The processing method of the tungsten electrodes and the current type choice influence on the shape of the welding arc in tungsten inert gas welding (TIG)

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Abstract: The paper presents the results obtained during the experiments carried out in order to establish the influence of the processing method applied to the refractory electrodes, used in Tungsten Inert Gas (TIG) welding, on the shape and stability of the welding arc, but also on some geometric parameters related to the deposit process, such as penetration. The variations of the dimensions of the welding arc, caused by the change of the geometrical shape at the top of the electrode, are presented in graphical form.

1. Introduction

The TIG welding process is one of the permanent joining processes that leads to a high quality joint compared to other arc fusion welding processes. Aside from the welding parameters (welding current, welding speed and arc voltage), the quality of the welded joints obtained by TIG welding are also influenced by other parameters, such as:

- the type and diameter of the tungsten electrode;
- the preparation of the tungsten electrode;
- the distance between the tungsten electrode and the welding material, known in the specialty literature as the welding arc-length, lₐ, and
- the position of the welding gun towards the welding piece etc.

If the electrode type is chosen depending on the nature of the materials to be welded and on the welding current and the arc length and welding gun position can be provided and maintained constant by using different equipment's/devices, in order to obtain an adequate quality special attention should be paid to how the tungsten electrode is prepared.

The preparation of the tungsten electrode for use in the welding process must be carried out primarily in accordance with the recommended processing direction, meaning processing it in a vertical direction along the electrode. Figure 1 presents the electrode preparation possibilities in vertical and longitudinal direction. The right version is presented in figure 1a) because, as it can be observed from the representation, a transverse processing as in figure 1b), leads to an unstable arc, fact explained by the occurrence of perturbations due to how the current lines close.

Another important recommendation is the use of a special equipment intended for proper processing of the electrode, a solution that leads to increased costs. Though in the majority of cases the tungsten electrodes producers may recommend the use of a grinding machine or a grinder [4], this
processing mode is inappropriate, inaccurate and dangerous. Without the help of a special equipment, continuity and quality of processing and constant processing angle cannot be ensured. In addition, it is dangerous for people and environment because the dust released by splintering the electrode is directly spread in the environment.

Figure 1. The preparation mode of the tungsten electrode and the effects generated by processing on the arc [2, 3].

Figure 2 presents the appropriate processing mode of the tungsten electrode and the effect of the angle obtained on the welding arc and on the geometrical configuration of the seam.

Figure 2. Tungsten electrodes processing [5]

a) Adequate and inadequate processing mode; b) The effects of the processing angle on the shape of the arc.

The TIG welding may be carried out in direct current direct polarity (DCEP), direct current reversed polarity (DCEN) or alternating current (AC) [6]. Depending of the current type used to power the arc, the quantity of heat generated by it is differently distributed in the base material and in the electrode [4]; in DCEN, 1/3 of the heat is found in the electrode and 2/3 in the base material, in DCEP 2/3 of the heat is found in the electrode and 1/3 in the base material and in AC the heat is evenly distributed in the electrode and the base material.

The heat distribution has the effect of modifying the geometric elements of a joint such as penetration, cord width, etc. In addition, the processing mode of the electrode influences the temperature in the welding area [7, 8].

With regard to the theoretical size of the processing angle of the tungsten electrode, it can have any value, but as a matter of applicability, from the literature as well as from practice, a reduced number of values and shapes can be identified.

The main values of the processing angles used in TIG welding are:
- 30 ° angle with sharp tip - figure 3a);
- 30 ° angle with conic tip - figure 3b);
- 60 ° angle with sharp tip - figure 3c);
- 60 ° angle with conic tip - figure 3d);
- 90° angle with sharp tip - figure 3e);
- 90° angle with conic tip - figure 3f).

![Diagram of tungsten electrode processing angles](image)

**Figure 3.** Common processing angles of the tungsten electrode.

Regardless of the initial processing mode, during welding, the electrode changes its shape [11,12].

### 2. Experimental procedure

#### 2.1. Materials

2.1.1. Type of electrodes used in the experiments

The types of tungsten electrodes used in TIG welding are indicated in EN ISO 6848:2015, Arc welding and cutting -- Nonconsumable tungsten electrodes – Classification”

Among the electrodes indicated in the above mentioned standard, two types of tungsten electrodes were used to perform the experiments:

- WP - pure tungsten electrode (99.8%), standardized marking: green color;
- WT 20 - tungsten electrode with ThO2 oxide (1.7 – 2.20 %), standardized marking: red color.

2.1.2. Base material

Taking into account that the paper aims to highlight the influence of the angle sharpening of the tungsten electrode on the shape of the arc, the chosen base material was an unalloyed steal, S235JR, delivered in the form of plat band.

2.1.3. Experimental parameters

The welding parameters were chosen from the value range recommended by the manufacturer of the chosen electrodes, taking into account, as far as possible, the provision of a stable arc.

The experimental parameters have been divided in two categories:

- Constant parameters, presented in table 1, defined as to be the parameters that remain unchanged during the experiment, such as: gas type and flow, specimen-electrode distance, electrode diameter, welding speed etc.;
- Variable parameters, presented in table 2, such as: current type, electrode type, electrode processing.

| No. | Parameter      | Value      |
|-----|----------------|------------|
| 1   | Shielding gas  | Ar 100%    |
| 2   | Gas flow [l/min] | 12         |
3 Specimen-electrode distance [mm] 4,5
4 Electrode diameter [mm] 3,2
5 Welding speed [cm/min] 17
6 Welding current [A], Alternative current, AC 80
  used to power the arc in: Direct current, reversed polarity, DCEN 120
  Direct current, direct polarity, DCEP 30

Table 2. Variable parameters.

| No. | Parameter          | Value                          |
|-----|--------------------|--------------------------------|
| 1   | Current type       | DCEN/DCEP/ AC*                 |
| 2   | Electrode type     | WP/WT 20**                     |
| 3   | Tip                |                                 |
|     |sharp [°]           | 30  60  90                     |
|     |conic [°]           | 30  60  90                     |

* AC – alternating current; DCEN - Direct current electrode negative; DCEP - Direct current electrode positive;
** WP - Pure Welding Tungsten electrode, WT 20 – Thoriated Tungsten Welding Electrode – 2% Thoriated

The parameters used within the experiments for each sample are presented in table 3, for WT 20 electrode type and in table 4 for WP electrode type.

Table 3. Experimental parameters - WT 20 electrode.

| No. | Experiment code | Processing angle [degree] | Processing shape * | Current type | Welding current [A] |
|-----|-----------------|----------------------------|--------------------|--------------|---------------------|
| 1.  | 1.1a            | 30                         | sharp              | AC           | 80                  |
| 2.  | 1.1b            | 30                         | conic              | AC           | 80                  |
| 3.  | 1.5a            | 30                         | sharp              | DCEN         | 120                 |
| 4.  | 1.5b            | 30                         | conic              | DCEN         | 120                 |
| 5.  | 1.9a            | 30                         | sharp              | DCEP         | 30                  |
| 6.  | 1.9b            | 30                         | conic              | DCEP         | 30                  |
| 7.  | 1.2a            | 60                         | sharp              | AC           | 80                  |
| 8.  | 1.2b            | 60                         | conic              | AC           | 80                  |
| 9.  | 1.6a            | 60                         | sharp              | DCEN         | 120                 |
| 10. | 1.6b            | 60                         | conic              | DCEN         | 120                 |
| 11. | 1.10a           | 60                         | sharp              | DCEP         | 30                  |
| 12. | 1.10b           | 60                         | conic              | DCEP         | 30                  |
| 13. | 1.3a            | 90                         | sharp              | AC           | 80                  |
| 14. | 1.3b            | 90                         | conic              | AC           | 80                  |
| 15. | 1.7a            | 90                         | sharp              | DCEN         | 120                 |
| 16. | 1.7b            | 90                         | conic              | DCEN         | 120                 |
| 17. | 1.11a           | 90                         | sharp              | DCEP         | 30                  |
| 18. | 1.11b           | 90                         | conic              | DCEP         | 30                  |
| 19. | 1CA             | unprocessed                | conic              | AC           | 80                  |
| 20. | 1CCEN           | unprocessed                | conic              | DCEN         | 120                 |
| 21. | 1CCEP           | unprocessed                | conic              | DCEP         | 30                  |

* as presented in figure 3

2.2. Experimental procedure
In order to highlight the dependence between the processing of tungsten electrodes, the parameters of the welding depositing regime and the shape of the arc, the following steps were taken:
- Analysing the experimental plan and calculating the material requirements;
- Checking shielding gas stocks, availability of welding equipment;
– Base material reception;
– Making positioning stencil, figure 4;
– Making the holding device for maintaining the specimen at the appropriate height, figure 5;
– Assembly and calibration of welding equipment.

![Device for ensuring a constant distance between the electrode and the specimen](image)

**Figure 4.** Device for ensuring a constant distance between the electrode and the specimen

1 – gas nozzle; 2 – positioning stencil; 3 – tungsten electrode; 4 – base material subjected to welding.

**Table 4.** Experimental parameters - WT electrode.

| No. | Experiment code | Processing angle [degree] | Processing shape * | Current type | Welding current [A] |
|-----|-----------------|---------------------------|-------------------|--------------|---------------------|
| 1.  | 2.1a            | 30                        | conic             | AC           | 80                  |
| 2.  | 2.1b            | 30                        | sharp             | AC           | 80                  |
| 3.  | 2.5a            | 30                        | conic             | DCEN         | 120                 |
| 4.  | 2.5b            | 30                        | sharp             | DCEN         | 120                 |
| 5.  | 2.9a            | 30                        | conic             | DCEP         | 30                  |
| 6.  | 2.9b            | 30                        | sharp             | DCEP         | 30                  |
| 7.  | 2.2a            | 60                        | conic             | AC           | 80                  |
| 8.  | 2.2b            | 60                        | sharp             | AC           | 80                  |
| 9.  | 2.6a            | 60                        | conic             | DCEN         | 120                 |
| 10. | 2.6b            | 60                        | sharp             | DCEN         | 120                 |
| 11. | 2.10a           | 60                        | conic             | DCEP         | 30                  |
| 12. | 2.10b           | 60                        | sharp             | DCEP         | 30                  |
| 13. | 2.3a            | 90                        | conic             | AC           | 80                  |
| 14. | 2.3b            | 90                        | sharp             | AC           | 80                  |
| 15. | 2.7a            | 90                        | conic             | DCEN         | 120                 |
| 16. | 2.7b            | 90                        | sharp             | DCEN         | 120                 |
| 17. | 2.11a           | 90                        | conic             | DCEP         | 30                  |
| 18. | 2.11b           | 90                        | conic             | DCEP         | 30                  |
| 19. | 2CA             | unprocessed               | conic             | AC           | 80                  |
| 20. | 2CCEN           | unprocessed               | conic             | DCEN         | 120                 |
| 21. | 2CCEP           | unprocessed               | conic             | DCEP         | 30                  |

* as presented in figure 3
Figure 5. Adjustable device to ensure the flatness of the sample
1 – surface for the welding specimen; 2 – M14 screw nut (8 pieces); 3 - Flat head screws M14 x 100 (4 pieces); 4 – level for ensuring flatness.

Experiments:
✓ Processing of tungsten electrode: sharpening the electrode at pre-set angles, positioning each electrode on millimeter paper and taking pictures to establish the processing precision and comparing it with the post-welding shape, figure 6

Figure 6. Electrode processing:
a) 60° sharp tip electrode; b) electrode sharpening equipment; c) 30° conic tip electrode figure 4.

✓ Specimen positioning on the supporting device and writing the experiment code, figure 7
✓ Position the electrode in the welding gun tweezers and adjust the distance from the specimen with the help of the device that keeps the electrode-specimen distance constant, figure 8

Figure 7. Specimen positioning and marking.
Figure 8. Electrode positioning with the help of the designed device.

✓ Turn on data acquisition equipment (photo-video equipment);
✓ Start welding equipment (welding gun and welding tractor);
✓ Stop welding equipment (welding gun and welding tractor);
✓ Turn off data acquisition equipment (photo-video equipment);
✓ Specimen handling: Visual Marking Check, Taking Pictures and Archiving Outputs, figure 9;
✓ Tungsten electrode handling: electrode removal from the welding gun, electrode positioning on millimeter paper to determine its shape after use, Shooting;
✓ Resetting the equipment to its original position.
Figure 9. Samples resulted after welding.

- Processing the obtained experimental data based on the following categories of digital data:
  - Video files containing recordings of the electric arc for each experiment;
  - Images of tungsten electrodes used in experiments, before and after use;
  - Images of the specimens on which the experiments were performed.

For each experiment, a working methodology was applied that consisted of:

- Extracting images. From the files with the *.mov extension, for each video sample, frame-by-frame, clear images with the electric arc during the experiment were drawn, figure 10;

- Chromatic processing of images: a) Importing the data file into the software and cutting (according to a predefined template) the area of interest to be processed; b) Applying primary corrections, raising the contrast level to enhance the main shades and lowering the level of brightness; c) Applying the threshold function to a level of approximately 230 units, transforming the colour image into a pure black and white image, resulting in a clear contour of the electric arc.

- Electric arc measurement with the help of Autodesk Autocad, figure 11: a. Import processed images and scaling them having as reference the constant diameter of the tungsten electrode, $\varnothing$ 3,2 mm; b. Measuring the height of the electric arc on the processed image and showing changes in contrast and brightness; c. Drawing an electric arc contour on the image that has the threshold mask applied; d. Extracting the contour of the electric arc and making the intersection points with the...
reference lines (those at a 1 mm interval); e. Measuring the quotas between the intersection points on each line and completing the table for each sample.

– **Digital measurement of the seam and the overheated zone** with the help of Autodesk Autocad:
  a) Importing images of the samples and scaling them with reference to the constant width of the steel plate - 50 mm; b) Marking measurement values on the seam image and if visible, on the overheated zone, figure 12.

![Figure 11. Electric arc measuring](image)

*Figure 11. Electric arc measuring*

a) initial shape, b) applying contrast; c) Thresold; d) arc shape after processing.

![Figure 12. Digital measuring example of the seam and overheated zone– sample 1.6a.](image)

*Figure 12. Digital measuring example of the seam and overheated zone– sample 1.6a.*

The working methodology for the analysis of the welded samples indicated in figure 9 consisted of:

a) transfer of the marking, and cutting in the transverse direction on the welding cord; b) processing, in the seam area, on the grinding machine, followed by grinding with metallographic paper of different granulations: 280, 600, 1200; c) Chemical attack with 2% sulfuric acid; d) analyzing the samples with the MZ-630T microscope and measuring the penetration for each sample;

3 Results and discussion

3.1. Results obtained

Following all the above-mentioned steps, the following results were obtained:

3.1.1. The measured values of the electric arc for each sample

Values obtained from measurements made on real samples are shown in the tables and graphs below for each set of experiments.

| No. | Type/ Current value | Experiment codification | Arc length \( l_a \) [mm] | Welded seam width | Seamed width | Overheated zone width |
|-----|---------------------|-------------------------|--------------------------|-------------------|--------------|-----------------------|
| 1   | AC/80A              | ICA                     | 6.4                      | 8.1               | 8.1          |                       |
Table 6. Results obtained - Samples made with WP electrode.

| No. | Type/Current value | Experiment codification | Arc length $l_a$ [mm] | Welded seam width | Seamed zone width |
|-----|------------------|------------------------|-----------------------|-------------------|------------------|
| 1   | AC/80A           | 2CA                    | 6.1                   | 10.5              | 10.5             |
|    |    |    |    |    |    |    |
|---|---|---|---|---|---|---|
|2  | 2.1a | 7.5 | 9.8 | 9.8 |
|3  | 2.2a | 5.5 | 9.2 | 9.2 |
|4  | 2.3a | 5   | 9.6 | 9.6 |
|5  | DCEN/120A | 2DCEN | 6.2 | 2.7 | 7.3 |
|6  | 2.5a | 4.7 | 4.4 | 7.6 |
|7  | 2.6a | 4.6 | 3.6 | 6.5 |
|8  | 2.7a | 4.7 | 3.4 | 6.8 |
|9  | 2.5b | 4.8 | 4.3 | 7   |
|10 | 2.6b | 4.6 | 4.1 | 6.8 |
|11 | 2.7b | 4.6 | 4   | 7.4 |

**Figure 16.** Electric arc values - Samples made with WP/AC/80A electrodes.

|    |    |    |    |    |    |
|---|---|---|---|---|
|2  | 2.1a | 6.2 | 2.7 | 7.3 |
|3  | 2.2a | 5   | 9.6 | 9.6 |
|4  | 2.3a | 5   | 9.2 | 9.2 |
|5  | DCEN/120A | 2DCEN | 6.2 | 2.7 | 7.3 |
|6  | 2.5a | 4.7 | 4.4 | 7.6 |
|7  | 2.6a | 4.6 | 3.6 | 6.5 |
|8  | 2.7a | 4.7 | 3.4 | 6.8 |
|9  | 2.5b | 4.8 | 4.3 | 7   |
|10 | 2.6b | 4.6 | 4.1 | 6.8 |
|11 | 2.7b | 4.6 | 4   | 7.4 |

**Figure 17.** Electric arc values - Samples made with WP/DCEN/120A electrodes.

3.1.2. **Results on the shape of the electric arc related to the type of the electric current used**

Within the processing of the images taken during the experiments, it was aimed to highlight the shape of the arc for each sample.

In order to be able to read the obtained images more easily, an overlapping of the three types of electric arcs, DCEP, DCEN and AC was made, together with the quotas, overlapping presented in figure 18.

**Figure 18.** Form composition, welding arc wireframe, mm dimensions.

3.1.3 **Results obtained after analyzing the welded samples - welded seam**

For a further analysis, the macroscopic analysis described above was chosen, the results obtained for each type of electrode used being shown in the tables below.
Table 7. Penetration values - experiments carried out with WT20 electrode.

| Electrode, current, polarity | Code  | Penetration, p [mm] | Observations  |
|-----------------------------|-------|---------------------|---------------|
| WT20, 120A, DCEN            | 1 DCEN| 1.3                 | Unprocessed tip|
|                             | 1.5a  | 1.8                 | 30° sharp tip  |
|                             | 1.6a  | 2.3                 | 60° sharp tip  |
|                             | 1.7a  | 3                   | 90° sharp tip  |
|                             | 1.5b  | 2.3                 | 30° conic tip  |
|                             | 1.6b  | 2.7                 | 60° conic tip  |
|                             | 1.7b  | 3.2                 | 90° conic tip  |

Table 8. Penetration values - experiments carried out with WP electrode.

| Electrode, current, polarity | Code  | Penetration, p [mm] | Observations  |
|-----------------------------|-------|---------------------|---------------|
| WP, 120A, DCEN              | 2 DCEN| 1.1                 | Unprocessed tip|
|                             | 2.5a  | 1.5                 | 30° sharp tip  |
|                             | 2.6a  | 1.9                 | 60° sharp tip  |
|                             | 2.7a  | 2.5                 | 90° sharp tip  |
|                             | 2.5b  | 1.8                 | 30° conic tip  |
|                             | 2.6b  | 2.3                 | 60° conic tip  |
|                             | 2.7b  | 2.8                 | 90° conic tip  |

3.2. Results processing
Based on the results obtained, a series of graphs were drawn and a series of comparisons indicated below were made.

3.2.1. Data processing and results interpretation for analysing the influence of the electrode processing mode on the real height of the electric arc.
Based on the results, graphs presented in figure 19 and 20 were drawn up, where are indicated the measured heights of the electric arcs recorded, keeping as a base the initial distance between the electrode and the specimen, distance fixed and maintained during the experiments (4.5 mm).

Figure 19. Comparative analysis of the preset and real (measured) arc length - WT20 tungsten electrode case, measurement unit [mm].
Figure 20. Comparative analysis of the preset and real (measured) arc length - WP tungsten electrode case, measurement unit [mm]

Analysing the graphs presented in figures 19 and 20 it can be observed:

- An increase of the length of the electric arc occurs in the case where the alternating current was used, which is directly proportional with the decrease of the tip angle value of the electrode with sharp tip. Thus, even if the distance between the tip of the electrode and the specimen was constant (4.5 mm), in the case of samples 1.1a and 2.1a) the largest length of the electric arc (7.4 mm and 7.5 mm) was recorded while at the 1.3a and 2.3a samples the lowest values of the electric arc length were obtained in alternating current (7mm and 5mm);

- In direct current with the electrode connected to the negative pole, in the case of unprocessed electrode, the real length of the arc is higher than in cases where the electrode has been processed in various shapes and angles;

- In the case of unprocessed electrode, the electric arc was unstable and was located on the edges of the electrode;

- In direct current with the conic tip electrode, connected to the positive pole there wasn’t a significant influence on the length of the spring. In the case of WT20 electrodes, the length of the electric arc was constant regardless of the angle at which the electrodes were processed, whereas, in the case of the WP electrodes, a slight increase of the real arc length can be observed together with the decrease of the processing angle.

3.2.2. Data processing and results interpretation for analysing the influence of the electric arc and the geometrical characteristics of the resulted seam

The input data for drawing up the graphs presented in figure 21 and 22 is given by the measured dimensions of the electric arc at the surface of the specimen, the measured width of the seam and the overheated zone.

Figure 21. The analysis of the electric arc in relation to the width of the seam and the overheated zone in the case of WT20 electrodes, measurement unit [mm].
From the graphics presented in figures 21 and 22 the following conclusions can be drawn:

- by comparison, in the case of AC welding, resulted a real width of the electric arc, measured at the surface of the sample, higher in the case of WT20 electrodes, along with a lower overheating area;
- In DCEN, in can be observed that in the case of WT20 electrodes the width of the electric arc, measured at the surface of the sample exceeds in all cases the width of the seam, while in the case of WP electrodes this only applies in half of cases. This could happen because of the low stability of the arc for pure tungsten electrodes in case of DC.
- Also, in DCEN, the width of the electric arc measured at the sample level for the WT20 electrodes, there is a slight increase in the width of the cord, in both processing cases, sharp and conic, but only when switching from the 60º angle value to the 90º value.

3.2.3. Data processing and results interpretation for comparative analysis between the two tungsten electrodes in the case of direct current.

Figure 23 shows graphically the actual arc length. In this graph the dotted line represents the actual distance to which the tungsten electrode was positioned relative to the welding sample in the case of AC supply.

From the above graphic it can be observed that the electric arc, in AC case, decreases linearly with increase of the angle of electrode processing when using a sharp tip in both types of electrodes used.
Another important aspect resulting from the figure above and from the information resulted during the experiments is that there is a shape and stability difference between the two types of electrodes. If, in the case of WT20 electrodes, the variation is only a few tenths of millimeters, recording a total variation of 0.6 mm, in the case of WP electrodes values up to 2.5 mm have been recorded.

3.2.4. Data processing for comparative analysis between the height of the electric arcs generated by WT20 and WP electrodes in DCEN

The obtained results are presented graphically in figures 24 and 25.

![Figure 24. Comparative analysis of the length of the electric arc measured in DCEN for sharpen tip electrodes.](image)

![Figure 25. Comparative analysis of the length of the electric arc measured in DCEN for conic tip electrodes.](image)

Analysing figures 24 and 25 it can be noticed easily that the real length of the electric arc increases in DCEN cases regardless the electrode type, the processing angle for the sharpen tip electrodes, phenomenon noticed also in the case of WP electrodes with conic tip.

3.2.5. Data processing for comparative analysis between the penetrations obtained in the case of WT20 electrode for different ways of processing the electrode

The data resulted after processing are presented in the graphs below.

![Figure 26. Comparative analysis between the penetration obtained in the case of WT 20 electrode, measurement unit [mm].](image)

![Figure 27. Comparative analysis between the penetration obtained in the case of WP electrode, measurement unit [mm].](image)

From a quantitative analysis of 26 and 27 figures, it can be concluded that regardless of the electrode type used within the experiments or the electrode processing, the value of the penetration changes.
4. Conclusions
From the optical and dimensional analysis of the resulted samples, from the interpretation of the results obtained after processing the images but also from the obtained graphics, the following conclusions can be drawn:

✓ WT20 electrodes case:
- In AC and sharpen tip electrode case, samples 1.1a, 1.2a, 1.3a: The actual arc height decreases with increasing the electrode processing angle value, and the width of the seam decreases with increasing the angle value of the electrode;
- In DCEN and sharpen tip electrode case, samples 1.5a, 1.6a, 1.7a, the real length of the arc does not suffer any significant changes relative to the theoretical length (sample-electrode distance);
- In DCEN, in both cases, the apparent dimensions of the welded seam tend to remain constant relative to the angle of the electrode tip.
- The 1CCEN control sample has demonstrated that the angle of electrode processing regardless of its value, influences the penetration;

✓ WP electrodes case:
- In AC and sharpen tip electrode tip case, samples 2.1a, 2.2a, 2.3a, the real height of the welding arc decreases with the increase of the electrode processing angle value. Also for this case, the metallographic analysis didn't analysis did not reveal a welded seam that can be analysed, the penetration having very low values;
- In DCEN and sharpen tip electrode case, samples 2.5a, 2.6a, 2.7a, it was clearly noticed that the real length of the arc does not suffer any significant changes relative to the theoretical length (sample-electrode distance); and the apparent dimensions of the welded seam tend to remain constant no matter how it has been processed. In the case of penetration analysis, a linear increase can be clearly observed with the increase of the processing angle value.
- The 2CCEN control sample has demonstrated that the angle of electrode processing, regardless of the value, affects the penetration.
- In DCEN and conic tip electrode, samples 2.5b, 2.6b, 2.7b, it could be noticed that the real length of the arc does not suffer any significant changes relative to the theoretical length (sample-electrode distance), but it has been highlighted, in the case of penetration analysis, a linear increase of the penetration with the increase of the value of the processing angle;

By comparing the obtained results for the two type of electrodes and their processing mode the following conclusions can be drawn:
- The stability of the arc in DC is better in WT20 electrodes case.
- The length and the width of the arc measured at the level of the sample in the WT20 electrode case has lower variations than in WP electrodes case. This effect was noticed in both cases of tip processing, fact leading to the conclusion that the type of electrode itself affects the geometrical parameters that characterize an electric arc used in welding.

The general conclusion is that, the processing mode, characterized by the sharpening technique and the angle, considerably influences the stability of the arc and the penetration of the seam.

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