MODULAR ELECTROCHEMICAL POLISHING EQUIPMENT

STANCA Nicolae-Valentin[1], JINGA Razvan-Daniel[2], FIRARU[3] Mihaita-Florin[3], ENE[4] Alexandru[4] and Liviu Daniel GHICULESCU[2]
[1]Faculty of Industrial Engineering and Robotics, Specialization: INPN, IAAC, IEMA, IPFP, Year of study: I Master, e-mail: daniel.ghiculescu@gmail.com
[2]Faculty of Industrial Engineering and Robotics, Manufacturing Engineering Department, University POLITEHNICA of Bucharest

ABSTRACT: The paper deals with the current state of processing by electrochemical polishing. The main details in the polishing process are the sizing of the electrode-tool, the choice of the type of back pressure chamber, the choice of the type of electrolytic fluid flow, the type of surface treated and the establishment of a type of processing to streamline the quality of future surfaces. It is desired to build a modular electrochemical polishing equipment to obtain the highest quality surfaces, with the lowest possible roughness, in the shortest possible time. So, this paper will bring information about the process and the existing equipment on the market with the help of patents, to be developed in the dissertation. Finally, you will be presented with a concept proposal for the future equipment.

KEYWORDS: electropolishing, anode, cathode, electrolytic liquid , modular equipment , ECM.

1. Introduction

Electrochemical polishing, also known as anodic polishing or electrolytic polishing (especially in the field of metallography), is an electrochemical process that removes material from a metal part, reducing surface roughness by leveling micro-peaks and valleys, improving surface finish. This process takes the place of galvanizing. It is used for polishing, passivating and deburring metal parts. It can be used instead of fine abrasive polishing in the microstructural preparation of surfaces [1].

2. Current stage

Electrochemical polishing involves an anode consisting of the part to be processed and a cathode represented by the tool to be placed in an electrolyte bath, where basic, acidic or neutral solutions are found. The anode is connected to the positive (+) source of the current source, and the cathode to the negative (-) source. The current passes from the anode, where the surface metal is oxidized and dissolved in the electrolyte, and then the oxidation products pass to the cathode. At the cathode there is a reduction reaction that produces hydrogen. [3] This reduces the roughness of the machining surface according to the scheme in Figure 2.1, based on the anodic dissolution, which occurs in the electrolyte bath, and as a result creates an electric field between the tool and the part. And on the surface of the semi-finished product a passivated layer is formed in the region of the micro-peaks, where the current intensity is higher, so the electrical resistance is lower in these areas. [4]

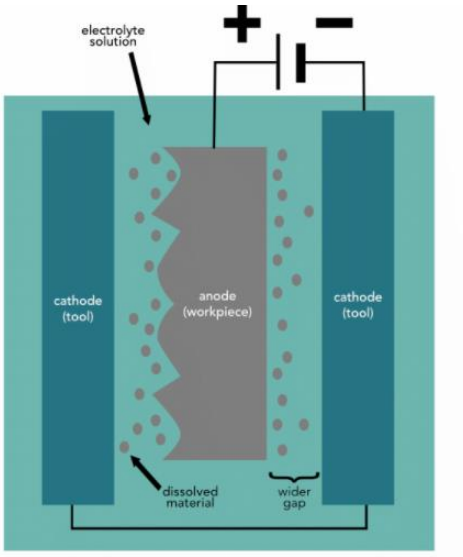

Fig. 1. Schematic of electrochemical polishing process[4]

Fig. 2 Modular equipment structure

3. Strategic product marketing

3.1. Identifying market opportunities

In order to identify the market opportunities, first, must be found the needs of future customers. Needs that will be satisfied by the chosen product.

The 5 needs that were identified:

- The need to create surfaces with high corrosion resistance and to increase the lifetime of the parts;
- The need to increase productivity;
- The need to create surfaces with minimal risk of contamination (sterile);
- The need to remove radioactivity from certain surfaces;
- The need to create surfaces with low roughness.

Following these needs, the following market opportunities were determined:

- Most industries want parts to have a longer lifetime, as long as the cost is favorable. This leads to reduced maintenance costs;
- SMEs and companies that process metal parts by polishing want to streamline the process;
- The existence of areas where the creation of sterilized and uncontaminated surfaces is necessary, such as: the medical field, the pharmaceutical field, the nuclear field, the food industry, etc .;
- The nuclear field is a developing one in the context of the energy crisis;
- Need for precise surfaces for different assemblies.

Competing products

Fig. 3 Competing products[5],[6],[7]

Selection of potential customers – Market:

- Small and medium-sized enterprises (SMEs) that are processing on metal parts;
- Educational units;
- Research institutions.

Data collected from potential customers:

The questionnaire will be used to identify customer requirements. The questionnaire guide used to collect raw data is intended to provide answers to questions such as:

1. In what field do you work?
6. Would electrochemical polishing equipment be useful in your work?
7. Which of the following benefits do you consider most important?

The results of these questions are as follows:

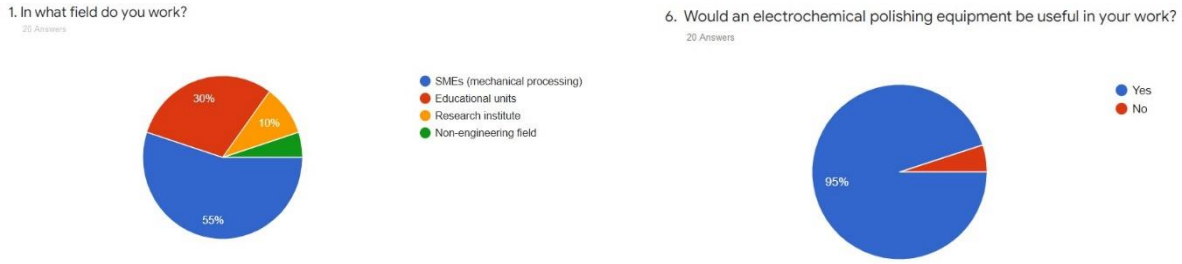

Fig. 4 Questions 1 and 6

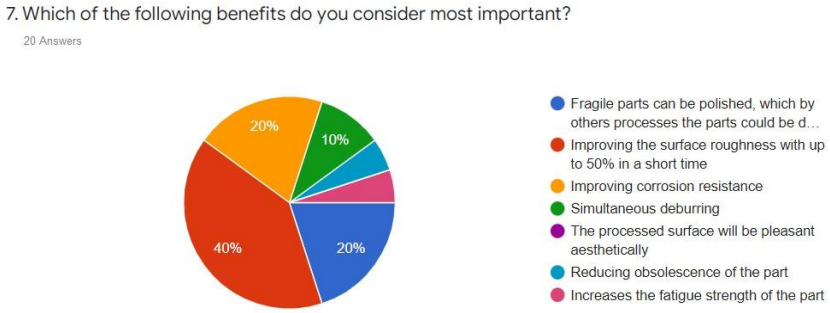

Fig. 5 Question 7

Following the answers received, we can say that there is a great interest in the product. Electrochemical polishing being preferred over mechanical finishing, respondents considered that electrochemical polishing equipment would be useful.

4. Conceptual design

Once the 5 needs have been identified (N1, N2, N3, N4, N5), the development of the interview questionnaire and its application to a population sample according to the Selection Matrix, it is necessary to generate concepts using techniques and methods to stimulate creativity.

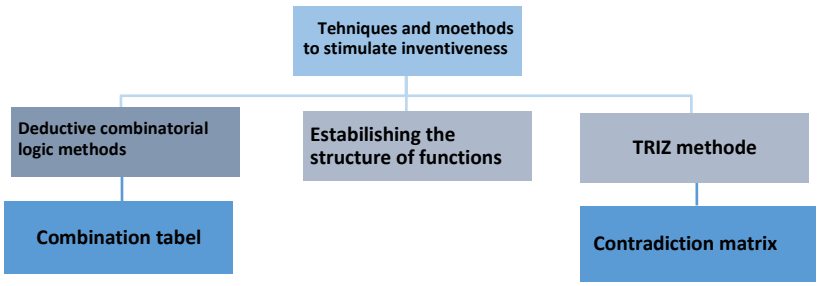

Fig. 9 Tehniques and moethods to stimulate inventiveness

4.1. TRIZ method - Development of concepts with the help of technical contradictions

The contradiction matrix is a tool for selecting the inventive principles used to resolve a particular contradiction. On the rows of this matrix are listed the parameters that need to be improved, and on the columns the parameters that get worse as a result of the improvement of the parameters on the rows.

- *Problem desctription*

The product to be analyzed in the dissertation project is a modular electrochemical polishing equipment. In order to bring something innovative compared to the already existing products on the market, technical contradictions will be formulated, and solving them will lead to the development of an innovative concept.

- *Formulation of the tehnical contradiction*

Technical conflicts arise when an improvement of one feature of the system leads to the worsening of another feature of the system. A technical conflict therefore involves two features of the system, as follows:

- Increasing the complexity of the equipment reduces the ease of manufacture and ease of use operation.
- Reducing the weight of the deburring equipment decreases its strength over time.

Table 1. Tehnical conflict summary table [15]

Parameter that iproves	Worsening parameter	14	32
		Resistance	Manufacture easyness
2.	The weight of the stationary object	3, 16, 22	-
36.	Complexity of the object	-	18, 24, 37

- Estabilishing generic of the TRIZ principles fotm Matrix Contradictions

Generic solutions and specifics solutiuons for modular eletrochemical polishing equimpment can be found in Table 6.

Tabelul 2. Table of generic solutions [15]

Nr. Princ	**Frenquency of occurrences**	**Triz Principles**	**Priciples DFE Strategies**	**Specific solutions**
1	2	Segmentation	A. Divide the objects in parts independent; B. Make the object easy to disassemble ; C. Increase the degree of segmentation.	#1.Equipment wil hae modular compartimentation. #2. The elements to be interconnected.
2	1	Removing from context	Extract the necessary parts of the object Extract the property that bothers you from object	#3. Poka-yoke system to prevents mistakes
13	2	Reverse	A. Reverse the action used to solve the problem. B. Make the moving parts or the external environment fixed. C. Turn the object / process upside down.	#4. Interchange of the working head to increase the complexity of the processed surfaces
26	2	Copy	Instead of fragile, hard-to-obtain, expensive, or environmentally polluting materials, use simple, inexpensive copies. B. Replace the polluting object or process with optical copies.	# 6. Using virtual renderings for easy validation of the concept #5. Using printed prototypes to validate the concept.

4.2. Combination table

Tabelul 3. Combination summary table

Maximum polishing capacity (A)	Tank volume (l)	Electrolyte system	Type of surfaces	Adaptabilty	Portability	Volume of parts machined	Fluid flow	Processing regime
250	30	yes	Intersecting hole	no	yes	1	Tangential flow	DC
200	10	yes	Outside surface	yes	no	3	Reverse flow	DC
300	45	yes	Inside surface	no	no	2	Direct flow	DC

4.3. External research

Analyzing recent patents, it was decided to present electrochemical polishing processing plants. Figure 6 shows the patent for an electrochemical processing device. The tool electrode 2 is connected to the cathode, being on the tool holder head (1), having an adjustable feedrate. The maintenance of a certain gap imposed by the processing process is performed with the help of the automatic feed regulator, depending on the sizes in the workspace.

A technical pump-filter system directs the electrolyte into the space between the electrodes. During the process, the electrolyte comes out under pressure loaded with metal hydroxides, formed as a result of erosion, hydrogen bubbles, oxides, air, vapors, etc., heated to a temperature higher than the inlet.

The machine base, on which the processing unit is mounted, must be of rigid construction, to withstand the deformations produced by the hydrostatic forces of the electrolyte, having high pressure, the mass of the machine and the processing chamber, made of corrosion resistant materials and provided with screen. transparent to stop the visual control of the processing process.

The mass of the machine must be movable in order to center the part in relation to the electrode-tool, its feed system being kept constant.

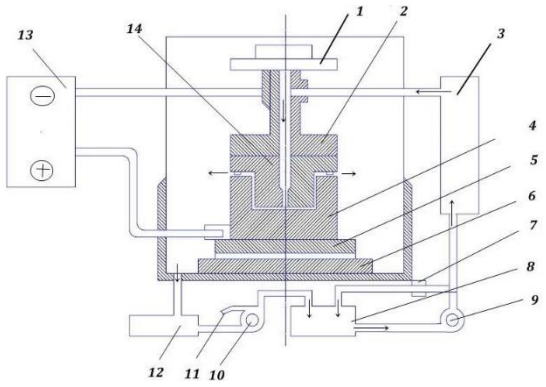

Fig 6. Patent nr.US6699380B1 [2]

Figure 7 shows the patent for an automatic and portable electrochemical polishing equipment. It has advantages such as simplicity of operation, low construction costs, flexibility, occupying a relatively small space. The patent brings as a novelty the portability of the equipment. [3]

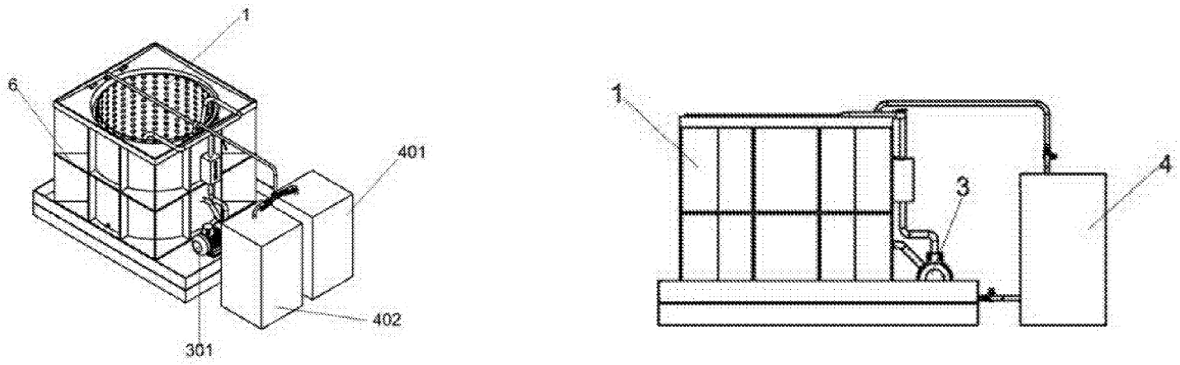

Fig 7. Patent no. US2014076719A1 [3]

5. Partial concept

The designed device is installed on the table of the machine tool
For the processing of PSF the following steps are followed:

1. Attach the PSF to the device as follows: Tightening and orienting the PSF is done with the help of 4 guide and fixing wedges POI, a CII type plate, 4 locking and fixing elements, and then the tightening is done with the help of 4 screws with hexagonal seat DIN 912 M5.
2. Assemble the plexiglass panel;
3. It is fastened with 4 screws with hexagon socket DIN 912 M10;
4. Position the Plexiglas panel using 2 three-dimensional corners;
5. It is fixed with the help of 6 screws with hexagon socket DIN 912 M4;
6. Lower the electrode tool for processing;
7. It is allowed to enter the electrolytic liquid with the help of valve 1 .;
8. Open valve 2 for the flow of electrolytic liquid from the device;
9. PSF is processed;
10. After processing, remove the electrode tool;
11. Turn off valve 1 to stop the electrolyte from entering the device;
12. Remove the 2 three-dimensional corners and the hexagon socket screws to detach the Plexiglas panel;
13. Remove the Plexiglas panel;
14. Loosen the 4 hexagon socket screws, together with the locking and fixing elements;
15. Remove the PSF from the device;
16. The cycle resumes.

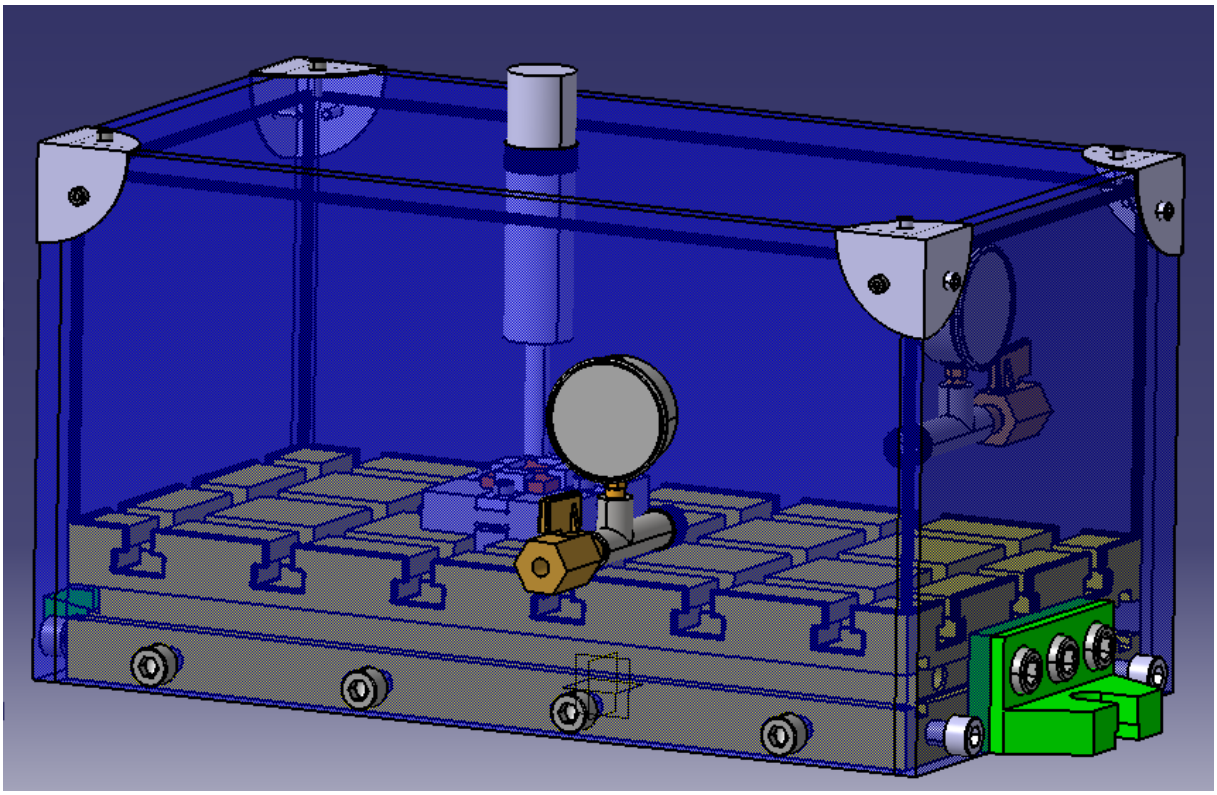

Fig 8. Partial concept

6. Product selling

The next step that we need to follow represents the selling of the product. In order to define a product or a service as being “successful ”, we need to commercialize it above everything else. After we are sure that our product does not break any laws or rules, we consider the problem of the marketplace. Where would we try to sell our product ? Of course, we cannot choose a place like a mall or a supermarket. On the other hand, we can try to create a link between identified appliable domains and the companies that work in that domain. When it comes to new clients, even if they already have a supplier or they consider that they actual equipment is ok, we can try to offer them a “pro-bono”. We can give them a free trial (for example a trial of 30 days) in order to see the efficiency and innovation brought by our product.

6.1. Future potential clients

After analyzing the client’s needs and requirements, we identified a series of clients that might be interested in buying our product. There is to be mentioned that the appliance of ECM is very large, and these potential clients are clients with large application domains.**Universitatea de Medicină și Farmacie ”Carol Davila”**

- Medical and Pharmaceutical College “Carol Davila”
- Feromet
- Carrus Expert
- Electro Optic

6.2. Route planning for distribution. Estimated costs. Product recycling.

After identifying the potential clients, we will consider the eventual distribution cost. Using the free software Google Maps, and having just a car for delivery, with a 10 litters average consumption, we get a daily distribution cost of 60 RONS per day and a total delivery time of 120 minutes. On the same way, we used a professional route planning software called Routific. Therefore , the daily distribution cost is now 29 RONS and the delivery time is 86 minutes.

Fig 9. Recycling process

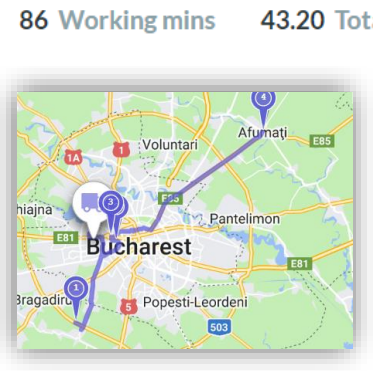

Fig 10. Customer location

7. Conclusions

In conclusion, in the written paper were treated the current state of processing by electrochemical polishing. The main details in the polishing process were the sizing of the electrode tool, the choice of the type of back pressure chamber, the choice of the type of electrolytic fluid flow, the type of treated surface and the stability of a processing type to streamline the quality of future surfaces.

It was wanted to build a modular electrochemical polishing equipment to obtain the highest quality surfaces, with the lowest possible roughness, in the shortest possible time, which was mentioned in the conceptual design chapter.

8. Bibliography

[1] *** Ghiculescu D., Tehnologii de fabricare electrochimica, available https://curs.upb.ro/, accesed 21/4/2022.
[2] Marinescu N.I. et al (2006), Tratat de Tehnologii Neconvenționale, PRINTECH, București, ISBN (10) 973-718-613-3, ISBN (13) 978-973-718-613-3.
[3] *** Electropolishing equipment available at https://worldwide.espacenet.com/patent/search/family/050273331/publication/US2014076719A1 accesed la 24.04.2022.
[4] *** Hegmann S., Electropolishing vs. Pulsed Electrochemical Machining (PECM), Voxel Innovations Inc., Education Portal, Noiembrie 2021, article available athttps://www.voxelinnovations.com/post/electropolishing-vs-ecm, accesed la 22/01/2022
[5] *** https://www.brindustry.ro/lustruirea-otelului-inoxidabil-gama-clinox/ accesed la 12/05/2022
[6] ***https://www.presi.com/en/product/polisec-c25/ accesed 12/05/2022
[7] ***https://www.directindustry.com/prod/otec-praezisionsfinish-gmbh/product-29530-1839877.html accesed 12/05/2022
[8] ***https://lege5.ro/Gratuit/gezdiobqha/reguli-generale-de-comercializare-a-produselor-si-serviciilor-ordonanta-99-2000?dp=gm3tcnruha3tq, accesed 18/03/2022
[9] *** https://www.feromet.ro/servicii/zincare-electrochimica accesed 19/03/2022
[10] *** https://carrusexpert.ro/servicii-atelier-2/ accesed la 19/03/2022
[11] *** https://electro-optic.ro/en/services-2/ accesed 19/03/2022
[12] *** https://conspecte.com/expertiza-merceologica/certificarea-calitatii.html accesed 9/03/2022
[13] *** https://app.routific.com/#/hud/questionnaire accesed la 14/04/2022
[14] *** https://www.google.ro/maps accesed 14/04/2022
[15] *** Ionescu N., Creativitate și proprietate intelectuală, available at https://curs.upb.ro/, accesed 13/4/2022.