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DEVICE FOR SWINGING THE WELDING TORCH DURING ASCENDING VERTICAL MIG/MAG WELDING

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Abstract: During ascending vertical welding, the welding torch, positioned at a certain angle against the welding direction, must execute a supplementary swinging movement of a certain amplitude and frequency imposed by the welding technology. This movement is performed by means of certain specialized swinging devices, whose form and construction differ from one equipment manufacturer to another.

INTRODUCTION

Vertical welding is generally considered a difficult issue to deal with because of the leakage risks of metal bath and melted metal dross slag under the action of gravity which makes the control of the welding process difficult and increases the incidence of welding defects, respectively.

The process may result in two variants of welding namely ascending vertical welding which is recommended for the making of resistance welding works and descending vertical welding which is recommended for the making of less important welding works.

Out of the two welding types herein above, the vertical descending welding is considered more complicated because of the difficult control of the metal bath and dross, and because of increased risk of occurrence of defects in welded joints, respectively.

Problem solving is ensured by taking measures to contain the technological leakage trends in welding bath.

In case of MIG / MAG welding the technological measures made for vertical ascending or descending welding are as follows:

- *Using the short circuit transfer or pulsed current modes* respectively, characterized by low linear energy controlled at low values of welding current;
- Reducing the arc voltage to its stability limit;
- *Using flux core wire instead of filled wire;*
- *Using red schorl, sealed and seamless cored flux core wire* which deposits a fast solidification speed dross thus supporting the metal bath, and the amount of dross that is very small coefficient of admission of the wire k_u = 12-14%;
- Suppressing the human factor by *moving from manual semi-mechanical welding to mechanized, automatic or robotic welding* which allows for the use of complex swinging techniques and thus ensuring a smooth control over metal bath.

1. SWINGING DEVICE PRESENTATION

Hence at vertical ascending welding the torch welding positioned at certain angle against the welding direction must perform additionally a swinging motion of a certain amplitude and frequency required by welding technology required. This fluctuation is performed by using some specialized swinging mechanisms, whose shape and construction vary from one equipment manufacturer to another.

1.1. DESCRIPTION OF THE SWINGING DEVICE

Figure 1 hereunder shows the swinging device designed and built for vertical mechanized MAG welding and based on an eccentric based mechanism which involves an articulated leverage.

The main components of the device are shown in Figure 1 below.

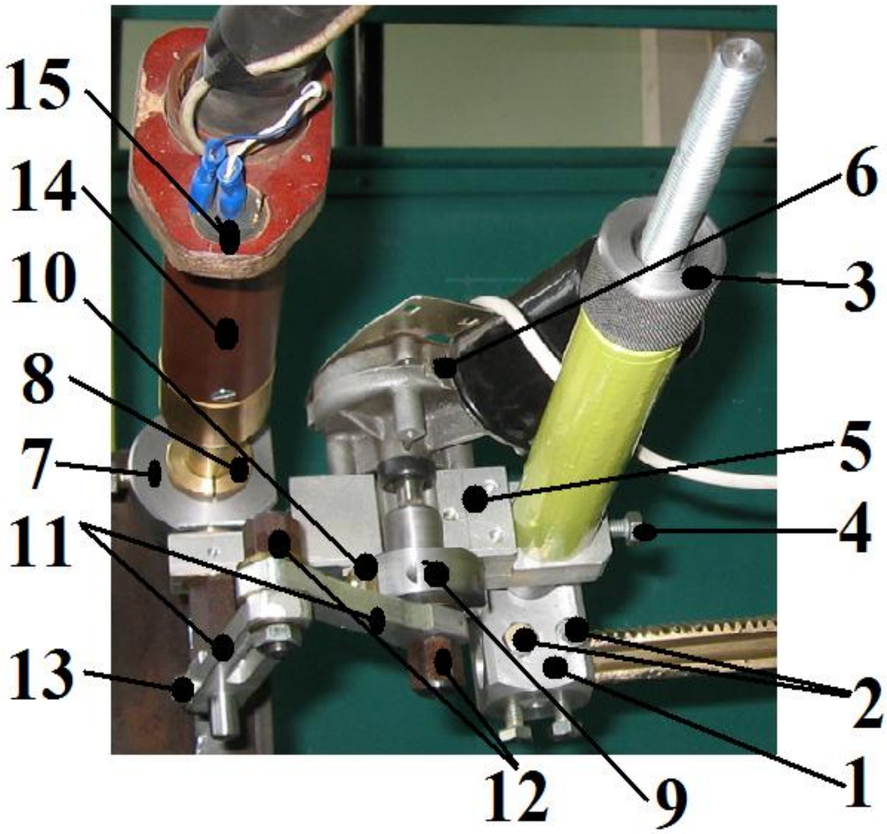


Figure 1. Swinging device

1. ***Fixing and tilting holders for welding torch***
2. Fixing screws
3. Adjustment nut for lose end length
4. Adjustment screw for the lose end mechanism
5. ***Holder for swinging device***
6. DC gear motor to achieve swinging
7. ***Swivel of welding torch***
8. Chuck collet for fixing welding torch
9. Eccentric gear for adjusting the swinging amplitude
10. Adjustment screw of eccentricity
11. ***Articulated leverage***
12. Arms adjustment and fixing screws
13. Symmetrical adjustment screw of torch to the joint axis
14. Torch for mechanized welding
15. Welding power switch

1.2 SWINGING DEVICE OPERATION

Welding head (14) mounted on swivel (7) is involved in a swinging motion of a certain amplitude and frequency adjustable by an articulated leverage (11) driven by a DC gear motor (6) by means of eccentric gear (9).

Fixing holder (1) is meant to support the whole swinging device kit and, at the same time, it provides welding torch with a certain slope as against welding direction. Fastening screws (2) are designed to fix all the whole kit at the desired tilt position.

From the adjustment nut (3) one is set the accurate positioning of the torch as against the piece and the length of the lose end implicitly and by means of the screw (4) it blocks up this motion to the position expected.

DC gear motor (6) is fixed on the holder (5) to achieve the swinging motion; the mobile gear of welding torch fixing holder is fixed on the holder too through a chuck collet (8) by means of its fixing screw.

From the eccentric gear (9) and through adjusting screw (10) one adjusts both the parameters of the eccentricity of gear rotary motion, and the swinging amplitude of the welding head for a given length of the leverage arms. Additionally from the fixing and adjustment screws (12) of the slewing bracket (11) an adjustment of the swinging amplitude of the torch can be performed if needed, for some given parameters of eccentricity. Finally, the swinging amplitude can be adjusted by moving torches (14) in the holder (7) as the effect of the change of the swivel length of the head welding.

The role of adjustment and fixing screws (13) is to restore swinging symmetry when acting on the change of the eccentric parameters or the length of slewing bracket (11).

Starting the welding is done by pressing the power switch (15).

2. ADJUST TILTING DEVICE

Adjustment of the parameters of swinging device consists in regulating the main parameters of swinging namely the swinging frequency and the adjustment of swinging amplitude, respectively. Adjusting the two parameters is based on technological needs observed when welding.

2.1. ADJUSTING THE SWINGING FREQUENCY

Adjusting the swinging frequency of the welding head is achieved by regulating the speed of DC gear motor through an adjustable power supply of rotor voltage thereof.

The use of DC current engine is recommended due to the smooth control of its speed by means of changing the supply voltage of the rotor, $U_{al.rot}$ as follows:

$$n = \frac{U_{rotor} - I_{rotor} \cdot R_{trotor}}{k \cdot i_e}$$

where:
- U_{rotor} - rotor power supply;
- I_{rotor} - rotor current;
- R_{trotor} - total resistance of the rotor;
- I_e - exciting current of the motor.

From the equation above there are two possibilities for adjusting the engine speed, as follows:

- *By changing the exciting current i_e;*

- *By changing the rotor power supply U_{rotor}.*

In reality, speed control is made only through changing the rotor voltage by using relatively simple electrical circuits with thyristors or transistors.

There shall not be used speed control by means of exciting current for the following reasons:

- *For a speed $n > n_{nom}$, it should that $i_e < i_{enom}$ which is possible, but the mechanical loading of motor collector allows only one $n_{max} = 1.25n_{nominal}$, which means a small range of speed control in terms of technology.*
- *For a speed $n < n_{nom}$ it should that $i_e > i_{enom,}$ and this is not possible because separate exciting is sized from thermal point of view at i_{enom}.*

Due these two reasons the exciting current is maintained constant and equal to the nominal one and adjustment is made only by changing rotor voltage.

Electronic scheme on controlling the rotor voltage is shown in Figure 2 below:

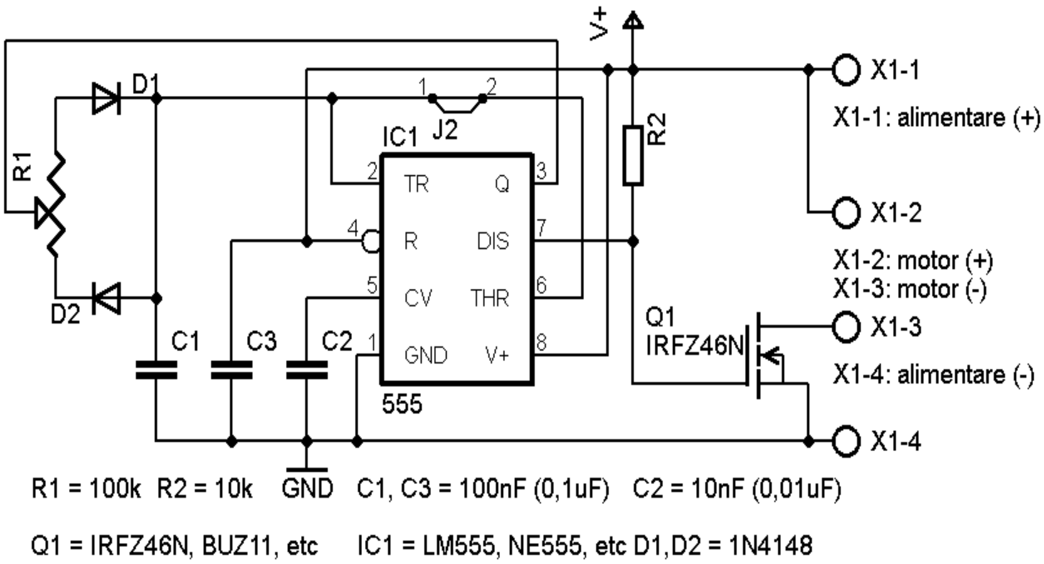


Figure 2: Electronic scheme on controlling the DC gear motor voltage

Rotor voltage control method is PWM (power wave modulation). Source generates power rectangular pulses of very high frequency which width can be changed continuously as required. A coefficient of admission factor $k_u = t_i/T$ is defined, where t_i is pulse duration and T is the cycle (period) duration. Figure 3 shows the parameters of rotor voltage for 3 values of the coefficient of admission of k_u = 10%, 50% and 90%, respectively.

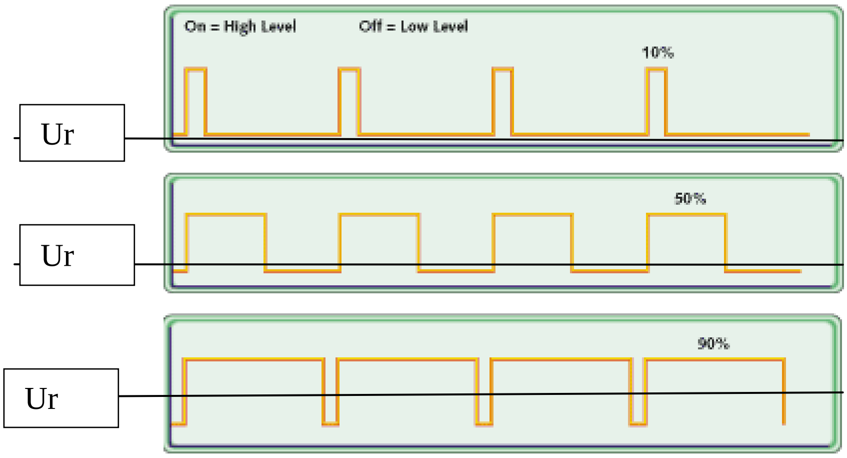
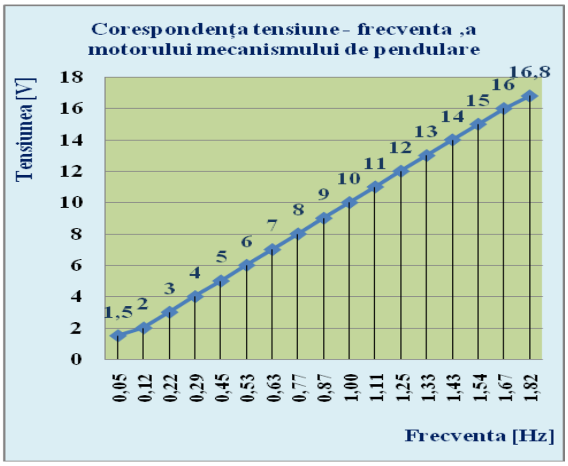


Figure 3. Adjustment of rotor voltage through coefficient of admission k_u

Correspondence between voltage displayed at a digital voltmeter terminals – see figure 4 – and the swinging frequency was performed by measuring a number of ***"n"*** rotations in a given unit of time ***[s]*** by means of an electronic revolution counter (tachometer), and after the calculation of speed and time ration one resulted swinging frequency [Hz].

Correlation between the voltage reached at the motor terminals [V], and swinging frequency [Hz] is presented in Table 1, respectively in Figure 5 below.



Voltage – frequency correspondence of the swinging device motor (Voltage – V, Frequency Hz)

Figure 4 – Measurement of rotor voltage of swinging device

Figure 5. Graphic f = f(U_{rotor})

Table 1. Calibration of the meter: correlation between rotor voltage – swinging frequency

Rotor voltage [V]	Time [s]	Rotations	Swinging frequency [Hz]
1.5	104	5	0.05
2	41	5	0.12
3	46	10	0.22
4	34	10	0.29
5	22	10	0.45
6	19	10	0.53
7	16	10	0.63
8	26	20	0.77
9	23	20	0.87
10	20	20	1.00
11	18	20	1.11
12	16	20	1.25
13	15	20	1.33
14	14	20	1.43
15	13	20	1.54
16	12	20	1.67
16.8	11	20	1.82

One may notice that frequency adjustment can be done continuously by changing rotor voltage, within a feasible range of 0.5 - 2Hz.

2.2. ADJUSTMENT OF DEVICE SWINGING AMPLITUDE

A tuning of swinging range is made mechanically by means of an eccentric gear and an articulated leverage.

From engineering approach there are 3 ways for adjusting the amplitude of swinging, shown in the Figure 6 bellow, as follows:

- By changing the eccentricity parameters by using its adjustment screw ;
- By altering the length of the arms of the articulated leverage;
- By changing position of the torch in its mounting holder.

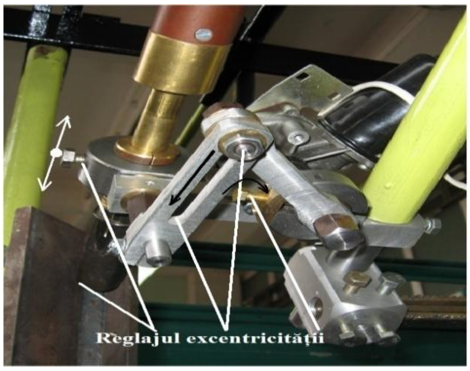


Figure 6. Eccentricity tuning

The question raised is finding a correlation between eccentricity values of rotation and swinging amplitude for a given position of the welding torch and the slewing bracket, respectively.

To establish these parameters and finding correlation between the values of eccentricity, welding head position and the leverage arms length, there wee used three methods to determine the amplitude of swinging of the gear, as follows:

1. Analytical method
2. Graphical method
3. Experimental method

These calculation methods allow determining the minimum and maximum ranges of variation of the swinging amplitude for a wide range of values of eccentricity, related to a specific position of welding torch and leverage arms, based on technological needs.

2.2.1. THE ANALYTICAL METHOD

This method consists in a geometrical calculation of the swinging amplitude by testing the variation limits of the torch arm angle at eccentric rotation for a given value of eccentricity and for fixed parameters of the torch arm and leverage arms, respectively. Leverage consists of three arms forming a triangle, of which 2 remain unchanged, and the third one varies depending on the eccentricity parameters.

Although by this method, the way to attain a certain correlation between the eccentric value and swinging amplitude is very difficult and cumbersome, hereinafter on presents a calculation method for eccentricity value e = 10mm.

Let triangle ABC, see Figure 7, consisting of the three slewing brackets. AB and AC wings are fixed, and the BC wing varies depending on the eccentricity parameters.

To ease the calculation one shall consider the gear in 3 particular positions:

a. Value of eccentricity e = 0;
b. Value of eccentricity e = 10mm, the minimum value of the arm $BC' = BC_{e=0} - e$;
c. Value of eccentricity e = 10mm, the maximum radius $BC'' = BC_{e=0} + e$;

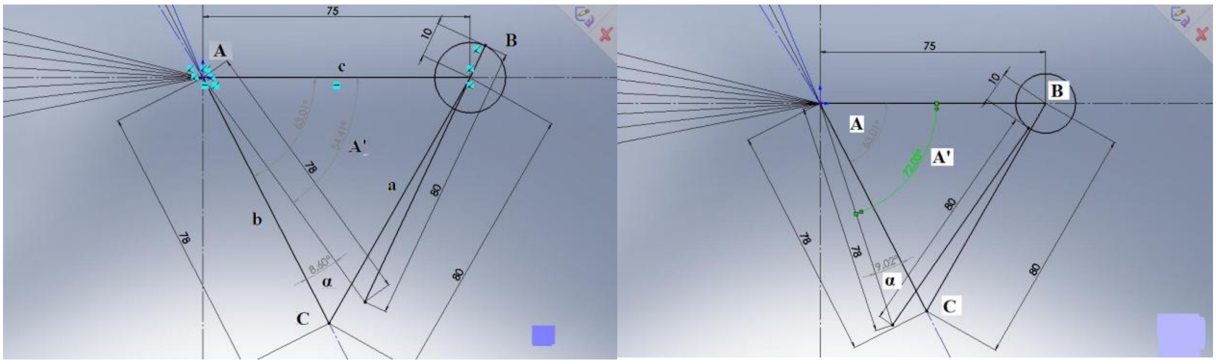


Figure 7. Testing the variation limits of angle A

One presents hereinafter the calculation for first case (a), see Figure 7

Calculation data: **AB = 75 mm – fixed**; **AC = 78 mm – fixed; BC = 80 mm – variable; e = 0**

For **e = 0** one computes the value of angle A by a geometrical calculation. Cosine rule applies in triangle **ABC** as follows:

$$BC^2 = AB^2 + AC^2 - 2 \times AB \times AC \times \cos A$$

it results:

$$\cos A = \frac{AB^2 + AC^2 - BC^2}{2 \times AB \times AC} = \frac{75^2 + 78^2 - 80^2}{2 \times 75 \times 78} = \frac{5625 + 6084 - 6400}{11700} = \frac{5309}{11700} =$$

cosA = 0.45376

Angle A = arccos 0.45376 => **A = 63º**

So when the value of **e = 0, A= 63º**

Similar calculations are made for the minimum length of the arm BC' = 70mm, respectively for the maximum length of the arm BC'' = 90mm, resulting in variations of the angle A between 55^0 and 72^0 , respectively thus a variation of the angle A of 17^0 .

One may extrapolate the calculations for different values of eccentricity allowed by eccentric gear, *e = 0 ... 10mm*.

The results of these calculations for a given value of 200mm of the torch arm are presented in Table 2 below.

Table 2. Swinging amplitude depending on eccentricity value

Eccentricity e [mm]	Angle α_{total} [º]	$C = \frac{\pi \times \alpha}{180}$	Arm length B_p [mm]	Swinging amplitude A [mm]
0	0	0	200	0
1	1.76	0.03071	200	6.14
2	3.41	0.05951	200	11.90
3	5.29	0.09232	200	18.48
4	7.03	0.12269	200	24.53
5	8.8	0.15358	200	30.71
6	10.56	0.18430	200	36.86
7	12.32	0.21502	200	43.00
8	14.08	0.24574	200	49.14
9	15.85	0.27663	200	55.32
10	17.61	0.30735	200	61.47

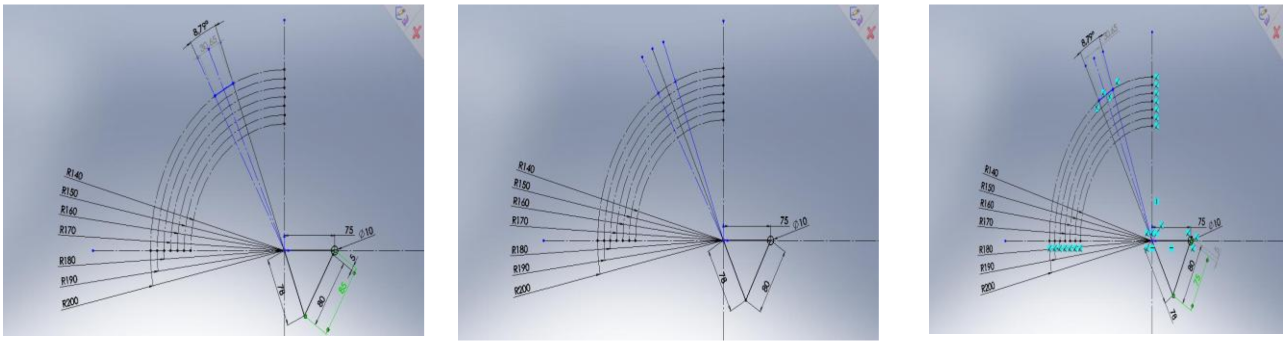
To set the values of swinging amplitude for other welding torch arm lengths, similar calculations are required for each arm's length. Experimental measurements have showed a good correlation with theoretical calculations performed above.

2.2.2. THE GRAPHICAL METHOD

The analytical calculation method is considered to be a difficult and cumbersome method therefore one shall present a graphical method to test the swinging amplitude parameters by means of simulating using specific utility software i.e. "**Solid Works**".

One feed in the swinging device leverage in this software which was feed in with the successive values the variable, i.e. the length of BC lever arm.

Figure 8 bellow summarizes these measurements for the values of the eccentric ***e = ± 5 mm***, respectively for ***e = 0***.



a. e = -5mm b. e = 0mm c. e = +5mm

Figure 8. Graphic testing of swinging amplitude

Table 3 below shows the swinging amplitude for different parameters of eccentricity and the welding head arm.

Table 3. Swinging amplitude set up graphically

Angle α [°]	e [mm]	Arm b=140 [mm]	Arm b=150 [mm]	Arm b=160 [mm]	Arm b=170 [mm]	Arm b=180 [mm]	Arm b=190 [mm]	Arm b=200 [mm]
1.76	1	4.29	4.61	4.91	5.22	5.53	5.84	6.14
3.52	2	8.59	9.21	9.82	10.43	11.05	11.67	12.28
5.27	3	12.84	13.77	14.71	15.63	16.55	17.47	18.37
7.04	4	17.14	18.41	19.65	20.87	22.10	23.33	24.56
8.79	5	21.44	22.98	24.52	26.04	27.59	29.12	30.65
10.56	6	25.75	27.60	29.45	31.28	33.13	34.97	36.81
12.33	7	30.05	32.20	34.37	36.50	38.66	40.81	42.96
14.09	8	34.32	36.78	39.25	41.68	44.15	46.61	49.06
15.85	9	38.58	41.35	44.12	46.86	49.64	52.39	55.15
17.62	10	42.86	45.93	49.01	52.05	55.14	58.20	61.26

Comparing the above results with those determined by the analytical method one results closed values while the test accuracy outputs being satisfactory.

2.2.3. EXPERIMENTAL METHOD

This method consists in testing the practical, visual swinging amplitude, and its shape and lie by *drawing on paper*, for different values of eccentricity, swinging frequency and welding rate, respectively while maintaining both the leverage arms and torch arm constant, see Figure 9.

To this end, the contact tip of welding torch was replaced by a special nozzle where a graphite pencil was mounted into and which simulates the electrode tip. In the holder of the workpiece there was fit a plexiglas panel on which a sheet of paper had been stuck on.

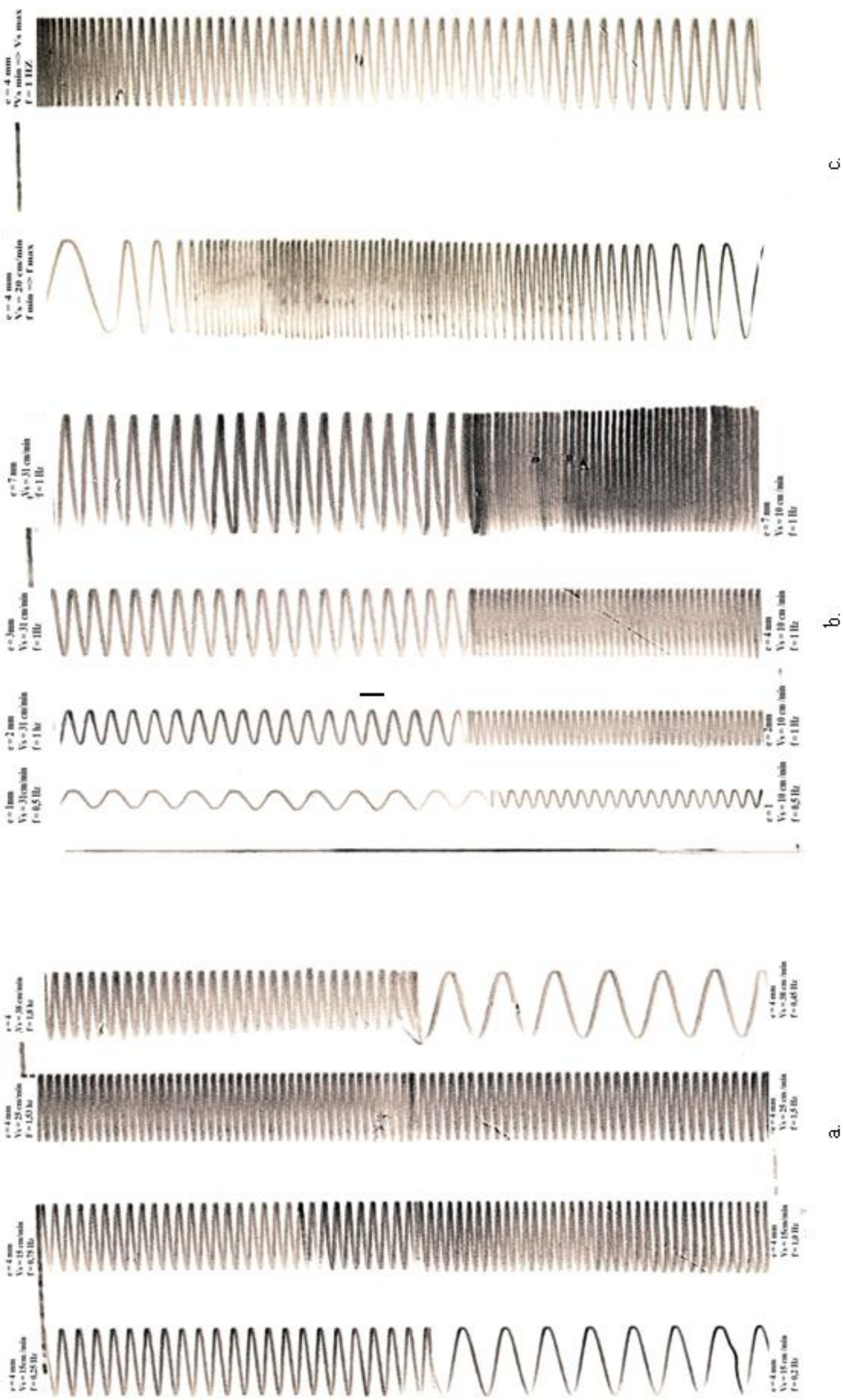


Figure 9. Experimental recording of swinging movement of the welding head:
a when changing welding frequency and rate; b when changing eccentricity; c for extreme values of the welding frequency and rate.

Different unloaded running welding technologies have been subsequently tested, namely with the welding supply powered off, while plotting on papers the trajectories described by the pen tip (by default by the tip of the electrode wire when welding in real terms).

In this way one could compare the results set by the two theoretical methods, with the actual values obtained on swinging charts and recorded on the sheet of paper.

Hereinafter there are some swinging forms of the welding torch through combining technological parameters, swinging amplitude and frequency, and welding rate:

- 9.a.when changing welding frequency and rate, e = ct. = 4mm;
- 9.b. when changing eccentricity: e = 1, 2, 4, 7 mm;
- 9.c at extreme values of welding frequency and rate: f (min, max) - v = (min, max);

The advantage of this method is that it allows the simulation and visualization of welding technologies before actual welding is performed resulting in savings of time and sampling otherwise allotted to check such technologies.

The method is simple and accurate as it suppresses the theoretical calculations, and the graphical testing which are compulsory in the other two methods and it prevents even miscalculations when feeding in data inappropriately.

Viewing of the welding head trajectory allows for a priori assessment of welding technology from the point of view of arc welding movement parameters.

Checking the operating of swinging device, setting the limits of technological parameters and their correlation and adjustment was done by conducting test for depositing of welding beads, vertically ascendant and vertically descendant, on the 12 mm thick sheet metal parts, see Figure 10 bellow.

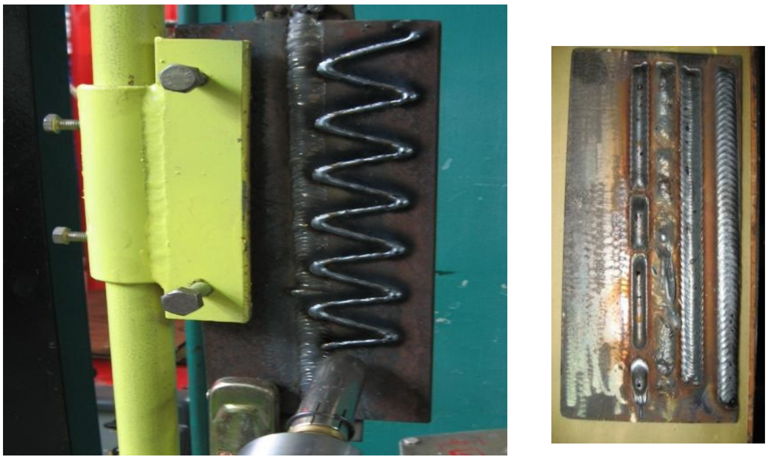


Figure 10. Checking the operation of the swinging device

Figure 10 shows the image of the vertically ascendant depositing with the swinging of the welding head (right), and the image of the vertically ascendant depositing without the swinging of the welding head (right).

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