COMPARATIVE ASPECTS OF ELECTRICAL EROSION PROCESSES

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ABSTRACT: The paper presents some theoretical aspects regarding the dimensional processing procedures by electrical erosion. A classification of the EE processing variants and their characterization according to the considered criteria is presented. In summary, the definition of specific concepts, their scope, as well as different schemes, technological methods, as well as specific characteristic operations for the four electrical erosion processing processes are presented. The paper presents some theoretical aspects regarding the dimensional processing procedures by electrical erosion. A classification of the EE processing variants and their characterization according to the considered criteria is presented. In summary, the definition of specific concepts, their scope, as well as different schemes, technological methods, as well as specific characteristic operations for the four electrical erosion processing processes are presented
KEYWORDS: erosion, electrical erosion, object subject to processing (OP), tool electrode (ES), transfer object (OT), electrical contact, processing method, principle diagram, forms of electrical erosion, electrical discharges, contact breakage, erosive agent, processing operations, differentiation criteria, impulse, filiform electrode (EF), generation of surfaces

1. CRITERIA FOR DIFFERENTIATING THE PROCESSING PROCEDURES BY ELECTRIC EROSION

1.1. The main criteria taken into account:

a) the method of priming the electric discharges;
b) the duration and form of electrical impulse discharges;
c) shape of the tool electrode.

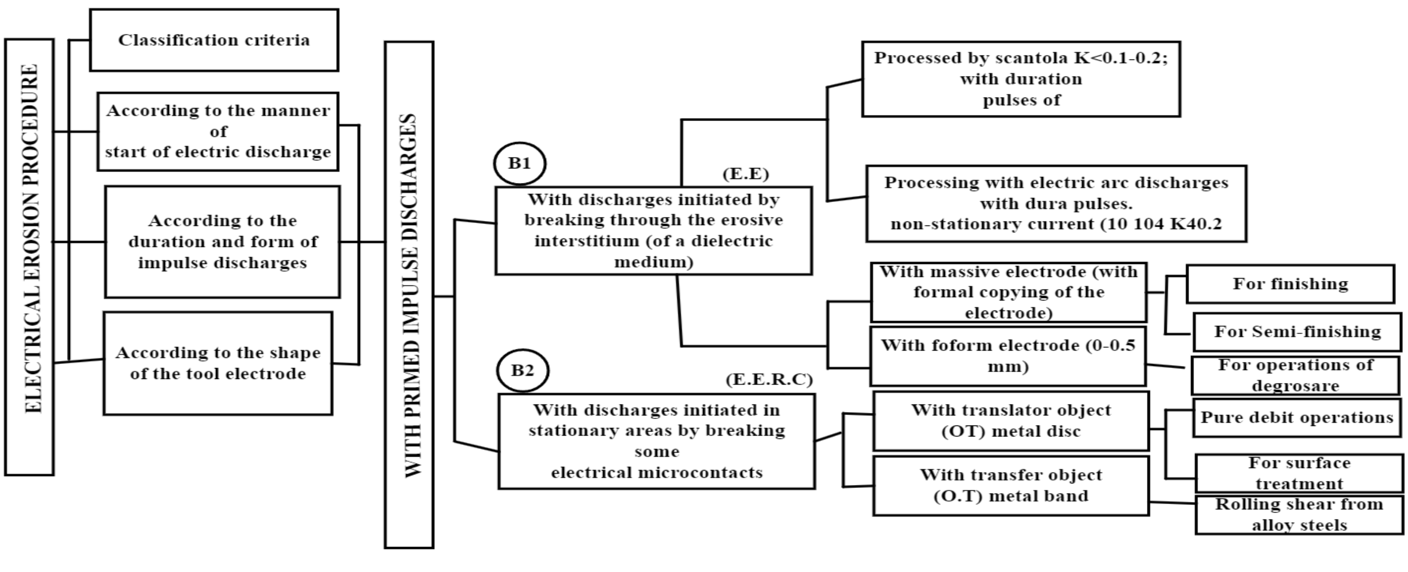


Figure 1. Classification of processing variants by EE

1.2. Characterization of the variants determined by the main criteria considered

A. - according to the priming method:

A1) This variant (according to the method of priming by piercing a dielectric medium) is characterized by the lack of direct contact between (OP) and (ES).

In this case, the size of the erosive interstitium is kept constant (at an optimal value), value determined by:

- t_a - the open-circuit voltage of the source (SA) (that is, of priming the impulse);
- SAA - the automatic advance system of the technological processing system (STP);

Obs.: The values of the priming voltage (t_a = 0.01...0.05 mm) are dependent on:

- working conditions;
- adjustment parameters.

A2) Depending on the impulse character of the electrical discharges

In this case, two components (a and b) are distinguished, with an impulse character, determined by the power source (SA), whose energy is transformed into:

a) thermal component (of energy), whose high values lead to local melting and vaporization of some microvolumes of material (on the surface of the two interacting objects, OP and OT).

Obs.: As a result, a preponderant removal of material takes place on the surface of the OP through the optimal direction of the erosive process.

b) the mechanical component of disruptive energy determines:

- the expulsion of liquid phases (formed as a result of the formation of some craters);
- material removal.

B) By the duration and shape of the electrical impulse discharges

1) with spark discharges;

2) with non-stationary electric arc discharges

C) According to the shape of the tool-electrode used:

- with tool electrode (ES);
- with filiform electrode (EF);
- with object of transfer (OT), which can be:
    - • metal disc (EEDm);
    - • metal strip (EEBm).

2. Theoretical aspects regarding electrical erosion

2.1. Definition of the concepts of erosion, electrical erosion and scope

a) The concept of erosion

a) According to DEX - this concept is defined as "the process of gnawing and digging" of bodies through which a fluid flows, or through the action of external agents, on their surfaces.

The phenomena underlying the appearance of the electrical erosion process that determines the "destruction of the electrical contacts (in the case of switches)", as an effect of the sparks produced when the flow of electrical current is interrupted.

Note: The electrical contact - a sub-assembly composed of two metal parts (called contact elements), through the contact of which the conduction in an electrical circuit is established and which causes their mechanical wear.

Touching the contact elements is achieved through micro contact points (in which the material is deformed).

The explanation of the appearance and destruction of electrical contacts in the case of a processing procedure was mentioned by researchers: Joseph Priestley (English physicist); Benedix (1912); Boris and Natalia Lazarenko (1940) etc.

The theories elaborated by Spouses Lazarenko, Zolotâh, Livsit, etc. should also be mentioned. (after 1949), regarding the specific phenomena that take place. b) Electrical erosion (EE) - is "the non-conventional process of dimensional processing of electroconductive materials, being a complex phenomenon, dependent on a series of parameters".

As a technological method of dimensional processing of metals, electrical erosion is part of the category of processing procedures based on actions to break the substance.

c) Scope of application

The following can be mentioned as scope of application:

• processing of metals and alloys with high hardness. Ex: refractory, stainless, anti-corrosive steels or metal carbides;

• processing of surfaces with complex configurations;

• various microdimensional holes, etc.

Note: In order to be able to process these metals and alloys, new processing technologies are being developed, called "unconventional technologies".

They are also called:

- with concentrated energies or
- alternatives.

2.2. Electrical erosion as a machining process (EE)

As a processing method, it is based on "polarized, complex, discontinuous and localized erosive effects of electrical impulse discharges, repeatedly initiated between two electrodes" called the object to be processed (OP) and the electrode-tool (ES).

Note: • The object to be processed (OP) - the part having the role of erosion object;

• Tool-electrode (ES) - acting as an erosive agent.

Non-conventional machining processes complement the machining specific to classical technologies which, in general, are based on erosion, overcoming

the limits imposed by existing classical, conventional machining methods.
Figure 2 shows the macroscopic localization scheme of elementary erosive effects.

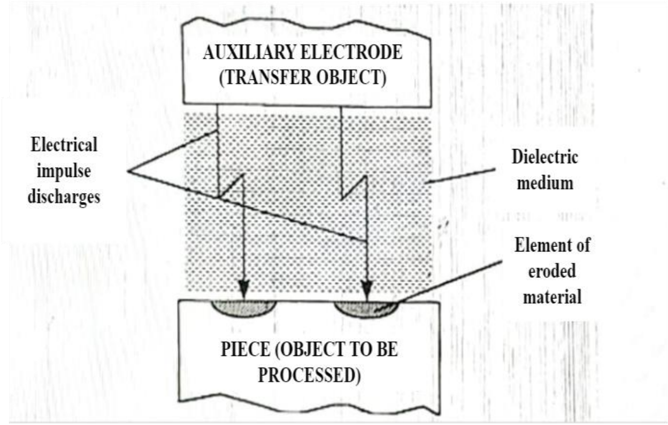


Figure 2. Scheme of macroscopic localization of elementary erosive effects

The EE processing process is characterized by relatively low characteristics, as well as the possibility of very easy generation of complex surfaces, with high execution precision, as well as the relative independence of the technological characteristics from the mechanical properties of the OP, a fact that leads to the placement of this process in the technological hierarchy in the field of dimensional processing.

3. Electrical erosion (EE) machining

3.1. Electrical erosion as a massive electrode machining process

3.1.1. Schematic diagram of EE processing

Figure 3 shows the principle diagram of EE machining (with solid electrode-tool).

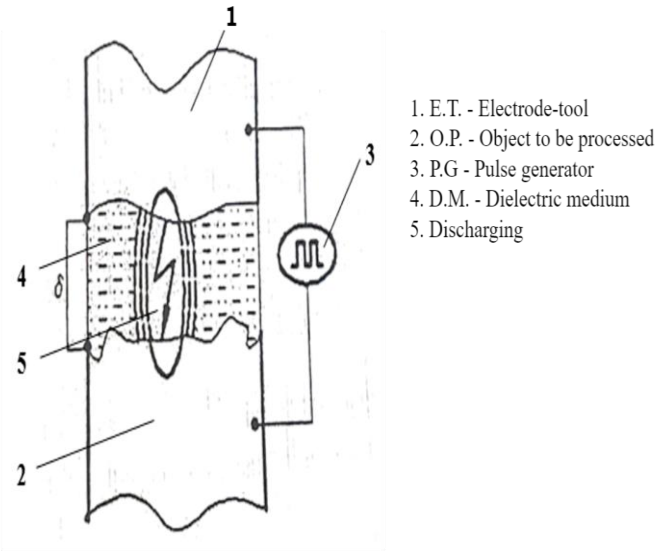


Figure 3. Schematic diagram of processing by EE (with solid electrode)

Note: An important place is occupied by the execution precision of the electrode (ES) which conditions the geometric precision of processing at the OP level.

3.1.2. Generation of machining surfaces

Figure 4 shows the sequence of movements regarding the generation of surfaces with materialized generators and kinematic directories.

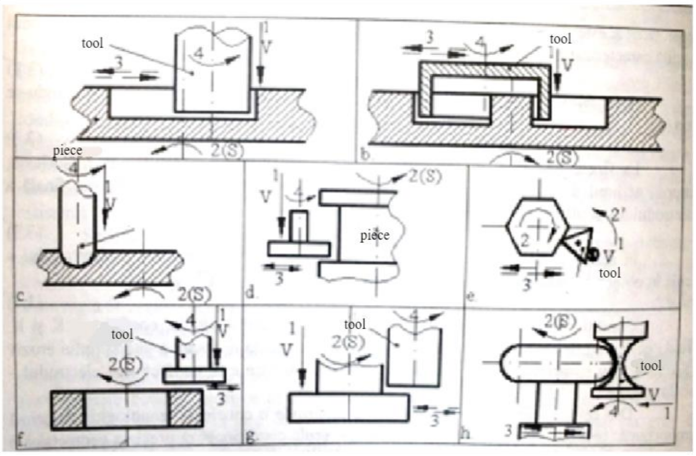


Figure 4. Generation of surfaces with materialized generators and kinematic directories
where: 1 - main movement (straight line); 2 - additional (rotational) movements; 3 - the movement to obtain the directory; 4 - ES wear compensation

3.1.3. The main forms of electrical erosion of technological interest

Figure 5 shows the main forms of technological interest of electrical erosion (EE), from the point of view of the erosive agent.

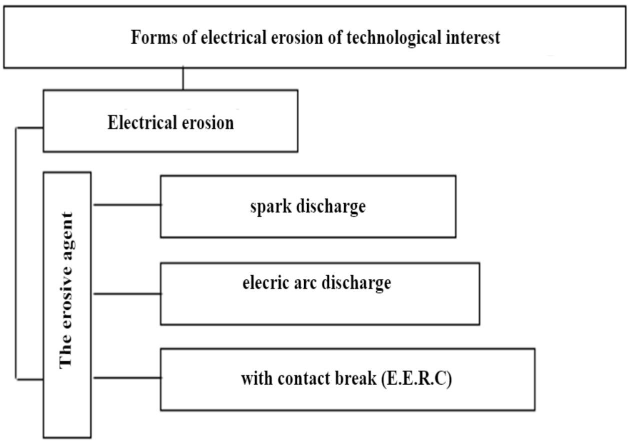


Figure 5. The main forms of technological interest of electrical erosion
(from the point of view of the erosive agent)

Note: In industrial sectors, electrical erosion processing occupies an important position, compared to the other erosion phenomena (chemical, electrochemical, radiation, abrasive or cavitational) that are applied worldwide.

From a technological point of view, EE processing is a final technological method. As a processing method through EE, it is based on the destruction and sampling of the surplus material (processing addition) from the OP surface, through the dynamic action of some erosive agents, of a different nature, introduced into the work space. The removal of material from the working space occurs as a result of the interaction between an erosive agent (which can be in the form of a complex physico-chemical system, capable of yielding energy to the ambient systems) and the object of erosion (OP).

3.1.4. Erosive agent interaction

Figure 6 shows the interaction of the erosive agent with the object of erosion (OP).

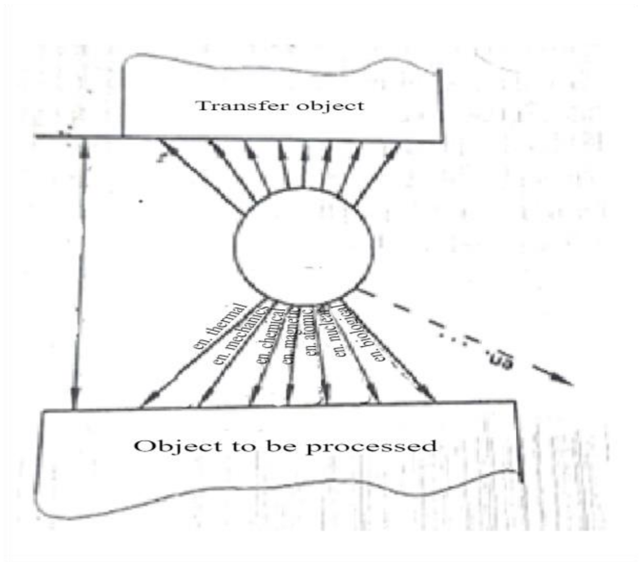


Figure 6. Interaction of the erosive agent with the OP

The energy contained in the erosive agent can be of the nature (especially in the case of EE): electric, thermal, mechanics.

3.1.5. Technological methods of dimensional processing through EE

The technological methods of dimensional processing through non-conventional technologies include a series of technological procedures.They differ mainly in the form and type of erosive agent, which determines the sampling of material. Figure 7 shows the different technological variants of a processing procedure (depending on certain particularities of application).

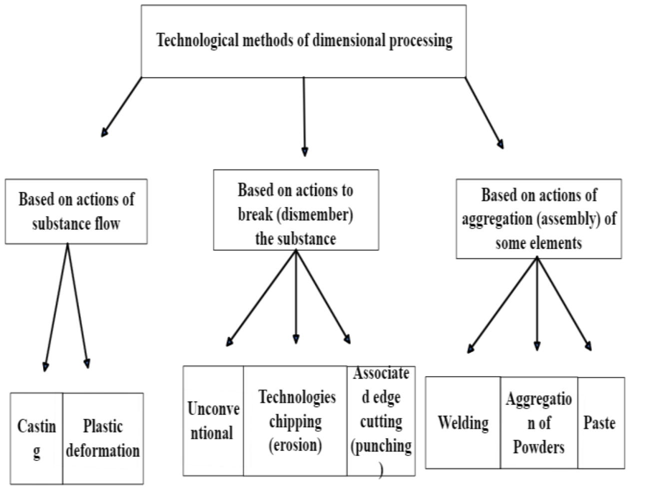


Figure 7. Technological methods of dimensional processing

3.2. Wire EDM (EEEF)

In this process, the tool electrode (ES) has a filiform shape with a small diameter (under 0.5 mm), in axial movement along a certain contour, which can be programmed.

The machining process is based on the removal of material from the part by successively applying (in repeated series) electric discharges, which are carried out between the workpiece (OP) and the tool called the filiform electrode (EF), in the presence of a dielectric fluid.Fields of application of the EEEF processing procedure:

1) processing of metals and alloys with high hardness;
2) the processing of materials that cannot be solved by conventional processes;
3) the processing of surfaces with complex configurations, or the generation of surfaces with variable geometry.

3.2.1. The principle of processing by EEEF

Figure 8 shows the principle diagram of EEEF processing.

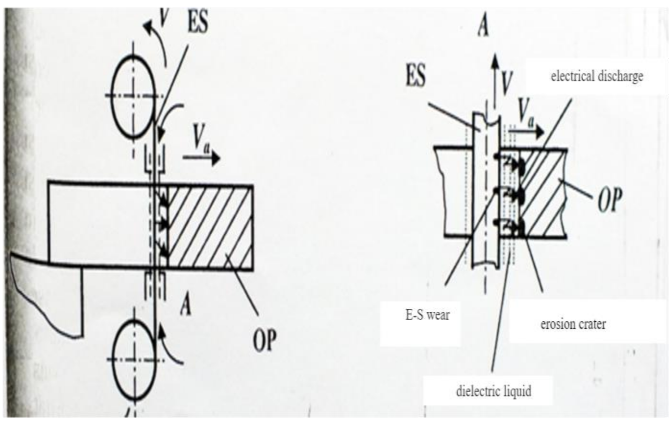


Figure 8. Principle scheme of processing by EEEF

As a process, EEEF machining is characterized by "the use of a wire-like electrode (Cu material) with high conductivity, which moves axially, guided and tensioned between two support arms".

3.2.1.1. Technological aspects regarding OP

The workpiece (OP) is clamped for processing in the console, between the two support arms of the filiform electrode (EF), so that the lower arm can provide access under the workpiece (OP), according to figure 9.

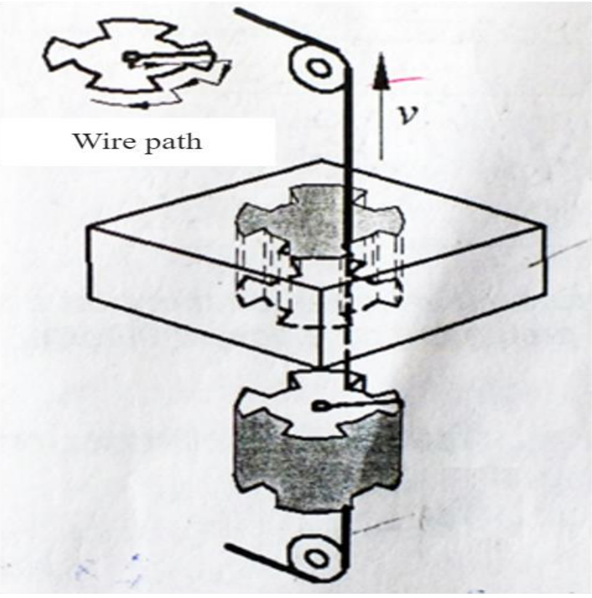


Figure 9. Principle of processing by EEEF

Note: It is necessary that the workpiece (OP) be positioned in relation to a laying plane parallel to the work table (m) of the machine, at the level of a straight segment (d) (included between the guides mounted on the support arms), according to figure 10.

3.2.1.2. Positioning the OP in relation to the workspace

Figure 1.10 shows the way of positioning the OP, with the existing working space (at the level of a straight segment), contained between the guides mounted on the support arms, where EF defines a straight line (d).

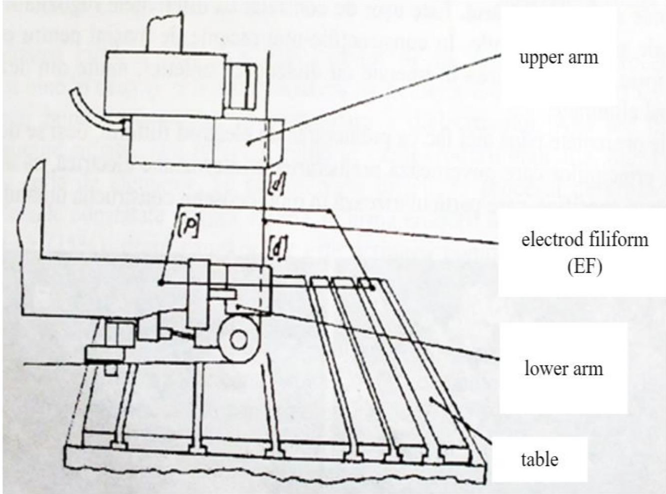


Figure 10. Principle of processing by EEEF

The workpiece (OP) is positioned in relation to a laying plane (P), parallel to the working table of the machine.

• right (d) - constitutes the generating curve;

• the plane (P) - in this plane the directional curve is defined.

Note: EEEF machining is a technological variant of EE machining (especially for cutting operations).

3.2.2 Generating inclined surfaces (by rotating the blank)

For the generation of inclined surfaces, a "special device" was designed, which is presented in figure 11.

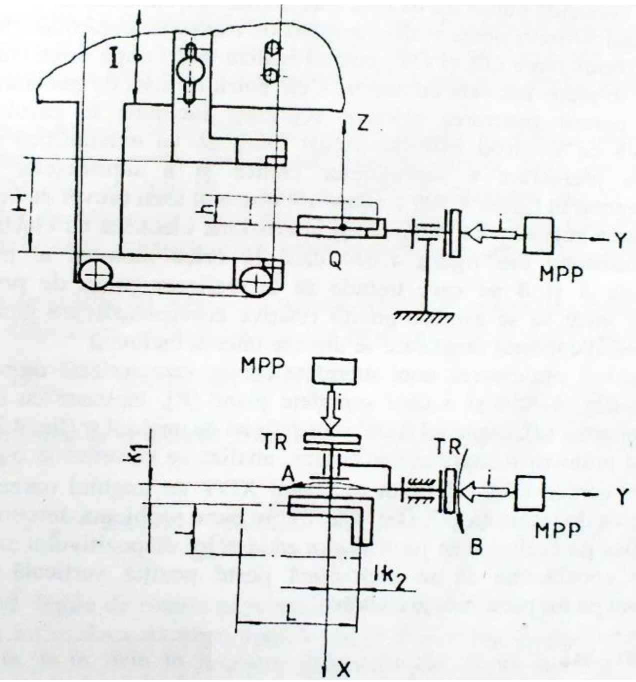


Figure 11. Principle diagram of the special device for generating inclined surfaces by rotating OP

It can be concluded that the machining of inclined surfaces by EEEF is possible, if at any moment of the machining it is possible to determine the rotations A and B, which the part (OP) clamped in the device must make, making it possible to follow the contour (if the inclined cut is followed).

Note: For the machining of conical surfaces, inclined plane surfaces, surfaces of revolution and hyperboloid surfaces, surface generation methods and devices that provide controlled rotations of the part (OP) or EF are designed

3.3. Electrical Erosion Machining (EERC)

3.3.1. Specific characteristic of EERC

An important feature of the EERC processing process is the fact that the removal of material takes place following the interaction between an erosive agent (the heat source considered a physico-chemical system capable of releasing energy to the ambient systems) and the object to be processed (OP), according to the figure 12.

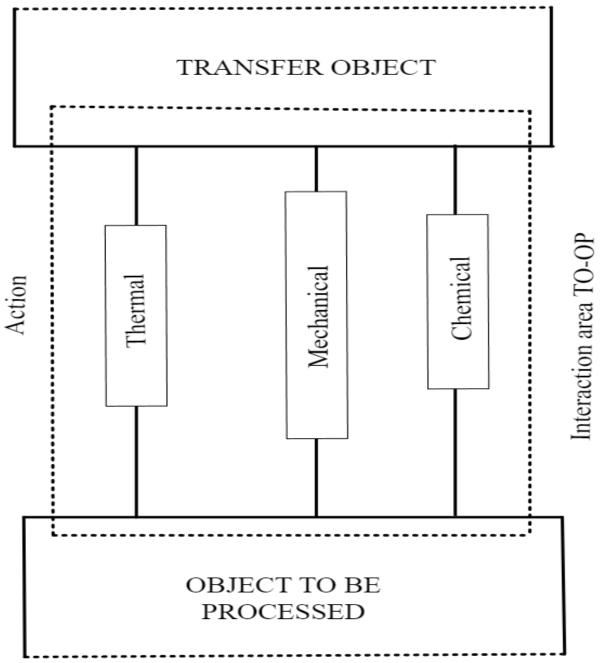


Figure 12. OT-OP interaction area

3.3.2. The place of electrical erosion with contact rupture (EERC) in the context of electrical erosion (EE) machining

Figure 13 shows the place of EERC in the context of erosion processing.

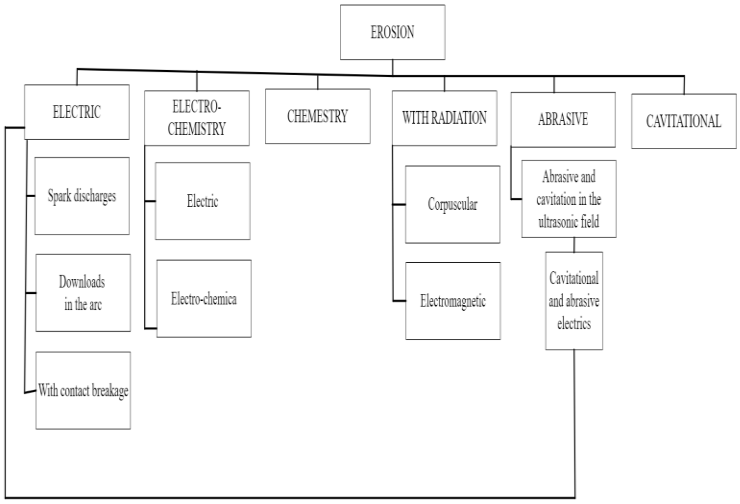


Figure 13. The place of EERC in the context of electrical erosion processing

The EERC processing process takes place at the contact surface of two objects:
- processing (OP)
- transfer (OT)

these being connected to a power supply (SA) with electricity.
The two objects (OP and OT) are in relative motion with a velocity (v) relative to each other. The process is based on the priming of electric discharges in non-stationary arc, by breaking the current-carrying electrical contacts, temporarily established between them (OP and OT).
A specific feature of EERC processing is the form and constructive dimensions of the OT, which can be in the form of:
- metal disk (Dm)
- metal strip (Bm)

Obs.: The transfer object determines, from a constructive point of view, the structure of the machines.

3.3.3. Schematics of processing through EERC

Figure 14 (a, b) shows the two principle schemes of the EERC processing process

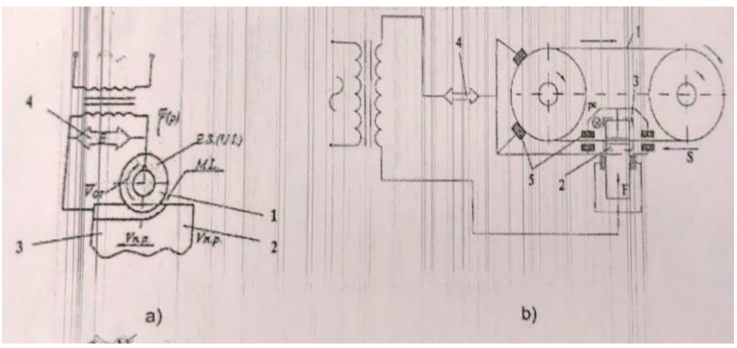


Figure 14. (a, b) Principle diagrams of the processing procedure through EERC

a) with metal disk
b) with metal tape

Obs.: The two objects OT and OP (in the figure) are brought into direct contact by the action of a force (F), which determines the development of a contact pressure (P c), being connected to a power supply (SA), direct or alternating current.

The process is aerated or watered, in order to achieve the effect energy (OT and OP cooling), as well as to activate the process of evacuating eroded particles into the working environment (ML).

The metal disk (Dm) is in relative motion with respect to OP, and the two objects (OT and OP) are in interaction, according to Figure 14 a.

The metal strip (Bm) is in continuous winding-unwinding motion on the cylinders (flywheels) and acts on the OP, by means of a thrust force (F) on the OP and a contact pressure (pc), according to Figure 14 b.

4. Specific characteristic operations

4.1. Characteristic operations specific to solid electrode EE machining

4.1.1. Solid electrode EDM (with electrode shape copying)

In this case, the final shape of the object under processing (OP) is obtained by copying the conjugate shape at the level of the tool electrode (ES).

Two cases are distinguished:

a) in the case of processing without additional generation equipment.

The automatic advance of the ES is carried out by the specific substituent, which ensures its penetration into the OP, by the simple rectilinear advance movement.

b) in the case of using additional generation equipment.

Among the operations in which electrical erosion processing is used, we can mention:

4.1.1.1. Extraction of broken and remaining tools in the blank and large bores

In general, the most common semi-finished products on which the tool-electrode must be used are: drills, taps, reamers, etc. For these machinings the ES diameter is according to the diameter of the broken tool in the joint piece.

Table 1 shows the choice of ES diameter, used when removing broken tools.

Tab. 1

The diameter of the broken tool	[mm]	3	4	5	8	10	12	16	18	20
Diameter ES	[mm]	1.5	2.0	2.5	4.0	5.0	7.0	10	12	14

4.1.1.2. Processing holes of different profiles

This operation can be executed from a technological point of view:
a) - for each processing phase (figure 16);
b) - or in steps (figure 17).

Obs: In case b) - for each stage the working regime (electrical) will be changed according to the values of the lateral interstice (corresponding to the processing phases).

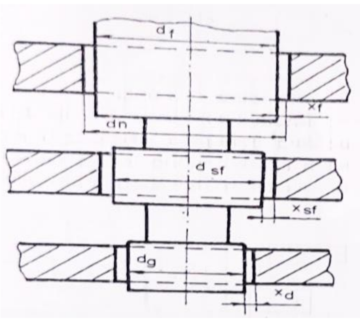
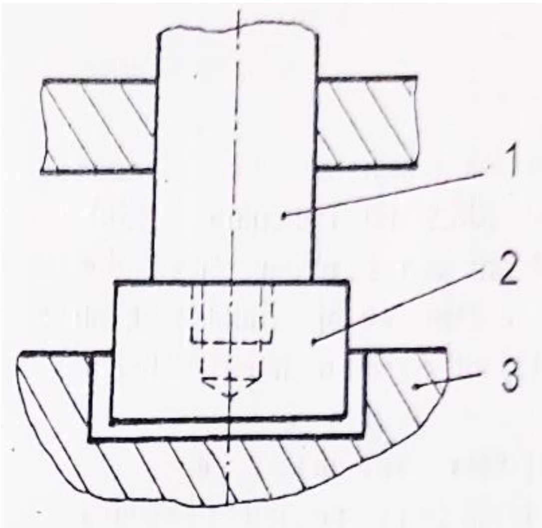


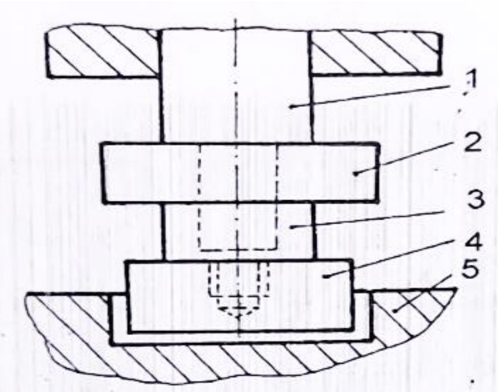
Figure 15. ES monobloc construction



1 - the fixing part
2 - the active part

3 - WORKPIECE (OP)

Figure 16. ES construction for each phase



1 - the fixing part;
2 - finishing step;
3 - spacer bushing;
4 - roughing part;s

5 - workpiece (OP)

Figure 17. ES construction from several parts

When processing large bores, it is executed from several parts, assembled together.
Obs.: The elements for assembly are separated by spacers placed on the connecting rod.

4.1.1.3. Processing of pierced circular bores

Figure 18 shows an assembled tubular ES. In this case, ES in the form of bars, or drilled ES (in the form of a pipe) can be used. Figure 19 shows the case of processing pierced holes with larger diameters (of 30 mm) using tubular ES.

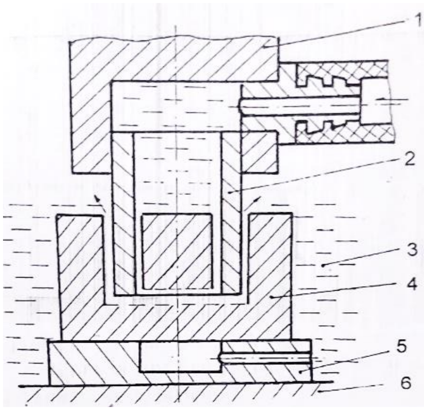


Figure 18. Processing with tubular ES

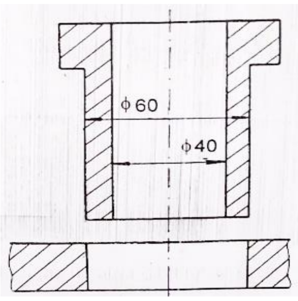


Figure 19. Machining large bores with tubular ES

Note: It is recommended to use these ES when machining drilled holes with diameters greater than 30 mm.

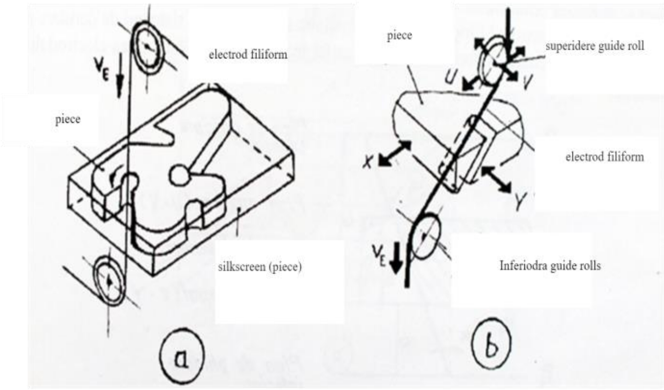


Figure 20. Types of cutting with EF (a) straight cutting; (b) slant cut

4.1.1.4. Solutions and means used to override some limits related to the EDM process with ES shape copying

Among the most effective ways of aligning the processing process through EE, in this case applied they consider the activations applied to it, which aim to superimpose on the erosive process in the interstitium some coercive fields (collaborative of different natures) through which they act on certain aspects of phenomenological intimacy.

Other applied activation solutions considered:

- ultrasonic activation of EE processing; - magnetic activation of processing by EE;

- cryogenic activation of EE processing;

4.2. Cutting operations with EF

4.2.1. Types of cutting with EEEF

According to the relative position that elements OP and EF occupy:

a) straight cut, when throughout the processing d ⊥ P, and (d, P) = 90°, according to figure 20 (a).

b) inclined cutting, when (d, P) ≠ 90°, throughout the processing.

c) mixed (combined) cutting - when the processing is carried out by straight cutting combined with inclined cutting.

By cutting with a filiform electrode, the resulting surface (after cutting) contains a multitude of craters, caused by electric sparks.

Pronounced wear of the filiform electrode (EF) has the effect of unevenly reducing the diameter of the wire, which can cause it to break.

4.2.2. Variants of processing with EEEF

In fig. 21 (a, b, c) some processing variants are presented, in which the cutting slot:

a) is equal; b) double or higher; c) double the working gap.

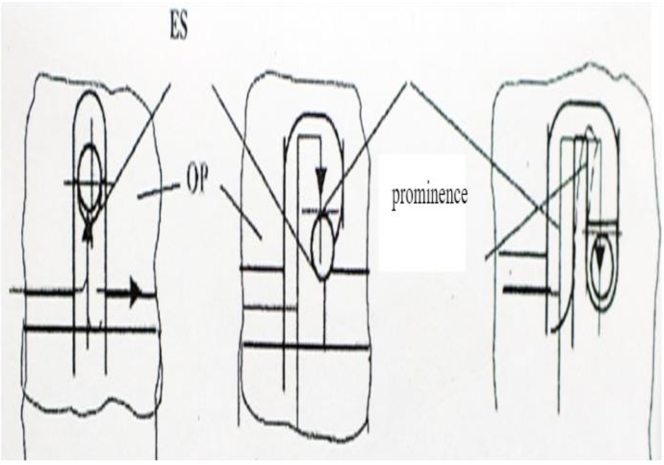


Figure 21. Machining variants depending on the ratio between the cutting slot and the working gap

4.3. Characteristic operations specific to EERCDm and EERCBm processing

4.3.1. Categories of processing operations through EERC Dm

From a technological point of view, the EERCDm processing procedure has found its applicability to the following categories of operations:

a) - cutting hard-to-process materials;

b) - removal of defects or defective (surface) layers, of parts in the metallurgical industry (and not only);

c) - sharpening of cutting (or other useful) tools;

d) - operations of drilling, smoothing, rectification of specific surfaces through semi-finishing and/or finishing, from the port industry or machine construction.

4.3.2. The main operations that are carried out through the EERC

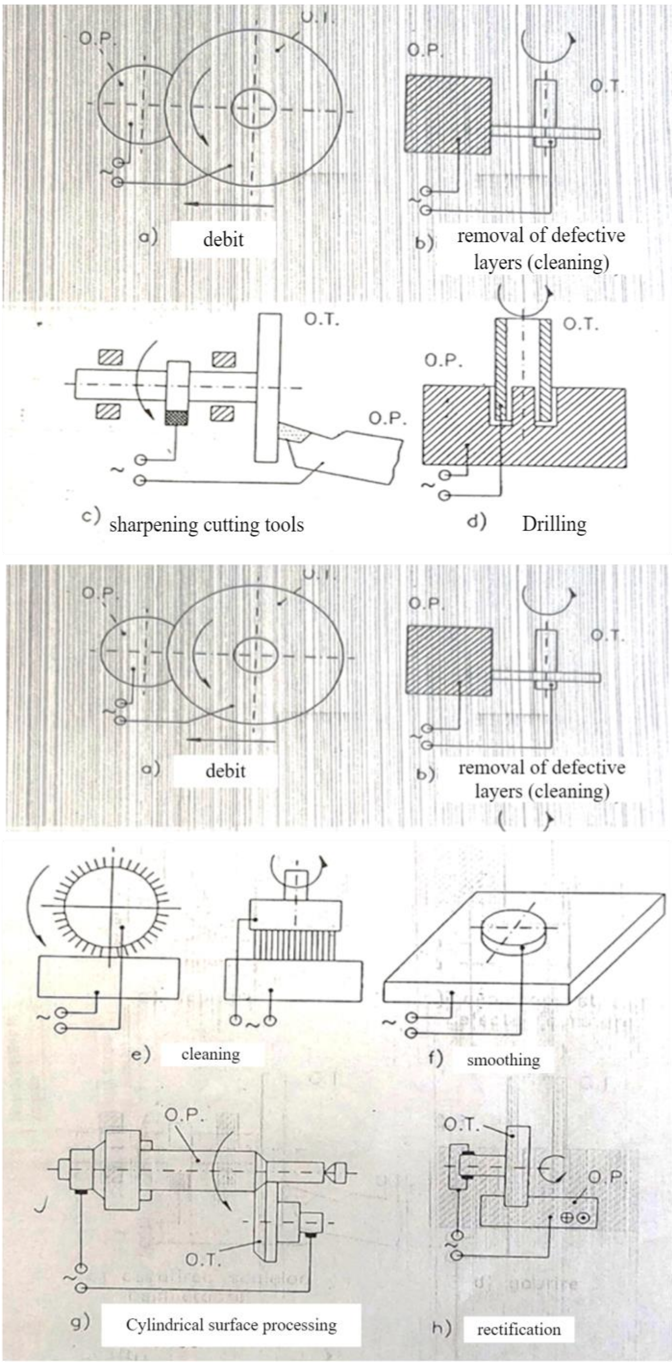


Figure 22. Operations characteristic of EERC machining (with metal disc)

Meaning of operations in figure 22:

a) - the metal disc (Dm) is recommended for cutting hard-to-process materials;

b) and c) - removing defects (or defective layers) of the OP, specific to the metallurgical industry (ingots, cups, cones, etc.);

d) - sharpening cutting tools;

e) - drilling;

f) - smoothing the surfaces;

g) - processing of frontal or cylindrical surfaces;

h) - rectification of some landmarks (bearings or ship propellers, etc.)

4.3.3. Cutting materials with metal tape

The specific technological operation for erosion processing with OT - metal strip (EERCBm) is the cutting operation of both thick sheets (50-150 mm) and cylindrical profiles.

The use of the metal strip can be applied if there are restrictions on the use of the metal disc.

The metal band can also be used in the case of cutting laminates with considerable sections and lengths (from ordinary or alloy steels).

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