X_t}$ and $\boldsymbol{E_2}$ both change.

Directions to perform practical welding

1. When performing welding you need to switch on the ventilation and to close the cabin.
2. Before the arc ignition you should warn the pupils, who are in the cabin.
3. Observe strictly the rules of safety measures.

Directions to take slopes of external characteristic

It is necessary to take a slope of three characteristics on the low currents range and three characteristics on the high currents range. The approximate adjustment of the transformer is shown in the protocol (table 3.1). Each slope is based on the following three dots: open circuit point ($\boldsymbol{U_t} = \boldsymbol{U_{oc}}$, $\boldsymbol{I_a} = 0$), short circuit point ($\boldsymbol{U_t} = 0$, $\boldsymbol{I_a} = \boldsymbol{I_{sc}}$) and operational mode ($\boldsymbol{U_t} = \boldsymbol{U_w}$, $\boldsymbol{I_a} = \boldsymbol{I_w}$).

All slopes shall be built on one graph in the scale 1V = 1 mm, 1A = 0.3 mm.

Table 3.1 - Protocol for building slopes of external characteristic

Num.of exp.	Current on the scale	Measurement			
		Open circuit voltage, U_{oc}, *V*	Short circuit current, I_{sc}, *A*	Operational mode	
				Current, I_w, *A*	Voltage U_w, *V*
1 2 3	90 150 240				
4 5 6	240 300 350				

Context of the report

1. Electric circuit of the transformer *ТД-500* and its technical performance.
2. Main analytical expressions as to the transformer. Triangle of voltage.
3. Protocol of testing the transformer.
4. Graphs of external characteristic slopes (Total 6 slops, 3 per each range).

Check questions

1. What are the main units of the apparatus *ТД-500* and their purposes.
2. How can we regulate the welding current on the apparatus *ТД-500*?
3. How can we realize stage switching on the apparatus *ТД-500*?
4. Which are the requirements to the apparatus for manual arc welding?
5. Which are the main analytical correlations with regard to welding transformer?
6. What does the inductive resistance of the transformer *ТД-500* depend on?
7. What is the voltage of electric arc?

Laboratory work № 5

ANALYSIS OF ELECTRIC ARC ATTRIBUTES AND EQUIPMENT FOR TIG WELDING

The aims of the work are:

1. To know the process of tungsten inert gas (TIG) welding, and structure of the *ИСТ-125* inverter.
2. To take measurements and draw slope of external characteristic *U = f (I)* of DC power supply *ИСТ-125* in continuous mode.
3. To get the measurements and draw the curve of current-voltage characteristics of arcs for two values of arc length.
4. To plot the dependence of arc voltage upon its length; determine the sum of cathode and anode voltage (U_c + U_{an}) and voltage drop per arc unit length (U_0).
5. To make some training welds under definite welding conditions.
6. To draw up the report.

Inverter *ИСТ-125* for argon-arc welding

The TIG welding is dominated in production of aircrafts and air-engines, because of its universality and high quality of welds.

Argon has been chosen as the shielding gas. Argon is an inert, neutral gas; it does not react with metals and does not dissolve in them; argon creates safe protection of weld zone. Besides, there is increased electron mobility in argon atmosphere, and arc activation is superior.

There are two types of argon arc welding: welding with consumable electrode (MIG welding) and with non-consumable electrode.

Consumable electrode is made of material which has the chemistry approximately equal to the weldment material. Often it is stored on spools or coils. MIG welding is automated process and consumable electrode is fed automatically.

Tungsten is usually used as the material of non-consumable electrode (figure 5.1). The tungsten electrode can be heated up to a high temperature without melting, which results in radiating a large quantity of electrons (thermal electron emission). Arc remains stable even when the current is very small (down to 1.0 A). Electrode wears out insignificantly in argon atmosphere.

Filler metals are also used in nearly all applications of TIG welding, the major exception being the welding of thin materials.

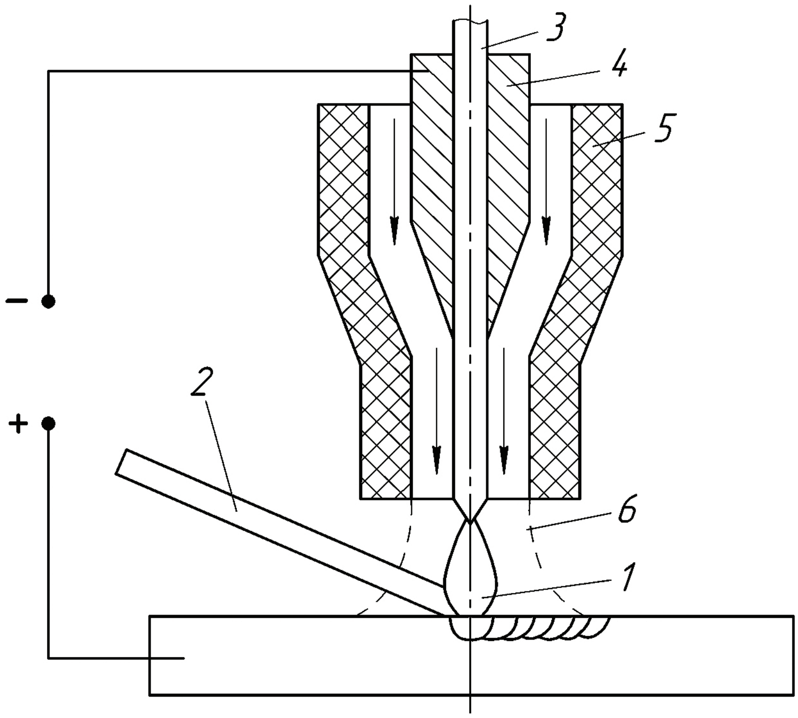


Figure 5.1 - Process of TIG welding:
1 – arc, 2 – filler metal, 3 – tungsten electrode, 4 – contact tube,
5 – nozzle, 6 – argon

Special current sources which meet the certain requirements are used for arc supplying. External characteristics of current source assume major significance. They show the dependence of voltage on supply terminals versus load, i.e. $U = f(I)$. These characteristics can be rigid, dropping and rising (figure 5.2).

Only steeply-falling external characteristic can guarantee steady-state arc burning under TIG welding.

Current-voltage (static) characteristic of arc shows the dependence between arc voltage $\boldsymbol{U_a}$ and current $\boldsymbol{I_a}$ (arc length $\boldsymbol{l_a}$ is constant).

Operating mode of arc (current $\boldsymbol{I_a}$, voltage $\boldsymbol{U_a}$) is defined by a cross point (A_1) of current-voltage characteristic of arc (4,5) and external characteristic (1) of power source.

Figure 5.2 shows that when external characteristic is steeply-falling, operating mode shifts from A_1 to A_2 in case of arc length change (from l_1 to l_2) on account of fluctuation of welding operator's hand. Here, current I_a varies by small amount. *ИСТ-125* power source (see below) meets such requirements.

The transistor device *ИСТ-125* is designed for tungsten inert arc welding of thin-gage metal (direct current straight polarity in argon atmosphere), and also for welding with consumable electrode (direct current straight or reversed polarity).

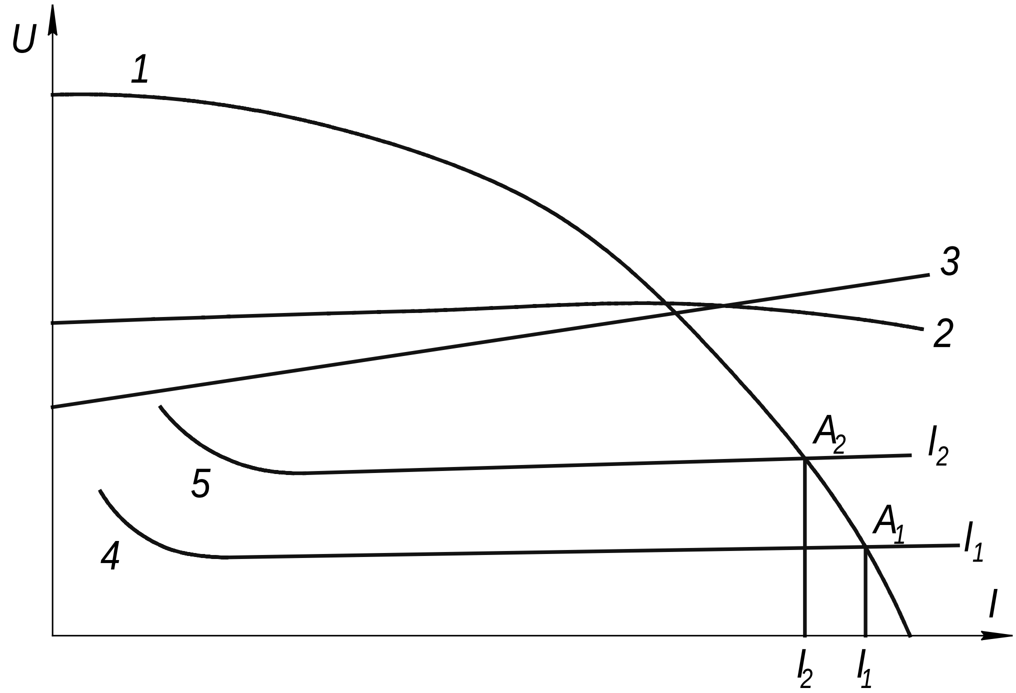


Figure 5.2 – Graph of current-voltage characteristics
1,2,3 – slopes of power source ; 4, 5 – characteristics slopes of arc

Technical data

1. Rated welding current	125 A
2. Current control range	25.0…125 A
3. Rated operating voltage	
– MMA welding	25 V
– TIG welding	15 V
4. Open circuit voltage	36 V
5. Maximum power consumed	6.0 kW
6. Supply voltage	220 V
7. Weight	35 kg

Principle of operation and structure of the device ИСТ-125

The principle of inverter operation (figure 5.3) consists in transformation of supply-line alternating voltage (220 V, frequency 50 Hz) to welding voltage (approximately 36 V) by means of high-frequency thyristor converter.

Due to the fact that converter has high frequency (16000 Hz), weight of converter and source elements in whole is substantially less than weight of traditional power sources elements.

The inverter consists of thyristor rectifier, filter, thyristor converter, outlet rectifier and control circuit. Alternating current which comes to input terminal of thyristor rectifier, is transformed to direct current, then – to the high-frequency current in thyristor converter, later the current is again rectified by the outlet rectifier to direct welding current and comes to output terminal of inverter.

Depending on welding process (manual metal arc welding or tungsten inert gas welding), external characteristics of inverter are generated by means of control circuit. The latter also protects the inverter from over currents and limits the open-circuit voltage at the output of inverter.

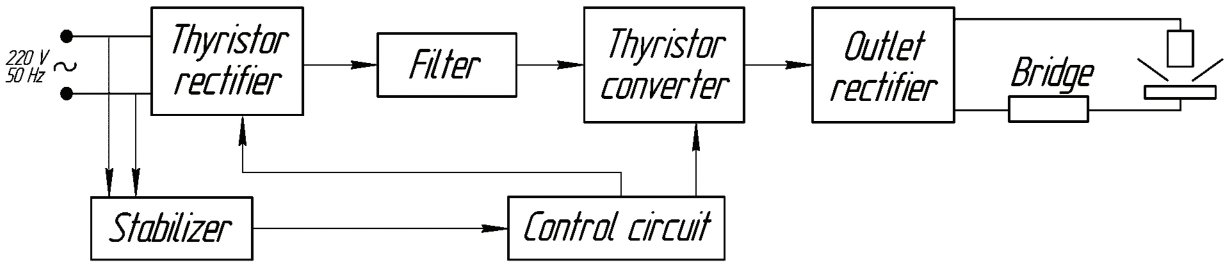


Figure 5.3 - Functional chart of the *ИСТ-125* inverter

Constructively, inverter has one case. Main structural components (front and rear faces, bottom, angle framework and casing) are made of duralumin. Elements of power circuit are mounted on two horizontal chassis made of dielectric. Elements of control circuits are mounted on four printed circuit boards integrated into one unit.

For cooling, inverter has forced air ventilation by fans. Just to this end, there are deflector blades on the side walls of the casing.

Front face of inverter has the following controllers and indicators:

a) amperemeter – for measuring of inverter welding current;
b) Network light – to warn about the presence of supply voltage;
c) Network switcher – to turn the inverter on and off;
d) Range switch (“25…70” or “70…125”) – to change the current range;
e) Toggle switch “Welding type” with positions “Manual metal arc welding” and “Tungsten inert gas welding” – to change the type of welding;
f) Smoothly knob – for smooth adjustment of welding current within the respective ranges;
g) Outlets “⊕” and “⊖” – to connect the welding leads.

Rear panel of inverter has the following components:

a) Nameplate;
b) Connector “Network” to connect the inverter to the current supply net;
c) Ground clamp “⊥” – to connect the ground lead;
d) Cover plate, which covers two protection devices of supply circuit by screws; there is a voltage sign “ϟ” on the cover plate;
e) Side wall of the case has a plate “Do not turn on without being ground”.

Working procedure of the ИСТ-125 device

1. Turn on the knife switch which is responsible for device feeding.
2. Set the toggle switch "Welding type" to the position "Manual arc welding".
3. Set the "Ranges" switch to the position which guarantees the residence of required welding current within the range.
4. Turn the "Network" switcher to the position "On".
5. Open the valve of the gas vessel, set the pressure to 5 newtons per square centimeter (0,05 MPa) over the low-pressure gauge by a reducer's screw (performed by instructor).
6. Current adjustment is performed by rotation of "Smoothly" knob. Every knob allows the current adjustment of appropriate range.
7. After completion of work, inverter should be disconnected by setting "Current network" switch to the position "Off".

Instructions for practical experience

1. Get the external characteristic of the *ИСТ-125* device for welding with nonconsumable electrode. Electric demand should be changed by variation of arc length l_a. For that, one should use the device in which the gas burner is fixed. Set the defined arc length l_a over the millimetric scale by rotation of device's micrometer screw.

While getting the characteristic $U = f(I)$, after arc excitation set the 40A current by direct current regulator. Then change the arc length (current regulator settings stay constant).

Put the measuring results into the table 5.1.

Table 5.1 – Output characteristic

Arc length l_a, mm	1	2	3	4	5
U, V					
I, A					

These data should be used also for plotting the dependence $U_a = f(l_a)$.

2. Get the current-voltage characteristic $U_a = f(I_a)$ for two values of arc length l_a. Put the results into the table 5.2.

Table 5.2 - Current-voltage characteristic of the arcs

I_a, A	25	30	40	50	60	70
U_a, V; l_a = 2 mm						
U_a, V; l_a = 5 mm						

Current is adjusted by a potentiometer «DC adjustment» on the front face. Initial current is 40 A.

3. Graph the dependencies: $U = f(I)$, $U_a = f(I_a)$, $U_a = f(l_a)$.
   All characteristics should be plotted together on one graph (use the following scale: 1 V ~ 4 mm, 1 A ~ 3 mm).
4. Determine $U_{an} + U_c$ and U_0:

$$U_a = U_{an} + U_c + U_0\, l_a,$$

where U_a – arc voltage, U_{an} – voltage drop in the anode spot, U_c – voltage drop in the cathode spot, U_0 – voltage drop per arc unit length, l_a – arc length.

For determination of these values, the curve $U_a = f(l_a)$ should be extended up to intersection with *y* axis.

5. Make training plate welds; put the results into the table 5.3.
6. Analyse the acquired results.

Table 5.3 – Welding mode

Material and its thickness, mm	Welding current polarity	Conditions	
		U_a, V	I_a, A

Content of the report

1. Purpose, technical data and functional chart of the *ИСТ-125* device.
2. Representation of the experimental results in the form of tables and charts.
3. Determination the values of $\boldsymbol{U_{an} + U_c}$ and $\boldsymbol{U_0}$.
4. Conclusions and explanation of the results obtained.

Check questions

1. What are the main protective qualities of argon.
2. Under what polarity the tungsten electrode wear is increased, and why?
3. What polarity causes the heightened heat evolution on the weldment?
4. Why does the arc welding with tungsten electrode provide the higher arc stability?
5. Which the formula of arc voltage. Determination of the $\boldsymbol{U_0}$ and $\boldsymbol{U_{an}} + \boldsymbol{U_c}$.
6. What is the requirement for the shape of power source external characteristic for manual welding with tungsten electrode?
7. How can we adjust the welding current in the device *ИСТ-125*.
8. Why does the current I_a remain practically constant under the changes of arc length l_a in the device *ИСТ-125*?
9. What are the main units of the device *ИСТ-125*, their purpose?

Laboratory work №6

MICROPLASMA WELDING

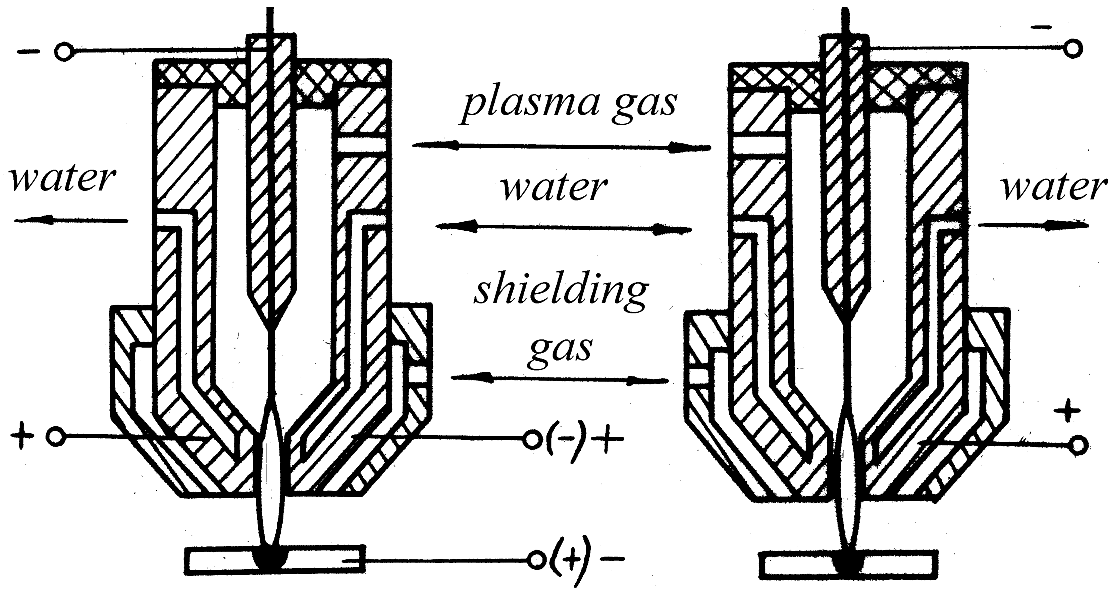
The aims of the work are:

1. To get acquainted with plasma welding technological process and the *МПУ-4* device structure.
2. To select the welding conditions for different materials and thickness; to weld the models.
3. To test the welding joints and the main metal for the strength (durability), to find the strength factor of the welding joints. To evaluate the heat flow density.
4. To prepare the report.

The description of micro plasma welding device *МПУ-4*

The *МПУ-4* device is intended for manual welding using plasma flow for ferrous, non-ferrous, light and refractory metals and the alloys with a thickness 0.1…0.3 mm. The plasma flow is received due to plasma torches (plasmatrones).

The direct action arc discharge can be used at the plasmatrones (figure 6.1), when the work metal is one of the arc electrode, and the non-transferred arc (figure 6.2) is used, when this metal isn't included in the current circuit. The second scheme can be used for the non-electro conductive materials treatment (ceramics, plastic and other).



a *b*

Figure 6.1 – Plasmatrone

The plasmatrone, as a rule, is powered by the direct current. In this case cathode is the internal tungsten electrode, and anode is the nozzle torch. Argon is commonly used as a working gas they in most cases, and in some cases- helium, hydrogen, nitrogen, air or mixture is used.

An electric arc is struck between the electrode and the nozzle. Into the nozzle (nozzle walls are cooled with water) plasma gas is fed under the pressure less than 50KPa. The outer layers of the gas flow passing through the outlet have a higher resistance, due to lower temperature, which is induced by the water cooling of the nozzle. That results in plasma concentration, its temperature rises sharply in the central part up to 10000…30000K. We have heavily ionized gas which passes through the outlet of the nozzle as luminous current. Due to heating the gas volume increases and this creates plasma flow of high velocity.

For weld zone protection an additional nozzle is installed, through which shielding gas (Ar, CO_2 and other) is fed.

МПУ-4 is powered by an alternating three-phase current (380V).

Technical data of the equipment

1. Working power, kW	-1.5
2. Shielding gas flow, l/min	-2…4
3. Cooling water flow, l/min	-0.5
4. Plasma generated gas flow, l/min	-0.2…0.5
5. Current source voltage of pilot arc, V	-70…80
6. Pilot arc current, A	-3
7. Current source no-load voltage of DCSP primary arc, V	-55…80
8. Straight polarity primary arc current , A	-2.5…30
9. Current source no-load voltage of DCRP primary arc, V	-70…80
10. Reverse polarity primary arc current , A	-4…12
11. Incendiary impulse amplitude, V	-220…260
12. Incendiary impulse duration, s	-2.

The important characteristics of the heat source are effective heat power $H_э$ and heat-flux density $\boldsymbol{q_э}$.

Plasmatrone arc voltage is higher, compared to the arc voltage under the influence atmosphere pressure, and equals to 30…50V.

During normal consumption the loss of heat equals to 50…70%, so the effective coefficient of efficiency is $\boldsymbol{\eta_э}$=0.3…0.5. For plasmatrone with non-transferred arc $\boldsymbol{\eta_э}$ is smaller and is equal to about 0.2.

It is typical for plasma torch to have high values of $\boldsymbol{q_f}$ (about $6x10^{-3}$ W/mm^2). That's why plasma torch welding has a higher effectiveness.

The device assures 4 welding modes:

1. Mode A- direct current straight polarity welding with the fine current adjustment (from 2.5 to 30 A);
2. Mode B- pulse-current straight polarity welding with the fine current adjustment (from 2.5 to 30 A) and discontinuous adjustment of pulse duration and intervals between them within the limits 0.02…0.5s;
3. Mode C- pulse-current straight and reverse polarity welding with the fine current adjustment within the given limits and discontinuous adjustment of pulse duration and intervals within the limits 0.02…0.5s;
4. Mode D- direct current reverse polarity welding with the fine current adjustment (from 4 to 12 A).

The device structure and functioning

Constructively all device units are fulfilled by their functional purposes, they are placed in the casing and are connected to each other with the braids, which have cut-off points. There are connection devices placed on the back wall, direction and control devices are placed out in the front panel. Transformers and the circuit board are placed inside the casing.

The primary winding and the secondary winding, which is fed pilot-arc, are placed on the three magnetic cores in the lower part of power transformer. Over these winding at the magnetic cores the primary-arc feeding moving winding of straight and reverse polarity are situated. The movable winding displacement is carried out by an engine using the gearbox, lead screw with the coil-bound nut. The last cable is connected to the measuring drum, by which one can determine the current on device setting through the front panel window. The displacement of moving winding shifting upward and downward is restricted by the end switches, which breaks the engine supply circuit.

The device has a water flow sensor, which is used to cut off power when there is insufficient water flow in the cooling system. Plasma and shielding gases are supplied to the torch through the two rotameters, which are designed for the gas flow regulation and control.

The device electric circuit description

The electric circuit *of the МПУ-4* consists of following functional nodes (figure 6.2):

1. Current source of straight polarity primary arc (SPA);
2. Current source of reverse polarity primary arc (RPA);
3. Pilot arc current source (PA);
4. Auxiliary current source (AS);
5. Switchboard;
6. Timing unit;

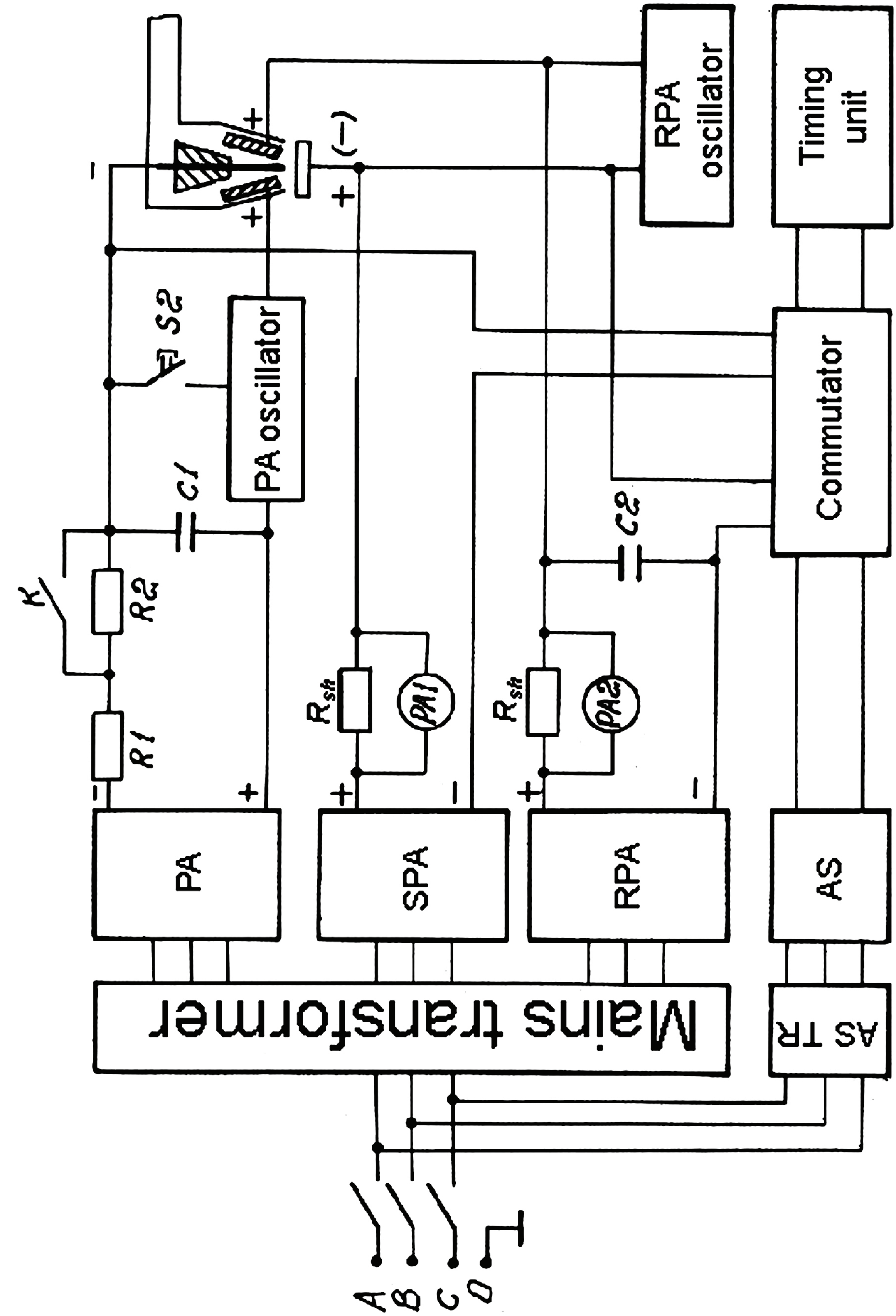


Figure 6.2 – Electric circuit of the device

7. Oscillator of pilot arc generation;
8. Oscillator of reverse polarity arc generation.

All power supplies are three-phase diode rectifiers.

The current source of straight polarity primary arc is assembled from three secondary movable winding of power transformer and from six diodes. The arc current is measured by the ampere meter A1 (direct current), which is connected with the shunt R_{sh}. The current source of reverse polarity arc is assembled in the same way, this arc current is measured by the amperemeter A2 (reverse current). The tapering of reverse and straight polarity arc current is carried out by the movable winding shifting upward and downward along the power transformer magnetic core using the electric motor. The shift handling is carried out by the buttons “Higher” and “Lower”.

The straight polarity arc current can be varied by the toggle switch “Arc current 10A…30A” stepwise, by means of which the solenoid starter is turned on, the contacts switch the primary windings of power transformer by the wye-connection and delta-connection.

Direct polarity arc current is possible to be changed in steps by using the toggle-switch “arc current” which may be turned on by the magnetic actuator contacts on which switch primary windings of the power transformer to a star or a triangle.

The pilot arc current source is assembled from three unmovable secondary winding of the power transformer and six diodes. For the restriction of the pilot arc current there are two resistors R1, R2, which are switched on in series, for increasing the current one of resistors is short-circuited to the relay contacts *S1*, which is switched on by pressing the button “ more”, the pilot arc current source is switched on by the toggle-switch *S2* “a pilot arc”. The auxiliary current source ensures the electronic switchboard operation. The electronic switchboard ensures the unit operation in modes ”A”, “ B”, “ C” , “ D”, and connecting power supply of direct or reverse polarity arc to the burns by means of two theristors . The time-setting electronic unit controls of the switchboard operation, giving the welding current impulse period and pauses duration between them in a mode “B” for an arc of direct polarity or impulse duration of direct and reverse polarity arc in the mode “C”.

The pilot arc ignition oscillator is switched on, in series into pilot arc supply circuit; it generates short duration high-voltage impulse which provides spark discharge of the gap between the electrode and the nozzle and ignition the pilot arc due to the plasma generating gas inside the torch. The oscillator is switched on by pressing the button “Ignition”.

The reverse polarity ignition arc oscillator is connected to the nozzle and to the article; it ensures the stable reverse polarity arc ignition. Place into operation in the modes “C” and “D”.

The capacitors C1 and C2 are used to protect the pilot arch power supplies and a reverse polarity current source against an oscillator high-level voltage.

A voltage change of the direct and reverse polarity current sources at the no-load running and under the operating conditions is carried out with the help of the voltmeter “welding voltage” by pressing the button “voltage measurement. Connection of the voltmeter to the corresponding sources is carried out by the toggle-switch “+” and”-“.

The machine operational procedure.

1. Check the grounding reliability.
2. Check the serviceability of gas system and system of cooling.
3. Check the correctness of tungsten electrode installation inside torch nozzle. The electrode shall not concern with the nozzle and shall be exposed to a depth not less than 1 mm.
4. Establish the control system in a starting position:

a) The toggle-switch “welding arc” shall be in position “switched off”

b) The toggle-switch “pilot arc” shall be in position “switched off”

c) The switch “mode” in the position “A”

5. Close rotameters ”argon” and “shielding gas”
6. Supply the running water to the cooling system of the machine; open the gate in front of the machine. Adjustment of the water flow rate is carried out by the training foreman or the instructor.
7. Supply a voltage from a power switchboard to the machine.
8. Set the toggle-switch “arc current” in the chosen position.
9. Set the switch “mode” in the position “A”
10. Press the button “switched on”. When doing this the indication lamps of a drum scales and rotameters shall begin to glow.
11. Open the gate on the gas bag filed with argon (operation is carried out by the training foreman or the instructor). Set the pre-assigned flow consumption of the plasma gas and shielding gas with the help of rotameters “Argon” and “Shielding gas”.
12. Set the rough welding current pressing the button “High” or “Low” on a drum scale.
13. Turn on the toggle-switch “Pilot arc”.
14. Press the button “Ignition”. When doing this the pilot arc between the electrode and the nozzle shall be initiated.

Note. Pilot arc ignition is carried out only in the modes "A" and "B". The modes "C" and "D" would be possible to be switched on after the pilot arc ignition.

15. Turn on the toggle-switch" the basic arc".

16. Bring the torch to a technological random of the distance of 1-2 mm and ignite the welding arc. Adjust the arc current by pressing the buttons "high", "low", supervising it by ammeters "straight current " or "reverse current"

17. Remove the torch from the article till welding arc goes down

18. Set a necessary mode of welding by the push-button switch "mode" and also by switches of welding impulses and pauses duration (for the modes "B" and "C").

19. Bring the torch to the welded article and make the welding only after the welding arc is ignited.

20. Turn off the toggle-switches "Welding arc" "Pilot arc" after the work finishes and switch the welder off by the button "network is switched off" by the knife switch on a switchboard.

21. Stop the supply of water and shielding gas into the machine, using the valves on the cylinder, the reducer and rotameters.

Directions to a practical work

1. Pick up the suitable welding modes for the set grades of material and thickness of a sheet, weld samples.

2. Make the durability test for samples and the basic material. Define welded connections durability factors:

$$K = \frac{P_c}{P_0}$$

where:

P_c - welded sample destruction effort;

P_o -destroying effort of a sample from the basic material.

3. Calculate the thermal flux density.

$$q_f = \frac{U_a \cdot I_a \cdot \eta_a}{P}$$

Define the heat input area $\boldsymbol{P}$ on the area of an erosive zone, which can be received as dot spots at the basic arc fast moving on a steel plate surface. The spot area is approximately equal to the area of input heat to the article. Define the sizes of the spot with the help of a counting microscope. At calculation $\boldsymbol{q_f}$ value of $\boldsymbol{\eta_e}$ to acceptequal *0,4*. Take the value of $\boldsymbol{U_a}$ and $\boldsymbol{I_a}$ from the report of optimal welding modes. Enter the results into the table 6.1

Content of the report

1. Plasmatrone torch schemes, main parameters of a plasma welding mode.
2. Bloke-diagram of the machine *МПУ-4*, technical dates, specification the of the basic nodes of the circuit
3. Results of the experiments (see Table 6.1)

Table 6.1 - The test report

Initial data. Parameters of a mode. Results.	Number of specimens.			
	1	2	3	
Material				
Thickness of the sheet, mm				
Type of joint				
Straight polarity arc welding current, A				
Reverse polarity arc welding current ,A				
Straight polarity arc welding voltage ,V				
Reverse polarity arch welding voltage, V				
The straight polarity arc power supply open circuit				
The reverse polarity arc power supply open circuit				
Straight polarity arch current impulse duration, s				
Reverse polarity arch current impulse duration, s				
Pause duration between the welding current impulses,				
Plasma gas consumption, l/min				
Shielding gas consumption, l/min				
Diameter of the tungsten electrode, mm				
Travel speed, m/h				
Breaking effort of a welded specimen , N				
Destroying effort of a specimen material, N				
Durability factor of welded connection, K_G				
Thermal flux density, W/mm^2				

Check questions

1. What is the difference between the plasma jet and usual electric arc?
2. What are the arcs of direct and reverse action?
3. What are the effective power and the thermal flux density with reference to a plasmatrone torch?
4. What are the main parameters of plasma welding mode?
5. What are the main units of the electric circuit?
6. What is the procedure of turning the machine and performing welding?
7. What is the structure of a plasmatrone torch on the apparatus *МПУ-4*?

Laboratory work № 7

RESISTANCE SEAM WELDING

<u>The aims of the work are:</u>

1. To know the process of resistance seam welding and the “МШ-1601” machine.
2. Depending on to the assignment, choice of welding conditions, adjust the machine and make some training welds.
3. To make a watertight test and selection the optimal welding conditions.
4. To prepare the report.

The procedure of resistance seam welding

Resistance seam welding is realized on special machines which use rotating wheels as electrodes providing the squeeze of weldments and current supply for a part heating (figure 7.1).

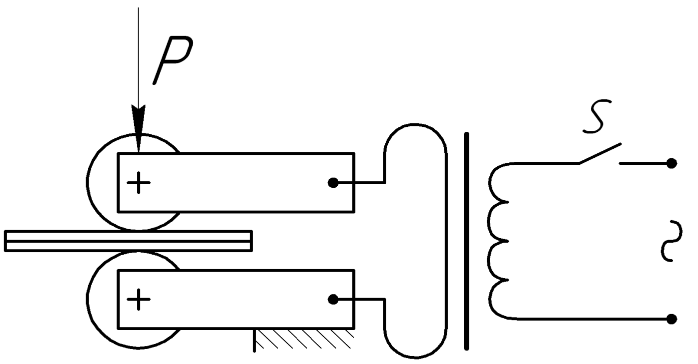


Figure 7.1 - The procedure of resistance seam welding process

In the case of spot welding, current transmission through the weldments causes metal melting in the area that is equidistant to roller contact surfaces. After metal consolidation welded seam is molded. If the current passed through the weldments is continuous then one can get a continuous juncture. This welding manner causes great heating of surrounding metal and increased buckling of welded construction.

If the current is supplied discontinuously, every heating cycle causes the welding of a increment (spot weld). Here, for getting a leak-tight juncture, values of heating cycle (impulse) time t_i, pause t_p and welding rate V_w must guarantee the overlap of spot welds (figure 7.2). Discrete method of current supply causes considerably less heating and buckling of welding elements.

Usually, during the welding process, rollers revolve continuously. However, for metals, which have a large shrinkage during the hardening, it is necessary to stop the rollers for a time of current passing and hardening of molten metal.

If a suture is discrete, the quality of seam welding mainly depends on size of spot welds and step between them (*l*), if a suture is continuous – the quality mainly depends on width and height of mutual melting area.

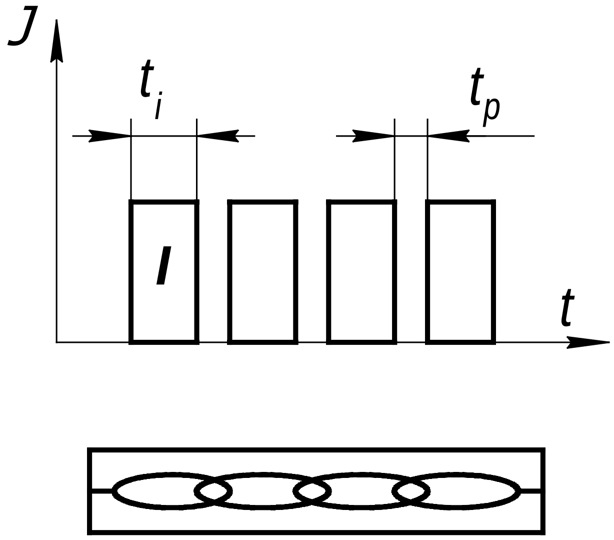


Figure 7.2 - Diagram of a welding current for discontinuous seam welding

The main parameters of seam welding are:

1) welding current I_w,
2) roller squeeze force ***P***,
3) width of roller working surface ***B***,
4) heating cycle (impulse) time t_i,
5) pause time t_p,
6) roller peripheral velocity or welding rate V_w.

Optimal values of these parameters depend on thickness and grade of welded materials, as well as on requirements to juncture (e.g. ensuring the tightness of a juncture).

Optimal conditions for seam welding of different metals and alloys are usually selected experimentally. These conditions are adduced in special industrial manuals.

The description of the МШ-1601 machine

The machine *МШ-1601* is designed for electro-contact seam welding of low-carbon and alloyed steels.

Technical data on the machine *МШ-1601*:

– rating at 20% duty cycle	– 75 kW,
– welding rate	– 0.8…4.5 m/min,
– number of power levels	– 8,
– welded sheet thickness	– 0.5…1.5 mm,
– working stroke of the upper electrode	– 50 mm,
– nominal outreach of electrodes	– 400 mm.

The structure of the machine МШ-1601

The main components of welder are (figure 7.3): welding transformer *TR* with power level switch *PDS*, multipurpose upper electrode assembly *1*, lower electrode assembly for transverse welding *2* and for longitudinal welding *3*, rotary actuator *4* of upper roller, pneumatic system with squeeze drive *5* and control unit *CU*.

The welder has a water cooling system. It is used for cooling of welding transformer, current-carrying shafts and rollers. Ignitron current circuit breaker *ПИШ-50-4* is accommodated in an individual box.

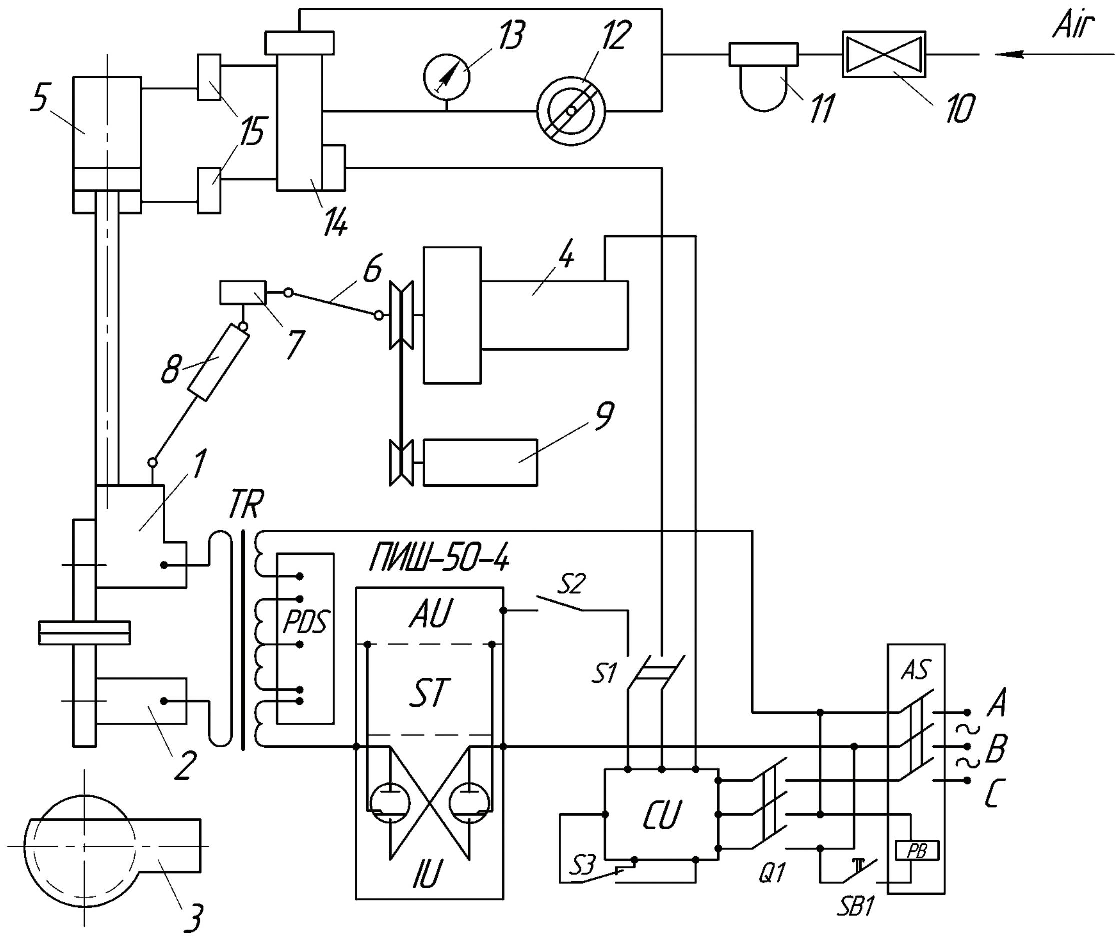


Figure 7.3 - Functional chart of the machine МШ-1601

The upper roller rotary actuator

Driving actuator is used for rotation of the upper roller. Inside the actuator there is a magnetic slip coupling between the electric motor and the working mechanism. Magnetic slip coupling enables some changes of coupling output shaft rotation speed, at the same time the speed of the electric motor remains constant. Tacho-generator *9* is used as a velocity sensor; it is connected to a coupling output shaft by V-belt transmission.

Coupling output shaft rotation speed is adjusted in discrete steps by a switch. Coupling output shaft rotation is transmitted to the upper roller by means of cardan shaft *6*, worm-and-wheel gearbox *7*, telescopic cardan shaft *8* and reducer of upper electrode assembly *1*.

The pneumatic squeeze drive

The pneumatic drive *5* provides sinking, raising of the upper roller as well as parts squeezing. Compressed air goes to pressure regulator *12* through entrance valve *10* and dehumidifier *11*, outgoing working pressure is adjusted in pressure regulator by manometer *13*. Compressed air also goes to electromagnetic pneumovalve *14* and moves its valve. When voltage is applied to pneumovalve control coil, air enters the pneumocylinder upper chamber and lowers piston with rod and squeezes the weldment between rollers. At the same time the air from the lower chamber passes to atmosphere through the pneumatic valve. When the latter is de-energized, the air goes to the lower chamber and lifts up the upper roller. The rate of air supply is regulated by throttle valves *15*.

The electric circuit of the machine

Primary winding of single-phase shell-type welding transformer has few coils, which are connected to the power level switch. Secondary winding consists of three copper discs with water cooling, it has one loop and is connected to current-carrying shafts of upper and lower rollers via conducting sleeves. Depending on power degree, secondary winding voltage varies between 2.3 and 4.4 V.

Primary winding of transformer is connected to the supply network in sequence by ignitron unit (*IU*) of the breaker *ПИШ-50-4*. *IU* provides a synchronous turning on of the welding current relatively to the phase of supply-line voltage and provides an even number of half-waves in every impulse. Each of two ignitrons carries current only in one direction.

To provide the flow of alternating current through the primary winding of transformer, ignitrons have an inverse-parallel connection. An ignitron carries current during the excitation of voltaic arc between anode and mercury cathode. A voltaic arc exists until an ignitron current falls to zero. Positive impulses are supplied to ignitron starter for ignitron excitation. Making a phase displacements of these impulses relatively to each half-cycle, one can get a smooth adjustment of welding current.

Electronic adjustment unit *AU* assigns the breaker operating mode and provides specified heating cycle (impulse) time and pause time between them. Adjustment unit is energized via Ferro resonant stabilizer *ST* for reducing of current oscillation influence on breaker functioning.

Relay control unit *CU* provides the required operating order for pneumatic drive, roller rotary actuator and breaker.

The preparation of the machine for welding

1. Open an entrance valve and pipe the air into the welder. Adjust the required operating air pressure by pressure regulator.
2. Switch on water cooling of the machine and breaker.
3. Adjust pre-assigned speed of upper roller rotation by a switch.
4. Set the required power level by three knives.
5. Close the welder door and switch on a supply-line knife switch and automatic switch *AS*. When the door is open, door blocking button *SB1* pins are disconnected and *AS* does not turn on.
6. Turn on a rotation switch *Q1* (“Voltage”).
7. Set a rotation switch “Motor activation” in the position “In cycle”, toggle switch *S1* (“Roller”) in the position “Downward”, turn off a toggle switch *S2* (“Welding current”).
8. Press the pedal button “PB” check the functioning of pneumatic drive and rotation actuator.
9. Turn on a rotary switch “Control circuits” on the breaker, at the same time a green light shell begin to glow. It shows that a liquid jet relay, which operates upon certain water supply rate in ignitron cooling system, turned on ignitron firing circuits.
10. Set the potentiometer “Heating” in the specified position. The potentiometer allows adjusting smoothly the welding current.
11. Set the prescribed heating cycle (impulse) time and pause time by switches. The multiplying factor of these switches is one period, equal to 0.02 s.
12. Turn on the toggle switch “Welding current” on the welder. The latter is ready for welding when the breaker’s red light began to glow (approximately in 5 minutes after turning on).

Operational procedure of the machine МШ-1601

Operational procedure of the machine *МШ-1601* is as follows:

1. Install the weldments between rollers and press the *S3* button. At the same time, relay *CU* turns the pneumovalve and electric motor of rotary actuator on. Upper roller goes downward and weldments are compressed between rollers.
2. Release the pedal button. At the same time, *CU* turns on the power supply for magnetic slip coupling and close breaker control circuits. The breaker turns on the current using the program, given by *AU*.
3. To stop welding, pedal button shall be pressed again, at the same time the welding current turns off, rotary actuator of the upper roller become de-energized, the roller rises and releases the weldments.
4. When the *S3* button is released, the machine comes back to original position.

If the weldments are installed between rollers incorrectly, the following should be done. Do not release the pedal button and turn off a toggle switch “Welding current”, then set a toggle switch “Roller” to the position “Up” and release the pedal. Rotary switch “Motor activation” is set to the position “Constantly” when welded seams are short.

Directions for practical work

1. Weld some specimens by interrupted seam welds with pre-assigned step. For that, adjust the roller squeeze force, power degree, heating cycle (impulse) time t_i, pause time t_p and step l by according to the table of welding conditions or instructor’s directions. Then, calculate the welding rate:

$$V_w = \frac{l}{t_i + t_p}.$$

Welding rate V_w is equal to the upper roller peripheral velocity, which depends on adjusted number of points m on the welding rate regulator scale:

$$V_w = m\Delta V_w,$$

ΔV_w – welding rate increment for one stage of regulation (one graduation interval).

For the installed drive *ПИШ-50-4*, the number of welding rate regulation stages shell be equals 58 and ΔV_w = 1.25 mmps.

To determine the welding rate for specified step, the number of points m shell be calculated by formula:

$$m = \frac{l}{\Delta V_w (t_i + t_p)}.$$

Adjust the obtained number of division m on welding rate regulator scale and make a welding of the sample. Change the step l; if there are some discrepancies with pre-assigned step, then amend the welding conditions (change the welding rate V_w or pause time t_p).

2. Choose the optimal welding conditions for a leak-tight seam: make a few welds on the sample with different step.

A leak-tight seam can be obtained in case when the weld nugget overlap is no less than 25% d_n. Weld nugget overlap Δ can be calculated by the following formula:

$$\Delta = (1 - \frac{l}{d_n}) \cdot 100\%.$$

Optimal nugget diameter (d_n) depends on weldments thickness δ:

$$d_n = 4\delta .$$

In that case, step *l* shall be no less than 3δ for a leak-tight seam.

3. Make a tightness chalk-kerosene test for junctures and choose the optimal welding conditions for a leak-tight seam.
4. Draw up the report.

Content of the report

1. Essence of the seam welding.
2. Main parameters of seam welding.
3. Technical data of machine *МШ-1601*.
4. Functional chart and the main components of the machine *МШ-1601* (figure 7.4).
5. Record of samples testing and welding conditions (table 7.1).

Table 7.1 – Protocol of samples testing

Number of experiment	Material – Sheet thickness – Roller width –							
	Welding conditions						Welding results	
	P, N	Power step	t_i, s	t_p, s	*m*	V_w, mmps	*l*, mm	Tightness test
1								
…								

6. Choice and grounds for welding conditions for leak-tight juncture.
7. Conclusions.

Check questions

1. Methods of seam welding.
2. What are the main parameters of seam welding?
3. Purpose of the main components of the machine *МШ-1601*?
4. Principle of operation and design of upper roller rotation actuator.
5. Design of pneumatic system.
6. Purpose of the main components of electric circuit.
7. Design of welding transformer.
8. Indicate the purpose of the main components of breaker *ПИШ-50-4*.
9. Principle of operation of breaker’s ignitron unit.
10. Procedure of adjustment of the machine onto specified welding conditions.
11. Operation procedure of welding devices and mechanisms in welding.

Laboratory work №8

Cold welding for plastic metals

<u>The aims of the work are:</u>

1. To know the working procedures of cold welding, the particulars of the machine *MCXC-5-3* for butt cold welding;
2. To butt weld the specimens made of plastic metals (similar or dissimilar) and test it's strength;
3. To select the optimal welding conditions;
4. To prepare the report.

The cold welding procedure

Cold welding is a simple and accessible process which allows getting crushproof, durable joints of plastic metals: aluminium, copper, nickel, titanium, lead, silver and gold. Joints of some dissimilar metals from mentioned above are possible to get by cold welding. Distinctive features of cold welding are low power consumption, high effectiveness, easy to atomise, good labour conditions.

Metal joining occurs in solid state due to metal bond are formed on welded surface under joint deformation. Such bonds are formed, if two abutting surfaces are brought together to the distance close to atomic radius (10^{-8} cm). It is necessary to have ideally clean surfaces in contact, without fat, oxide and gas absorbed layer.

To have a pure metal contact between welded parts plenty of plastic flow is required to bear juts and extrude metal this causes the surface film destruction and removal from welding zone.

There are three types of cold welding : spot welding of lap joints made by stamping punch; seam welding made by rollers; and butt welding.

Spot and seam cold welding could be single-side or double-side. Under single-side welding punches or rolls dent metal at one side of lap joint (figure 8.1, a). The toughness of welded joint will increase if you use punches or rolls with shoulders (figure 8.1.b), or, if you use squeezing of metal around the punch before stamping (figure 8.1.c).

In spot and seam welding operational parameters depend on thickness of welded sheets δ and material properties.

Main parameters of spot welding are punch diameter d = 1…3δ and punch denting depth h = 0.5…0.95δ. Under seam welding roll diameter d_p = 50δ, raised portion width b = 1…1.5δ, raised portion height (denting depth) h = 0.8…0.9δ, shoulders bearing portion width S = 2…4δ.

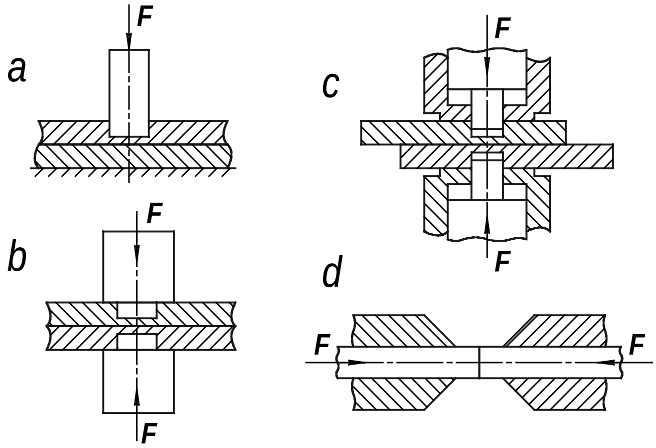


Figure 8.1 - Types of cold welding

Under butt cold welding main operational parameter is deformed stick-out length ***L*** of welded rods. It is selected depending on parts diameter and metal properties (figure 8.1.d). For aluminium ***L= 1…1.2d***, for copper ***L= 1.25…1.5d***.
The required force depends on cross-sectional area and welded metal strength.

For aluminium the required pressure is 700…800 N/mm^2, for copper 2000…2500 N/mm^2. In butt cold welding of dissimilar metals, the stick-out length of the rod made from stronger metal shall be larger.

The speed of force applying does not influence on joint strength, so any type of squeezer can be used hydraulic, eccentric, crank presses, etc.

Cold welding widely is used in electrical mounting for wire bonding, in production of casing for electronics, heat exchangers, refrigerators, apparatus, devices for joining of electric bus bar and trolleybus wires.

The butt cold welding machine MCXC-5-3

The machine *MCXC-5-3* (figure 8.2) is designed for welding of aluminium and copper wire with cross-section area 2…30 mm^2.

Technical performances:

- working pressure of compressed air	- 0.1…0.5 MN/m^2,
- rated upset force	- 50 kN,
- largest distance between inner edges of clamping jaws.	- 11 mm,
- consumption of compressed air per one weld	- 0.005 m^3,
- operating rate	- up 200 weld/hour
- machine weight	- 62 kg.

The gripping mechanism consists of unmovable *1* and movable *2* clamps. Movable clamp is shifted along two guide stanchions *3*. On clamps the changeable jaws are mounted, in which welded parts are griped by the eccentric mechanism. Ends of jaws are sharpened for cone with 60° angle and serve as blades, which cut off metal pressed out. Upsetting mechanism includes cylinder *5* with plunger, which shifts movable clamp along guide stanchions through shaft, lever and drawbar.

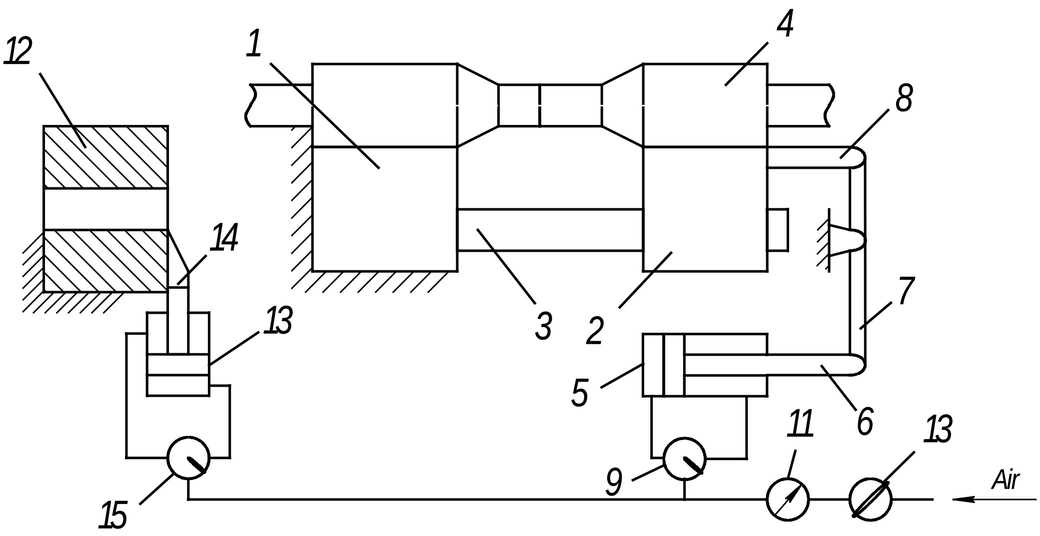


Figure 8.2 - Scheme of the machine *MCXC-5-3*

The three-way pneumatic valve *9* serves to handle upsetting mechanism. When the valve in the left position the right chamber of pneumatic cylinder opens to atmosphere, the left chamber of pneumatic cylinder fills with compressed air, which moves clamp to contact with unmovable clamp, ensuring deformation correspond to distance between clamp jaws and cutting fin off. When the valve in the right position, the movable clamp is returned to the initial right position. If the valve in the middle position, the clamp do not move. Compressed air pressure can be adjusted by air reductor *10* and controlled by manometer *11*.

To cut ends of rod the shears are set on the machine, which consists of the casing *12* and pneumatic cylinder *13* with plunger. On plunger-rod the special knife *14* is set. The cutter control valve *15* is located inside the machine on left side.

Operational procedure for practical work

1. Supply the compressed air to the machine.
2. Cut the ends off by placing the rods into the guide plate hole of cutter.
3. Place the rods to be welded into clamp jaws in such a way that allows locating the joint in the middle between clamp jaws. Fix the rods in clamp jaws by turning the handles of eccentric mechanism downward.
4. Turn the handle of tree-way valve to the left to weld rods.
5. Unlock the welded article by moving the upper clamp jaws upwards, turn the handles of the eccentric mechanism upwards.
6. Move the non-stationary clamp to the outmost right position, turning the valve handle to the right till it stops. Remove the welded article from lower clamp jaws.
7. Weld some articles from similar and dissimilar metal.
8. Test the welded articles, select optimal mode for cold welding

Content of the report

1. Purpose of the machine and its technical data.
2. Describe the main units of the machine.
3. Pneumatic system of the machine *MCXC-5-3* and its main elements.
4. Protocol of welding and breaking test in accordance with the form given in the table 8.1.

Table 8.1 - Protocol of welding and breaking test

Material – Wire cross-section area ***F***, mm^2 –				
Num. of exp.	Stick-out distance	Force of fracture, ***P***, kN	Nature of fracture	Note
1				
...				

Check questions

1. What is the procedure of formation of welded joint in cold welding?
2. How can interface surfaces be cleaned before cold welding?
3. What are the main parameters of spot, seam and butt cold welding?
4. What are the main units of the machine *MCXC-5-3*?

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