ELECTRICAL DISCHARGE DEPOSITION EQUIPMENT

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SUMMARY: The electric discharge deposition process (EDD) is a new machining process for metal fabrication. In this process, the high level of wear of the tool electrode is used to obtain the deposition of the metallic material. The equipment was modeled in Autodesk Inventor Professional 2022, and the simulation process was simulated in Comsol Multiphysics 5.5. In this paper, the coil was modeled to simulate the variation of the magnetic flux and how it affects the trajectory by changing the intensity.

KEY WORDS: deposition, electrical discharge, equipment, simalation, trajectory

1. Introduction

The demand for micro-scale parts production has been increasing day by day. The deposition of thin layers on metals and semiconductors finds a great application in these fields. Electric discharge deposition (EDD) is one of the most important deposition techniques in the research community. The following are reported from the literature currently available.

The μ-EDD process is performed in normal atmosphere, and the tool electrode is connected to the positive terminal, where ions are emitted from its surface and have a path directed by the magnetic field to the surface of the part. Because the ion pulse is higher, they lead to the deposition of the tool's material on the surface of the workpiece [1].

During the discharge process, a voltage is applied between two electrodes (the tool and the workpiece). When the electrodes are very close to each other, under the action of Joule heating and the force of the electric field, the surface of the cathode will emit a mass of electrons. Under the force of the electric field, the electrons are accelerated, going to the anode. High-speed electrons collide with the average electrical particles bringing a large portion of electropositive particles. This collision occurs continuously during the discharge process, so the electrical particles will grow, forming a plasma channel [2].

Fig. 1 shows the electrical discharge deposition equipment designed in Catia software for the conceptual design chapter.

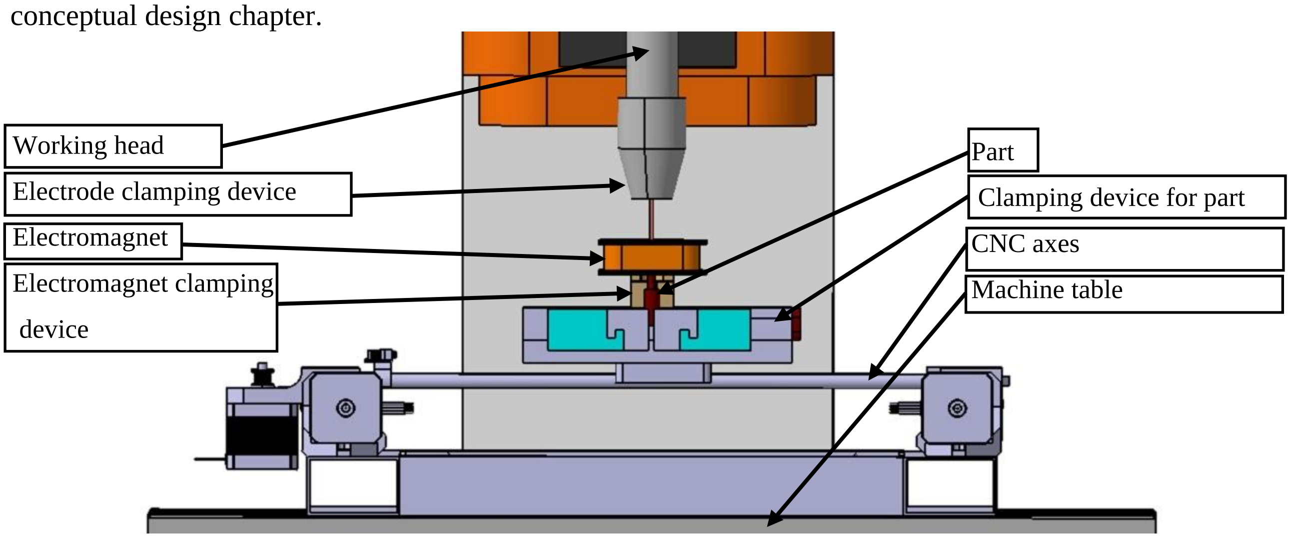

Fig. 1. Block diagram of electrical discharge deposition equipment

2. Conceptual design

2.1 General function and component functions

The general function of the EDD equipment, which is the subject of this paper, is to deposit material by electric discharge in the magnetic field.

The general function is subjected to an analysis process which will result in first the main functions and then the secondary ones. The main functions are properties of the product that determine the general function. Secondary functions result from the interaction between the main functions and are called internal interactions, and the interactions between the main functions and the environment are external interactions.

The functions of the EDD equipment are listed in Table 1.

Table 1. Functions of the EDD equipment

FG	***Layer deposition***
No.	*EDD Functions*
1	Attaching the tool electrode Secondary functions: chuck opening; electrode insertion; screwing in the chuck key to tighten the electrode.
2	Workpiece holding Secondary functions: vise opening; the introduction of the piece; screwing in the chuck key to tighten the electrode
3	Providing an electromagnetic field: Secondary functions: power supply start; Supply of the subassembly of electromagnets with electricity from the source;
4	Ensuring the generation of magnetic flux; Secondary functions: pressing the buttons on the control panel, adjusting the voltage and current, in the drives, adjusting the current density on the surface; ensuring a direction of propagation.

Among the main functions established above, a list of critical functions has been compiled (Table 2), which determines the commercial success of the product. These critical functions correspond to the sizes and requirements with the maximum relative importance.

Table 2. List of critical functions

Function number	***The critical function of the product***
1	Ensuring ion flow generation
2	Providing an electromagnetic field
3	Attaching the tool electrode
4	Workpiece holding

2.2. Result concept

Diagrams of ideas and solutions were made, and four concepts were developed from them. An evaluation matrix was necessary to adopt the optimal concept, which is represented in figure 2.

Electric spark deposition machine that has a mechanical clamping device for the part, numerically controlled and the provision of an electromagnetic field actuated by a button, the adjustment of the tool to the height is done by preliminary test passes.

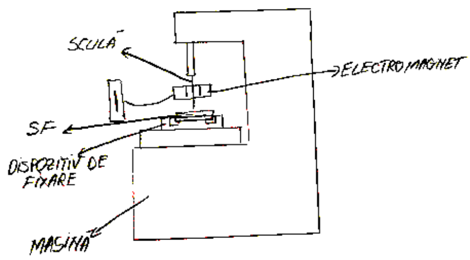

Fig. 2. Optimal solution

3. Prototype manufacturing

For the clamping of the tool electrode an elastic bushing is used, which is attached to the working head of the ELER electroerosion machine of the Unconventional Technologies Laboratory of the Faculty of Industrial Engineering and Robotics, Polytechnic University of Bucharest.

The figures below show the subassemblies of the developed EDD equipment:

Fig. 5. Framework

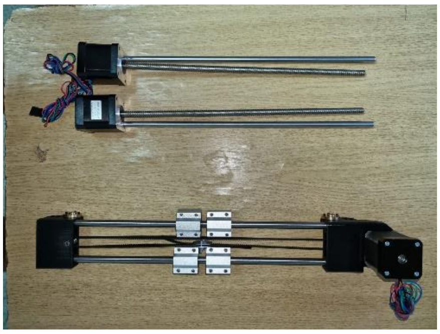

Fig.6. Axes, guide columns and stepper motors

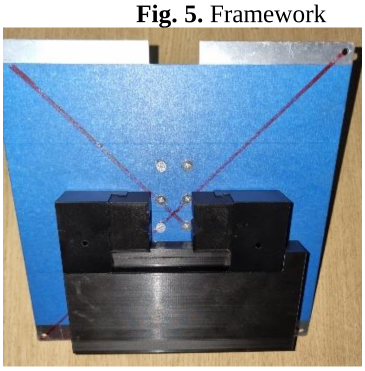

Fig.7. Part holding device

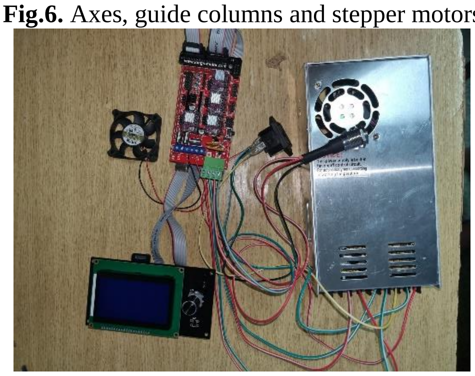

Fig.8. Electronic components

Fig.9. Coil

The product is clamped using a device (as shown in Fig. 10) placed on the machine table which can move on 2 numerically controlled axes with an accuracy of 0.1mm using the axes of a modified 3D printer, representative of Figure 11.

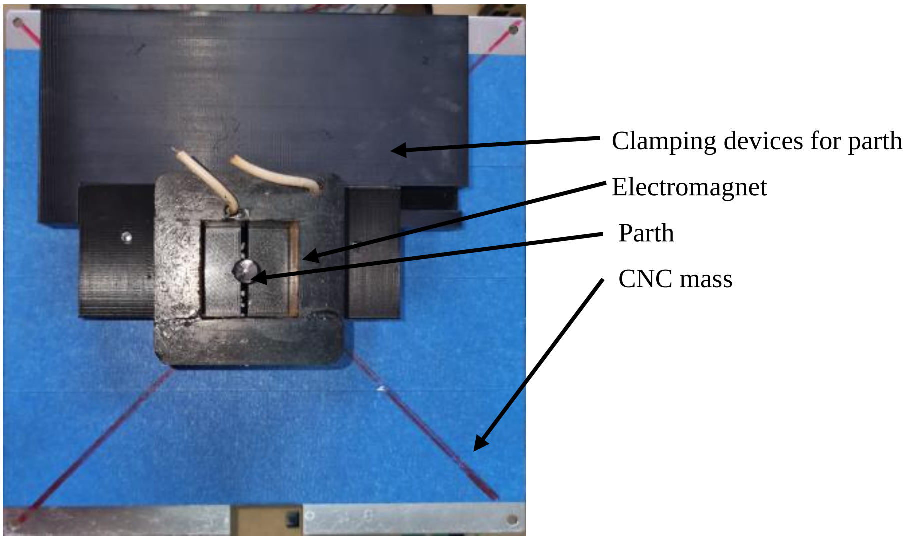

Fig. 10. Clamping devices for parth

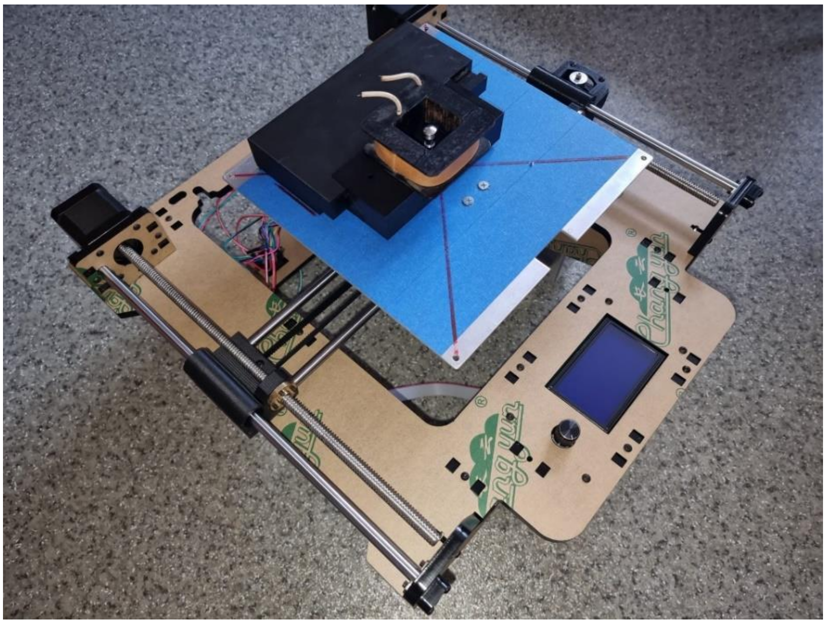

Fig. 11. CNC device

4. Modelling and simulation of the electrical discharge deposition process

Using the program Comsol Multiphysics 5.5, the magnetic flux created by the electromagnet and the particle path from the electrode were modeled and simulated, the results of these simulations are shown in Figs. 12, 13, and 14.

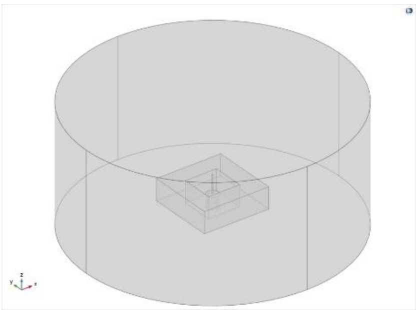

Fig. 12. Geometry of the working space

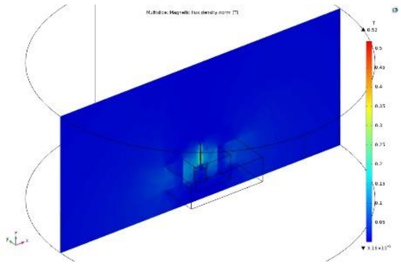

Fig. 13. Magnetic field simulation

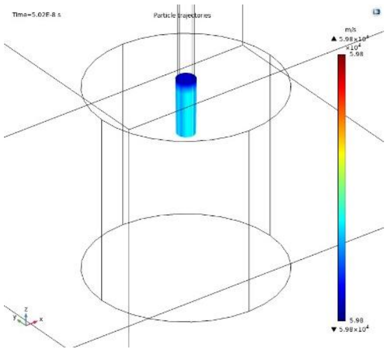

Fig. 14. Simulation of ion trajectories

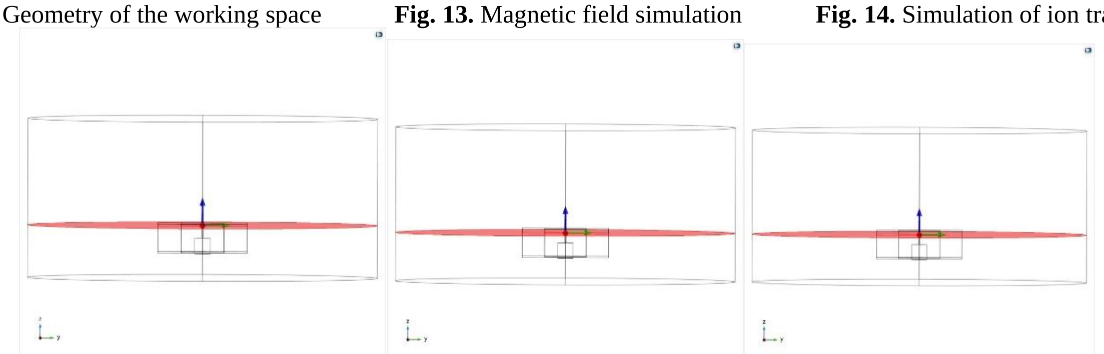

Fig. 15. Cutting planes at Z=3 mm; Z=2 mm; Z=0 mm;

In order to see the deviation of the beam trajectory, the planes in Figure 15 were used to highlight the beam position in red, black and blue respectively in the Poincaré graph, and the graph represents the trajectory of the ions from the electrode-shell above the electromagnetic coil, which is an unrealistic model because deposition by electrical discharge cannot be achieved.

Three simulations were analysed for three different materials, namely Wolfram, Aluminium and Nickel, and the difference in the visualisation of the particles in the three section planes can be seen in Fig. 16-18.

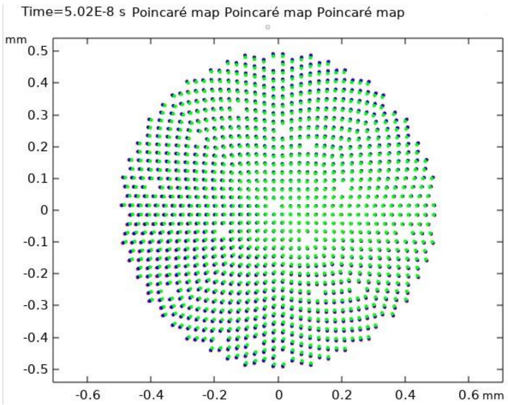

Fig. 16. Aluminium Poincaré Graph

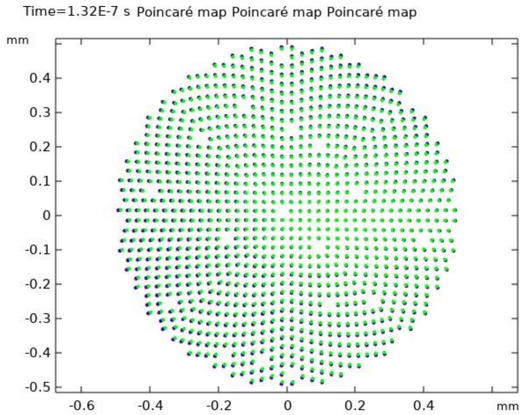

Fig. 17. Wolfram Poincaré Graph

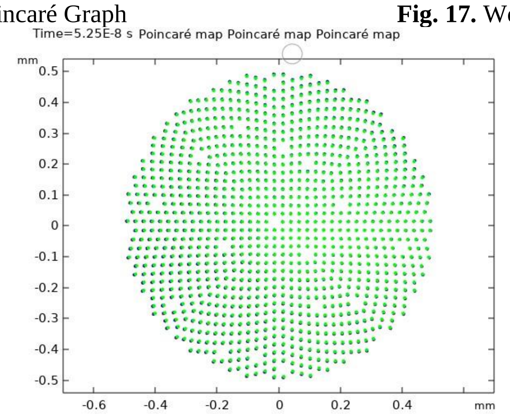

Fig. 18. Nickel Poincaré Chart

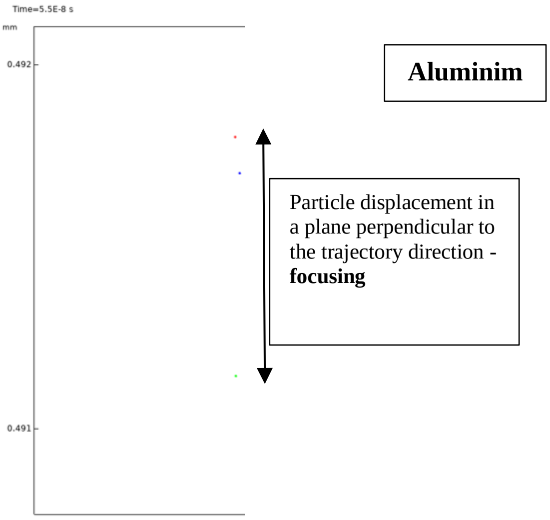

Fig. 19. Distribution in detail - focusing / defocusing of Al ions

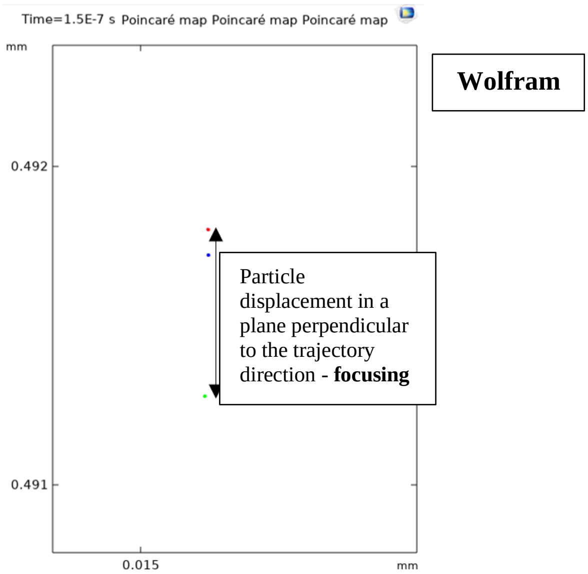

Fig. 20. Distribution in detail - focus/defocus of W ions

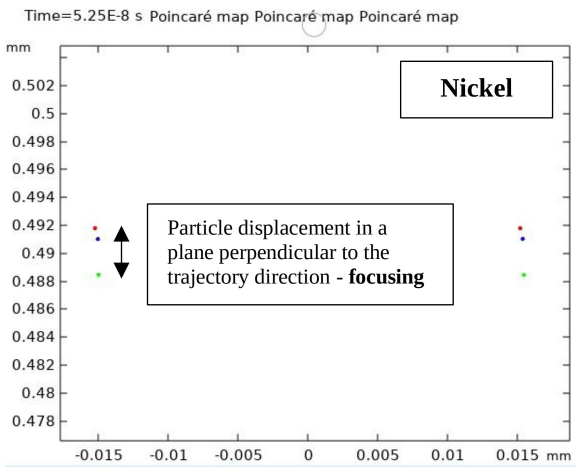

Fig. 21. Distribution in detail - focusing/defocusing of Ni ions

In Figures 19-21, it can be seen that for aluminium, tungsten and nickel ions the magnetic field focus is about 0.001 mm, the distance between the red and green points.

5. Conclusions

- The key factors influencing this electrical discharge machining process are current, duty cycle (deposition time) and pulse on time (pulse time).
- The multi-layer deposition process also shows the same trend as that followed by the single-layer deposition process.
- The deposition dimensions of the material are framed in a point (on a surface) with dimensions between 0.2 and 0.3mm.
- The deposition precision on a given trajectory is given by the precision with which the two axes can move, so the precision achieved by the equipment is 0.1mm.

6. Bibliography

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