Nonconventional Technologies Review
Romania, September 2019


# CONTRIBUTIONS TO THE OPTIMIZATION OF DIMENSIONAL PROCESSING TECHNOLOGY THROUGH ELECTRIC EROSION WITH CONTACT BREAKING WITH ELECTRODE-TOOL – THE METAL BAND

Viorel Bucur[1] and Aurel Mihail Țîțu [2]
[1] Lucian Blaga University of Sibiu, 10, Victoriei Street, Sibiu, România, viorel.bucur2018@yahoo.com
[2] Lucian Blaga University of Sibiu, 10, Victoriei Street, Sibiu, România, Lucian Blaga University of Sibiu, 10, Victoriei Street, Sibiu, România, The Academy of Romanian Scientists, 54, Splaiul Independenței, Sector 5, Bucharest, Romania, mihail.titu@ulbsibiu.ro

ABSTRACT: The paper is presented in the form of a review, of the research carried out in the doctoral thesis, of the nonconventional processing process, by cutting high alloyed steels, using as a metal transfer object. The paper presents the technological aspects, the average values obtained on the experimental installation, as well as some of its components, in the chapters specific to the nonconventional processing method. Some results obtained from the cutting of alloyed steels, using an original cutting by electric erosion with contact breaking with Electrode-Tool – the Metal Band. The concern of specialists around the world is to confirm the opportunity to address this area of great interest and a real benefit to the industry's top sectors in developed countries and beyond.
KEYWORDS: -Cutting steel; Electric Erosion with Contact Breaking; metal band, the physical processing mechanism, transfer object, processing object, the JOULE-LENZ effect, non-stationary electric arc, cooling/working environment.

## 1. THE PROCESSING BY ELECTRIC EROSION WITH CONTACT BREAKING

At present, several industry-leading areas (machine building, aeronautics, naval engineering) require the application of "nonconventional" technological processes to process metals with particular physical-chemical and mechanical properties.

Research on the original stand (the experimental stand) allowed identification of the causal links between the parameters of the technological system while making it possible to objectively test the correspondence of the model used and to highlight the optimum conditions for their deployment [1], [2], [3], [4], [5], [6].

In the paper, in Figure 1, the primary forms of erosion from the erosive agent, which are of technological interest, are presented.

The primary forms of erosion classified in terms of erosive agent exploit a wide range of physical, chemical phenomena, or combinations thereof.

The electrical erosion process has the highest share of the total erosion phenomena applied worldwide.

The process is based on destroying the integrity and extracting the excess material (machining allowance) from the surface of the processing object through the dynamic action of erosive agents of different nature introduced into the workspace [3], [4], [7], [8].

## 2. THE OPPORTUNITY TO USE TRANSFER OBJECT-METALLIC BANDS BY ELECTRIC EROSION WITH CONTACT BREAKING

Use for metal disk cutting operations, through electric erosion with contact breaking raises several issues of which the most significant are:

- high electricity consumption due to the discharges occurring during the machining process, in the form of the "wrong arc," between the side surfaces of the metal disc (transfer object) and the workpiece (processing object);
- energy losses in the form of "the wrong arc," lead to additional high energy consumptions needed for the work process;
- productivity dependence on the increase of discharges in the form of "wrong arc," i.e., "energy losses," resulting in a decrease in productivity;
- at individual sections of the processing object, the cutting process is no longer possible because of the "energy losses," which are very high, since the value of these "losses" increases proportionally with the increase of processing object. [1]

Considering the existence of restrictions in the case of the use of transfer object - the metal disc, it has been found that the use as transfer object - of the metallic band leads to several advantages, because:

- side contact surfaces that cause "wrong arc" production are considerably lower and reduce energy loss;

- due to lower values of the side contact surfaces, in this case, it is possible to use technological parameters with lower values and implicitly less electricity consumption;
- there is a possibility to ensure a better probability of the working process, compared to use as transfer object of the metal disc [2], [3], [9], [10].

## 3. THE PHYSICAL MECHANISM OF PROCESSING BY ELECTRIC EROSION WITH CONTACT BREAKING

In order to ensure the stability of the process of electrical erosion, necessary conditions are necessary, the most important being:

- Direct introduction of electric power into the transfer object – processing object contact area and realization of the necessary conditions for the priming of the discharges;
- The continuous and temporary pulse of electric energy in the transfer object - processing object interaction area;
- Ensuring a polarized character of the impulse electrical discharges, which will lead to the sampling of both the processing object and the transfer object;
- Continuous restoration of the initial state in the erosive range and continuous change of the transfer object position towards the processing object, making it possible to repeat the discharge periodically;
- Efficient disposal of erosive products.

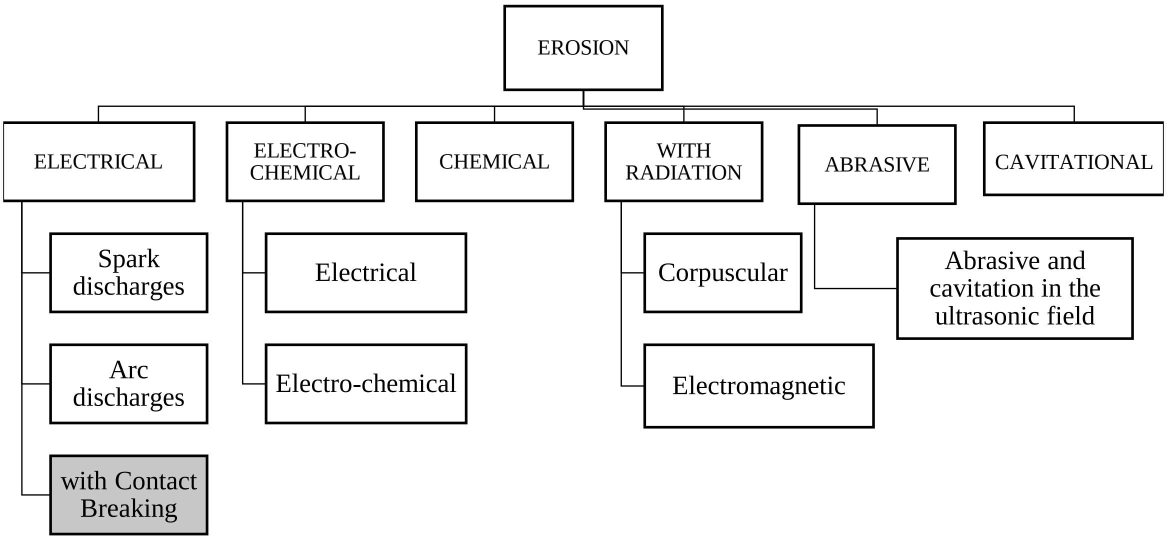



**Figure 1.** The primary forms of erosion of technological interest

These processes are formed and held in the space defined by elementary surfaces of transfer object interaction with the processing object and the work environment (W.E), according to Figure 2.

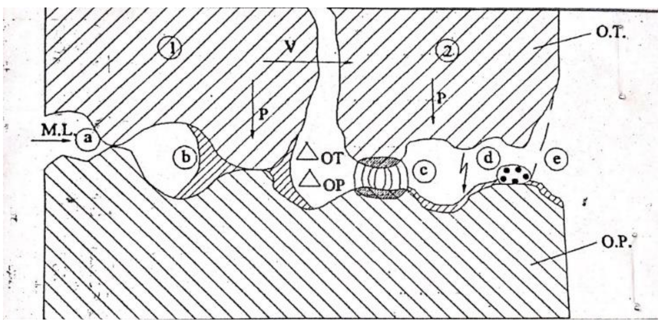



**Figure 2.** Structure of the elementary workspace

The most significant and real erosion elementary processes mentioned in the thesis, according to the literature, is aimed at:

a) Applying the supply voltage - to the contact surface transfer object - the processing object causes a potential difference defined by the structure and characteristic of the power supply circuit.

They are significant in this case:

- Occurrence/establishment of surface contacts (a) with a statistical distribution between the micro-irregularities of transfer object-processing object, under the influence of the contact pressure ($p_c$), which causes a substantial increase of the current density and causes the release of a large amount of heat Q (due to Joule - Lenz effect).

$$Q = I^2 \cdot R \cdot t \quad (1)$$

This heat developed and localized in the mass of the elements $\Delta_{OT}$, $\Delta_{OP}$, causes surface heating to the melting temperature.

- The appearance of an oxide film (b) resulting from the interaction of the heated metal with the dissociation elements in the cooling medium, which causes these oxide films.

The process acquires dynamic and continuity characteristics through the mechanical action exerted by transfer object and processing object, the contact pressure (pc) and relative velocity ($V_r$).

Under the mechanical action occurs breaking contact bridge paving appearance electric erosion by arc discharge triggering unsteady.

Thus, in the real process of development of the erosive process, distinct pairs are formed $\Delta_{OT}$ - $\Delta_{OP}$,- representing the point-to-point contacts of the micron-regularities of the two PO and TO objects in interaction.

The space between the transfer object and the processing object defined as a gap characterized by four areas:

- Short circuit area, ($\delta_{sc}$);
- non-stationary arc area, ($\delta_a$);
- Dielectric area, ($\delta_{di}$);
- Pulse discharge area.

Every pair $\Delta_{OT}$ - $\Delta_{OP}$, passes successively through the mentioned areas.

b) Non-stationary arc discharge:

- as a result of the development of non-stationary electrical discharges in the arc under the action of mechanical breakage occurs the contact bridge (c) which causes thermal phenomena characterized by increasing the temperature, leading to melting and even vaporization of the material micro volumes ($\Delta_{OT}$, $\Delta_{OP}$);
- Depending on the characteristics of the supply current (I) and the effect energy location conditions, the material sampling and the formation of new contact bridges take place;
- In areas adjacent to the molten metal micro-volumes, impulse discharge (d) may occur by easily piercing the oxide film (b) formed and characterized by low dielectric stiffness.

These electrical discharges are characterized by:

- high power densities;
- the duration of the discharge;
- high thermal effects.

Temperatures due to electrical discharge cause the melting and vaporization of metallic microwaves, along with the development of chemical processes to dissociate the elements from the cooling medium.

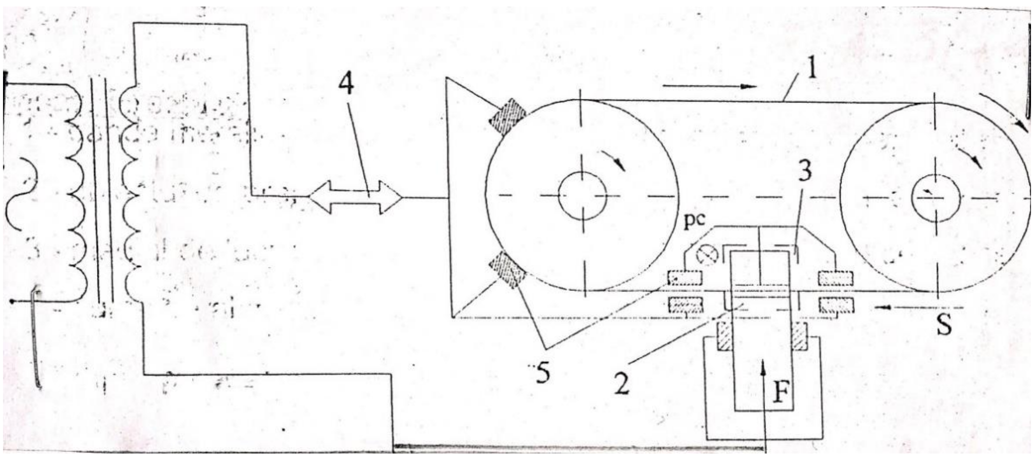
Obs: Specialty literature mentions a wide range of values for these electrical discharges.

- By removing micro volumes of material as erosive products (e), the configuration of contact surfaces changes to form new contact peaks and contact pressure pc) creates the premises for the formation of new bonding bridges, also generating new elementary erosion processes due to the relative movement between transfer object and processing object (metal band and piece).

## 4. THE PRINCIPLE OF PROCESSING BY ELECTRIC EROSION WITH CONTACT BREAKING- WITH TRANSFER OBJECT - METAL BAND

Erosion is part of the process based on rupture actions of the substance (emphasized by several specialists in the field, according to the literature, mentioned in the thesis).

Electric erosion with contact breaking process is based on non-stationary priming arc discharge by breaking the current carrying electrical contacts, temporarily established between transfer object and processing object, each connected to a pole of an electrical power generator.




1 – metal band (transfer object);
2 – the processed object;
3 – cooling/working environment (w.e.);
4 – power source (P.S.);
5 – Power receptors;
F – pushing force;
c – contact pressure;
S –feed movement of the transfer object

**Figure 3.** Schematic diagram of the process by electric erosion with contact breaking - with O.T. metal band

As a technological method, erosion processing is based on the complex, discontinuous and localized erosive effects of impulse electrical charges, repeatedly primed between two electrodes (transfer object and processing object/piece), the first having the role of the erosive agent, and the other is the subject of erosion.

It is noticed in Figure 3, in the schematic diagram, the two objects (transfer object and processing object) are connected to a DC / AC power source (PS), the process being aerated/wetted to locate the cooling/effect energy and to activate the process evacuation of eroded particles in the working environment (WE).

By the pressing force F, the contact pressure is ensured, and the feed movement S can be performed by transfer object and processing object.

When processing by electric erosion with contact breaking, the energy is transmitted to the piece processing object in discontinuous form as electric impulses, mechanically developed in the space bounded between the electrode (transfer object), the working environment (W.E) and the piece processing object.

Impulse development takes place mechanically via T transfer object - a metal band that performs translational movements relative to the processing object and moves tangentially to its surface.

Each impulse acting is part of an elemental erosion process, a process that takes place in a narrow space, consisting of the electric arc column, the working environment, and the two spots (anodic and cathodic) formed in transfer object and processing object.

Ejecting erosion products from the workspace and restoring disruptive distances by advancing one of the electrodes (transfer object or processing object) over the other, ensures the macroscopic continuity of the work process.

Providing electric power to the optimum value, determines the maintenance of the transformation processes physicochemical surface processing object, which as a consequence of the conversion of electrical energy into thermal energy based on the Joule-Lenz effect, which occurs at the contact point between the transfer object and processing object processes mentioned by a number of authors in the literature.

## 5. THE FIELDS OF APPLICATION FOR PROCESSING BY ELECTRIC EROSION WITH CONTACT BREAKING (WITH TRANSFER OBJECT - METAL BAND OR METAL DISC)

Electric erosion with contact breaking process has a wide range of application in industries specific to mechanical engineering or metallurgy.

The main applications of interest for processing by Electric erosion with contact breaking, are mentioned in Table 1.

**Table 1.** The main applications of interest for processing by Electric erosion with contact breaking

| No. | Name of the operation | The shape of the object transfer | Quality of the material |
|---|---|---|---|
| 1 | Dump-cleaning | Circular Disc | OL, OLC |
| 2 | Drilling | Cylindrical | OL, OLC, Cu |
| 3 | Surface treatment | Radial brushes | OL, Am, Cu |
| 4 | Cutting | Circular Disc | OL, OLC |
| | | Metal band | OL |

The paper refers specifically to the use of the manufacturing process by Electric erosion with contact breaking, in particular:

- cutting of steel/steel parts challenging to process;
- unmasking of castings;
- processing of surfaces (plane, cylindrical, front, etc.);
- sharpening of cutting tools;
- smoothing / rectifying machined surfaces;
- drilling, punching plates, profiles, etc.

## 6. CALCULATION OF THE CONTACT SURFACES BETWEEN TRANSFER OBJECT AND PROCESSING OBJECT

When cutting bodies with a complex profile, their side contact surfaces with the metal band are smaller than the metal disc, and the discharges occurring during the processing process in the form of "wrong arc" are implicitly lower.

These "lateral" discharges occurring during the machining process, (considered as "energy losses"), determine additional high energy consumption.

### 6.1 For bodies with a cylindrical section

In Figure 4 (a and b) there are presented the lateral contact surfaces between which the "wrong arches" are discharged, in the case of the metal disc and the metal band used as the transfer object, at the cutting of the cylindrical section bodies.

By approximating the arched circle arcs, the following relationships for the lateral contact surfaces (shown in Figure 4) were reached.

$$S_{D_1} = S_{AO,\ BO} = \frac{r^2}{2R}\sqrt{4R^2 - r^2}[mm^2] \quad (1)$$

$$S_{B_1} = S_{ABCD} = \left(r + \sqrt{r^2 - b^2}\right) \cdot b \quad [mm^2] \quad (2)$$

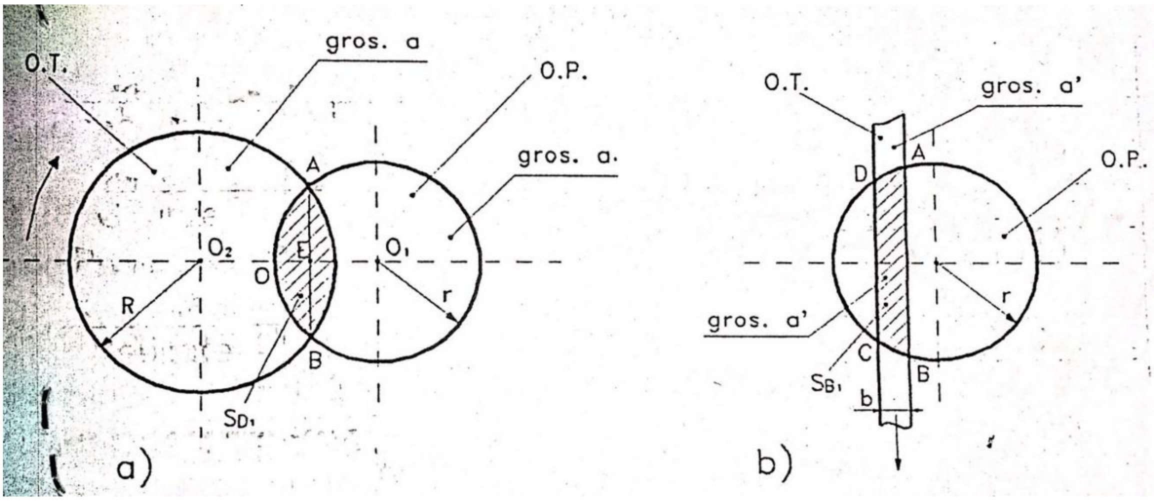



**Figure 4.** Contact surfaces between transfer object and O.P (between which take place as "wrong arc"): a) metal disc used as transfer object, b) metal band used as transfer object For prismatic sections

In Figure 5 (a and b) there are presented the lateral contact surfaces between which are discharges in the form of "erroneous arc", in the case of the metal disc and the metal strip, used as transfer object, at the cutting of prismatic sections.

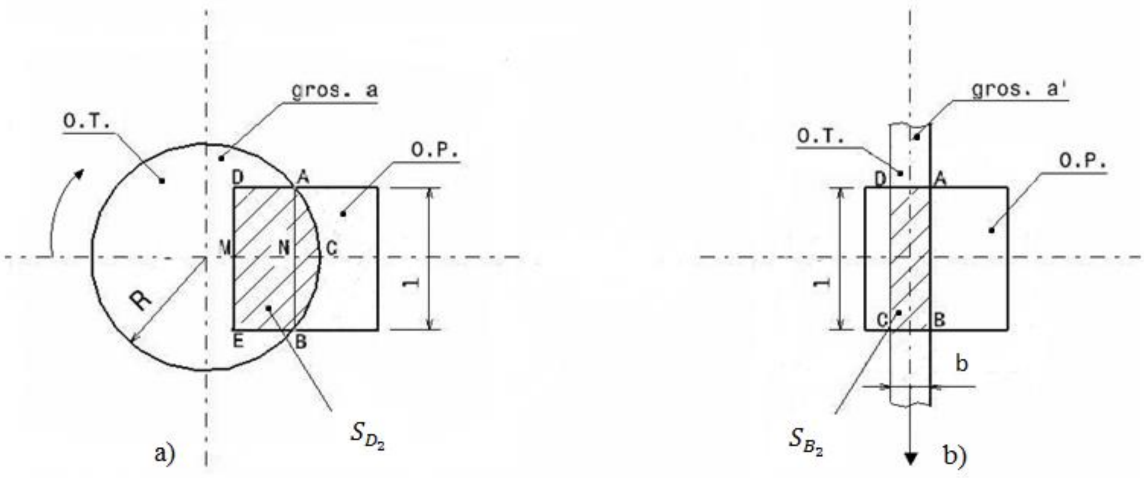



**Figure 5.** The contact surfaces between transfer object and O.P (between which take place in the form of "the wrong arc"); a) with transfer object –metal disc; b) with transfer object –metal band.

The calculation formulas are determined:

$$S_{D_2} = \left(\frac{l+\sqrt{4R^2-l^2}}{2} - R\right) \cdot l + \left(R - \frac{\sqrt{4R^2-l^2}}{2}\right) \cdot \frac{l}{2} \quad [mm^2] \quad (3)$$

$$S_{B_2} = l \cdot b \quad [mm^2] \quad (4)$$

The relationships highlight the existence of lateral contact surfaces of the metal disc, larger than with the use of the metal band, such as transfer object.

Table 2 compares the contact surfaces of the metal disc and the metal band for two categories of circular and square sections.

The values determined for the two transfer objects (metal disc and metal band), in the case of cylindrical sections with values of diameter D, mentioned in Tab. 1, for two categories of bodies (cylindrical and square section), are comparatively net favourable to the metal band, where the ratio of the side contact surfaces reaches half of that of the metal disc.

**Table 2.** The values determined for the two transfer objects (metal disc and metal band)

| No | Dimensions processing object D [mm] | Metal disc | | Metal band | | Report of lateral surfaces [%] |
|---|---|---|---|---|---|---|
| | | Disc radius R [mm] | Lateral contact surface $Sc_D$ $[mm^2]$ | Width b [mm] | Lateral contact surface $Sc_B$ $[mm^2]$ | |
| 1 | 200 | 300 | 9810,6 | 30 | 5862 | 59,7 |
| 2 | 400 | 500 | 39200 | 30 | 11391 | 31.0 |

## 7. USE OF THE METAL BAND AS TRANSFER OBJECT

### 7.1 Technological aspects considered in the design of the metal band as a transfer object

The researches carried out on the design of the metal-band transfer object aimed to clarify and solve some technological aspects, of which the most important ones were targeted:

- choosing the type of transfer object;
- choosing the most appropriate material;
- determining the working dimensions of the transfer object;
- establishing the main parameters (mechanical, electrical, etc.);
- performing resistance calculations;
- Execution, use, repair, and reuse technology.

The construction elements of transfer object (b, t, L) had to meet several conditions (technological, working, mounting, exploitation, and economic).

### 7.2 Geometrical parameters of the metal band and the metal disc

Since the optimum current density (J) used in the electric erosion with contact, the breaking process has values that can reach 20 A/$mm^2$, the use of the metal band as transfer object. leads to lower working currents relative to the projection of the cut bottom.

In Table 3, the much smaller geometric parameters corresponding to the metal band are exceeded compared to those of the metal disc.

**Table 3.** Geometrical parameters of the metal band and the metal disc

| No | Transfer object. –Metal Disc | | | Transfer object. –Metal Band | | | A current report required [%] | OBS. (current density) J=20A/$mm^2$] |
|---|---|---|---|---|---|---|---|---|
| | Lateral contact surface $Sc_D$ $[mm^2]$ | The surface of the projection of the cut bottom $s_P[mm^2]$ | Necessary working currents I [A] | Lateral contact surface $Sc_D$ $[mm^2]$ | The surface of the projection of the cut bottom $s_P[mm^2]$ | Necessary working currents I [A] | | |
| 1 | 9810,6 | 1177,5 | 23550 | 5862 | 200 | 4000 | 17 | $R_D$=300mm<br>$r_{op}$=100mm<br>a=5mm |
| 2 | 39200 | 3490,66 | 69813,12 | 11391 | 400 | 8000 | 11,45 | $R_D$=500mm<br>$r_{op}$=200mm<br>a=8mm |

where:

$A_c \equiv S_p$ - the area of contact or the surface of the projection of the cut bottom;

$R_D$ - the radius of the disc;

$r_{op}$ - the radius of the processing object (O.P);

a – the thickness of the transfer object.

Lower workflow values during the experiments ensurehigh processing stability with positive effects on the thermal influenced zone (TIZ).

### 7.3 Making the metal band like transfer object

The metal band was formed as a closed contour by welding, gluing or rolling, according to Figure 3 a and b; there is shown the metal band, wrapped on the steering wheels.

The chosen materials have rigorously metered and controlled chemical composition, ensuring the maintenance of transfer object. The joint ends of the metal band by welding was performed in order to obtain a continuous strip, with a closed contour.

The semi-automatic welding variant was chosen in a protective gas environment using an I.U.W-400 TIG-CT type installation, and the working parameters used are shown in Table 4.

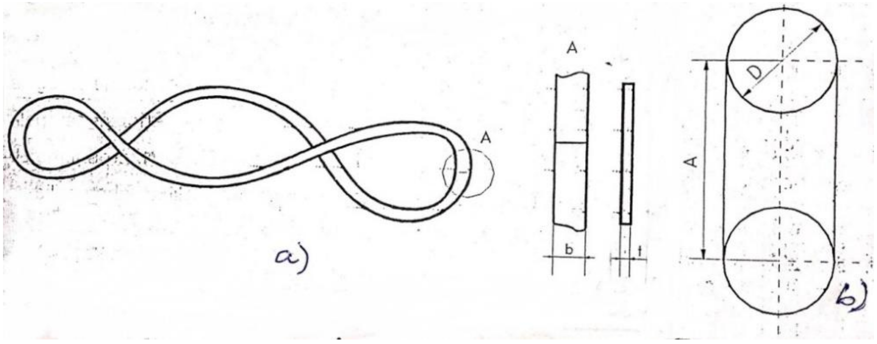



**Figure 6.** The metal band used as transfer object, wound.

**Table 4.** The working parameters used

| No. | NAME | M.U. | SIMBOL | WORK VALUE ADOPTED | OBS. |
|---|---|---|---|---|---|
| 1 | Protective gas (argon) | % | $A_r$ | 99,97 | PURITY |
| 2 | Welding current | A | I | 80 – 100 | |
| 3 | Arc tension | V | $U_a$ | 15 | |
| 4 | Gas flow | 1/min | $Q_{ar}$ | 5 – 7 | |
| 5 | Rod diameter | mm | Φ | 1,2 | $Cr_2$ Mn |

## 8. CONCLUSIONS

It can be concluded that the paper highlights the place of cutting through Electric Erosion with Contact Breaking with transfer object - metallic band in technological processes, underlining that this is one of the modern processing technologies that can solve some problems related to the processing/cutting of highly alloyed steels.

The paper presents in a synthesized form:

- the main forms of erosion;
- the "physical mechanism" of processing by electric erosion with contact breaking;
- Elemental erosion processes occurring in the workspace between the surfaces in interaction;
- non-stationary arc discharge;
- the principle of processing by electric erosion with contact breaking with transfer object - metal band;
- Areas of application of electric erosion with contact breaking processing (with the two transfer object forms).

The research carried out highlights by the obtained results that in the case of processing by electric erosion with contact breaking, it is more advantageous to use the metal band as a transfer object.

The much lower values of the geometric parameters of more than 30% of the metal band, compared to those of the metal disc, determine:

- lower working currents;
- high processing stability;
- better quality of debited surfaces;
- a lesser heat-affected area;
- better economic effects.

NOTE: The resulting percentage differences reflect the current losses occurring between the side contact surfaces in the two presented situations.

The chosen materials allowed better machinability of the metal band ends and the application of welding technologies involving lower costs, under particularly advantageous conditions.

- The variant of welding in the protective gas medium (Argon) provided good welded seam quality, proof being that the samples subjected to traction breaking tests broke into the base material.

## 9. REFERENCES


1. Bucur, V., *Contribuții la optimizarea tehnologiei de prelucrare dimensională prin Eroziune Electrică cu Rupere de Contact (E.E.R.C)* cu obiect de transfer - banda metalică. Teză de doctorat - Universitatea „Lucian Blaga”. Sibiu, (1999).
2. Nanu, A., *Tehnologia materialelor*. București: Editura Didactică și Pedagogică, (1983).
3. Nanu, D., Prelucrarea prin eroziune electrică: Editura ULBS, vol. II, (2004).
4. Revista de tehnologii neconvenționale. Timișoara: Editura Augusta, (1997-2019).
5. Nanu, D., Bucur, V., *Asupra oportunității utilizării benzii metalice ca obiect de transfer, la debitarea prin E.E.R.C.* Suceava: TEHNOMUS VII, vol IV, (1993).

6. Sălăgean, T., *Tehnologia proceselor de sudare cu arc*. București: Editura Tehnică, (1985).
7. Chakrabortya, S., Deya, V., Ghoshb, S.K., A review on the use of dielectric fluids and their effects in electrical discharge machining characteristics, Precision Engineering, 40, 1–6, (2015).
8. Torres, A., Puertas, I., Luis, C.J., Mechanical, Modelling of surface finish, electrode wear and material removal rate in electrical discharge machining of hard-to-machine alloys. Precision Engineering, 40, 33–45, (2015).
9. Steuer, P., Weber, O., Bähre, D., Structuring of wear-affected copper electrodes for electrical discharge machining using Pulse Electrochemical Machining. Int. Journal of Refractory Metals and Hard Materials, 52, 85–89, (2015).
10. Huanga, T.S., Hsieha, S.F., Chenb, S.L., Linb, M.H., Oua, S.F., Changa, W.T., Surface modification of TiNi-based shape memory alloys by dry electrical discharge machining, Journal of Materials Processing Technology, Volume July 221, 279–284, (2015).