MODULAR ELECTROCHEMICAL POLISHING EQUIPMENT

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ABSTRACT:This paper deals with the state of the art of electrochemical polishing. The main details of the polishing process are the dimensioning of the electrode-shell, the choice of the type of counter-pressure chamber, the choice of the type of flow of the electrolytic liquid, the type of surface to be polished and the establishment of a type of process that will improve the quality of future polished surfaces. The aim is to rebuild a modular electrochemical polishing equipment in order to obtain the highest quality surfaces with the lowest roughness in the shortest time. Thus, the present work will provide information about the process and the existing equipment on the market with the help of patents, to be developed in the dissertation. Finally a concept proposal for the future equipment will be presented.

KEYWORDS: electrochemical polishing, anode, cathode, electrolytic liquid, modular equipment, ECM.

1. Introduction

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

2. Current status

Electrochemical polishing involves an anode, consisting of the workpiece to be machined, and a cathode represented by the tool being placed in an electrolyte bath, where solutions of basic, acidic or neutral character are present. 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 oxidised and dissolved in the electrolyte, and then the oxidation products pass to the cathode. A reduction reaction takes place at the cathode, producing hydrogen. [3] This achieves the reduction of the roughness of the machining surface according to the scheme in Figure 2.1, underlying the anodic dissolution, which occurs in the electrolyte bath, and as a result an electric field is created between the tool and the

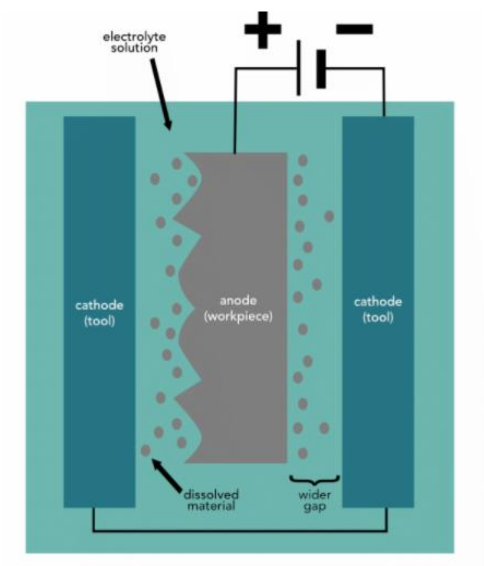


Fig. 1. Schematic of the electrochemical polishing process [4]

workpiece. And on the surface of the blank a passivated layer is formed in the region of the micro-warpage, where the current intensity is higher, so the electrical resistance is lower in these areas. [4].

3. Strategic product marketing

Identifying market opportunities

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

Thus, 5 needs were identified:

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

Data collected from potential customers:

The questionnaire will be used to identify customer requirements. The questionnaire guide used in the collection of raw data aims to obtain answers that answer questions such as:

1. What is your field of activity?

6. Would electrochemical polishing equipment be useful in your work?

7. Which of the following advantages do you consider the most important?

The results of these questions are as follows:

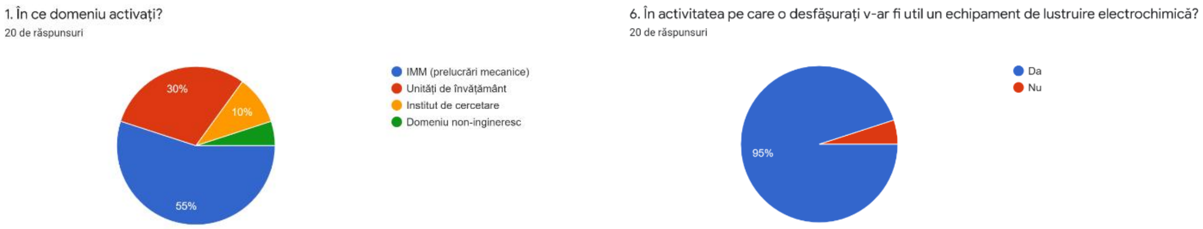


Fig. 2 Question 1 and 6

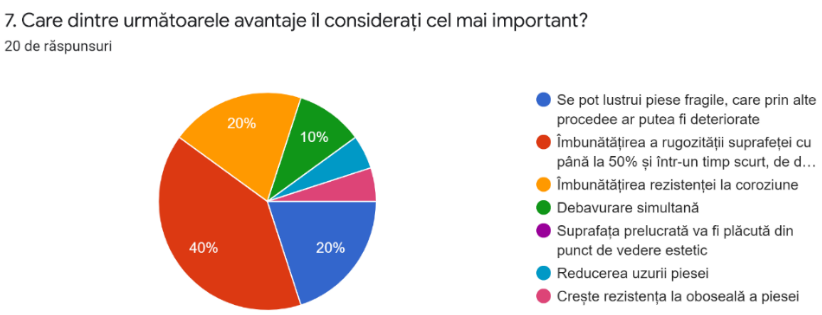


Fig. 3 Question 7

From the responses we received we can say that there is a great interest in the product. Electrochemical polishing is preferred over mechanical finishing, with respondents considering that electrochemical polishing equipment would be useful to them.

4. Modeling of electrolyte fluid flow

- Choice of calculation mode: Choose *2D Axisymmetric* dimensional space (for a part of revolution that has symmetry about a central axis), then the Physics mode used: Fluid Flow-Laminar Flow, then steady state. This assumes that the electrolyte flow is laminar (constant velocity in the machining gap).

In the figure below you can see the parameterization of the model:

Name	Expression	Value	Description
W1	10[mm]	0.01 m	rază piesă
H1	0.4[mm]	4E-4 m	interstițiu de prelucrare
W2	5[mm]	0.005 m	rază sculă
H2	1.5[mm]	0.0015 m	înălțime canal electrolit
a	0.0001[m]	1E-4 m	pas
b	0.000016[m]	1.6E-5 m	Rz
sigma	7.95[S/m]	7.95 S/m	conductivitate el NaCl
Eeq_K	-0.85[V]	-0.85 V	potential de ech catod
Eeq_A	-1.55[V]	-1.55 V	potential de ech anod
i0_K	0.3[A/m^2]	0.3 A/m²	densitate de curent de sc...
i0_A	1[A/m^2]	1 A/m²	densitate de curent de sc...
b_K	-220[mV]	-0.22 V	curba Tafel, catod
b_A	55[mV]	0.055 V	curba Tafel, anod

Fig. 4. Modelling parameters in Global Definitions

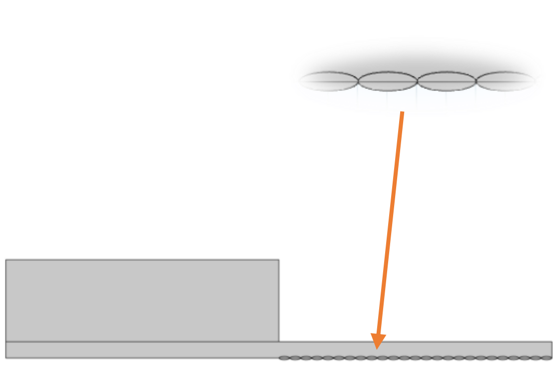


Fig. 5. Creating geometry in the work area

- The creation of the geometry is exemplified in figure 3.: Use the drawing tools integrated in the Geometry node of the Model Builder (*Rectangle*, *Ellipse*, *Boolene operations: Difference*, *Union*).
- The microgeometry of the modelled part is modelled with ellipses, starting from the parameter Ra=0.8 µm which is correlated with Rz=height of the ellipse.
- The material allocation is shown in Figure 8.: It is assimilated with water, the electrolyte liquid, its proportion in solution being over 90%. Search for the liquid in the COMSOL material library and allocate it to the geometry:

	Property	Variable	Value	Unit	Property group
✓	Density	rho	rho_liqu...	kg/m³	Basic
✓	Dynamic viscosity	mu	eta_liqui...	Pa·s	Basic
	Thermal conductivity	k_iso ;...	k_liquid...	W/(m·...	Basic
	Coefficient of thermal expansi...	alpha_...	(alpha_li...	1/K	Basic
	Heat capacity at constant pres...	Cp	C_liquid...	J/(kg·K)	Basic
	Local property HC	HC	HC_liqu...	J/(mol...	Local properties

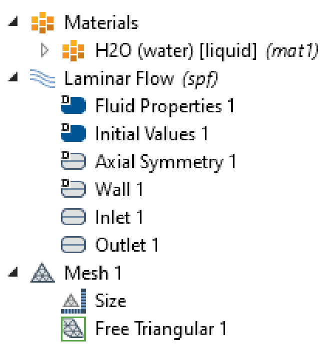


Fig. 6. Material allocation

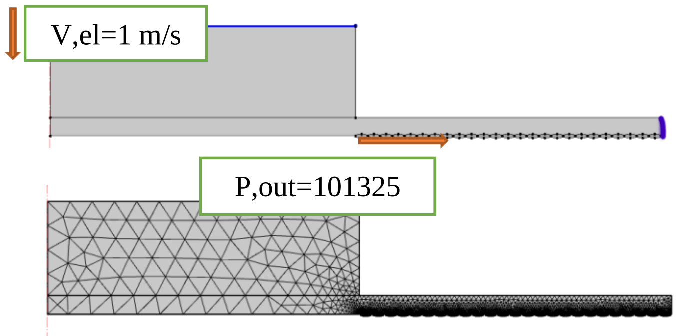


Fig. 7. Boundary conditions and discretization of the electrolyte fluid flow circuit

- The boundary conditions are shown in Fig. 7. as an inlet and an outlet at atmospheric pressure, Electrolyte inlet velocity, Vel - [m/s]; Outlet pressure - Pout [Pa];
- Discretization, shown in Fig. 7. with triangular elements of *finer* size. A division of the geometry into 16345 free triangular elements is observed.
- Run the model in steady state and visualize the results, watching the variation of flow velocity and pressure, as in Figure 9:

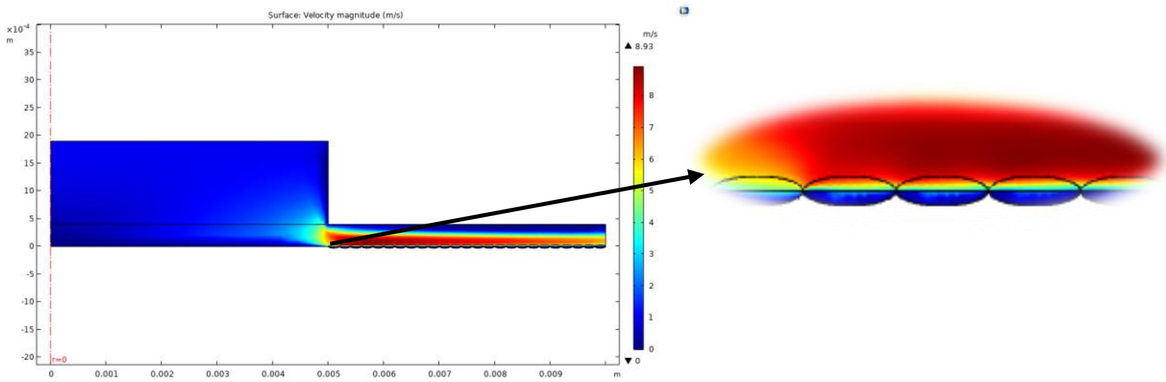


Fig. 8. Variation of electrolyte flow velocities and pressures at a processing gap sf=0.4 mm, initial Ra roughness of 0.8 µm and electrolyte inlet velocity 1m/s

5. Detailed design

The designed device is installed on the machine tool table
The following steps are taken to process the PSF:

1. The PSF is clamped in the device as follows:Clamping and orientation of the PSF is done by means of 4 guide and fixing wedges POI, a CII type plate, 4 locking and fixing elements, and then clamping is done by means of 4 hexagon socket screws DIN 912 M5
2. Assemble the Plexiglas front panel using 4 corners;
3. Fasten with 12 hexagon socket screws DIN 912 M4;
4. Lower the electrode tool for machining;
5. The electrolytic fluid is allowed to enter with tap 1;
6. Open tap 2 for the flow of electrolyte fluid from the device;
7. Process PSF;
8. After machining the electrode tool is withdrawn;

9. Turn off tap 1 to stop the electrolyte entering the device;
10. Remove the 4 three-dimensional corners and the hexagonal socket screws to remove the Plexiglas front panel;
11. Remove the Plexiglas front panel;
12. Loosen the 4 hexagon socket screws together with the locking and fastening elements;
13. Remove the PSF from the device;
14. The cycle begins again.

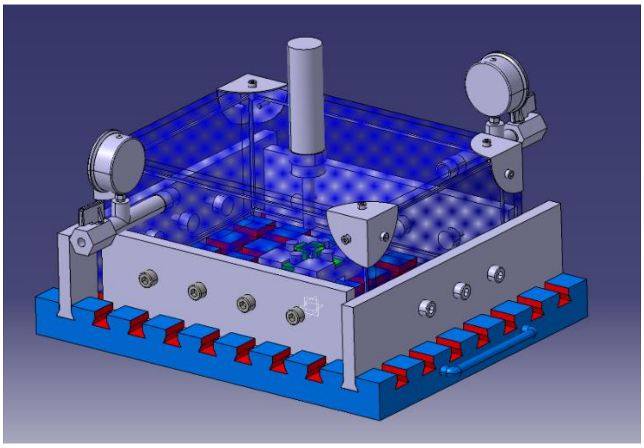
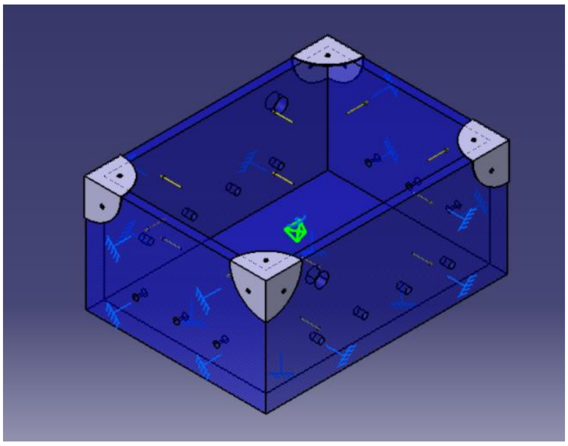


Fig 9. Partial concept

6. Manufacturing - product prototype testing

FEA check of side walls. In this part of the work it will be checked whether the deformations and unit stresses of the side walls have appropriate values within the required limits. During processing, the sidewalls will be subjected to a pressure of 20 atm (2 MPa), exerted by the electrolytic liquid.



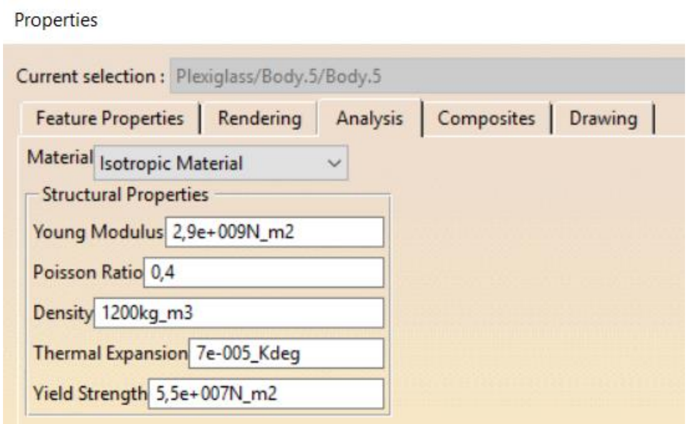


Fig.10 Defining the bearings and forces

Fig.11 Material properties

The foundations and forces have been defined as shown in the figure and the material properties of the side walls (Plexiglas) are shown in the figure. **Definition of the forces exerted**

by the electrolyte fluid and the amount of charges applied.

The wall widths are 30062 mm^2 and 21889 mm^2 . Thus the forces exerted on them are:

For walls 1 and 3:

P=F/S [Mpa]

P=2 MPa

S=30062 mm^2

$\rightarrow$F = 60124 N

And **for walls 2 and 4**, following the same formula resulted F=43778 N

Using this input data, FEA analysis was performed for the device walls. From the whole report of interest are the unit stresses (Von MisesStress) and the deformations (Displacement).

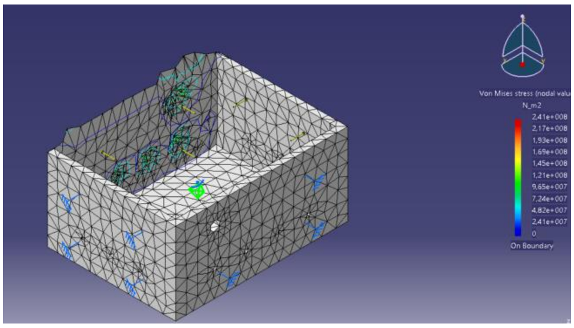


Fig.12 Unit efforts

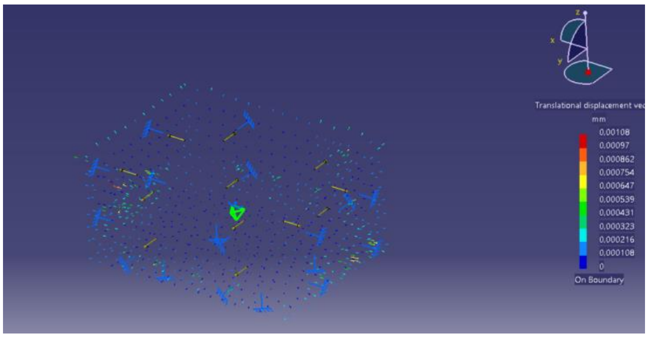


Fig.13 Deformations

The maximum breaking stresses occur in the upper area of the device and has values within the limits - 2.41e+08, and the deformations are 0.0011 mm .

7. Economic analysis of the product

What do we mean by economic analysis of a product?

Economic analysis is an extremely important step when it comes to the development and physical realisation of a product. This analysis can determine from the outset what the potential profitability is and what the potential costs will be.

By definition, analysis is a general method of researching a product and the phenomena that go to make it up, based on breaking them down into their component parts and studying each of them. It contributes to raising the level of knowledge from the particular to the general, from the concrete to the abstract [14].

Economic analysis involves a composition of phenomena that relate to production, distribution, goods and services. Thus, we can speak here of satisfying needs either through the consumption of goods and services from outside (for example, using the resources of other companies, persons or institutions in the form of purchases) or through the consumption of own goods and services. Own goods and services also include the time allocated by each team member, intellectual property, and the location or environment in which the work is carried out.

A product goes through a continuous process called the product life cycle. Thus, from the moment of conception to the moment of disposal, the product goes through a series of stages called launch, development, maturity and decline (Figure 14).

Fig. 14. Life cycle phases of a product

In engineering, when we talk about cost, it can be divided into several categories, being ultimately made from a division of several elements, such as the cost of raw material, materials to be used, the cost of semi-manufacturing, machining and finishing, the cost of each branch working on the production of a product (sections, departments), also known as the cost of labour, the cost of employees (CAS, taxes, salaries, bonuses, leave, compensation, etc.).) or unforeseen costs (defective items, production errors, accidents)[15].

In the framework of the project, we carried out an economic analysis based, initially, on direct costs. thus, we analysed the components that will take part in the realisation of the proposed concept, and later on, a more detailed economic analysis will be carried out, which will also include costs related to personnel, auxiliary materials, semi-manufacturing or labour.

Thus, in the table below we can find a list of products and items to be purchased for the realisation of the product under development.

Table 1.Table of initial estimated costs

Crt.	Name	Quantity	Technical features	Date of purchase	Estimated cost
1	Mass of the device	1	Dimensions : 300x200x100 Material: Steel	14.04.2023	1800 RON
2	Device table clamp	2	Dimensions : 50x25x35 Material: Steel		88 RON
3	Hexagon socket screws	38	Diameter: M8x10 Group: 8.8, 10.9 Material: steel, stainless steel Coating: Burnished, Galvanized, White		54 RON
4	Plexiglas panel	5	Dimensions : (L x W)(mm) 100x67x5 cm		1245 RON
5	Pressure gauge	2	Measuring range: 0.5-7.5 bar Length x width x height : 100x30x160 mm		44 RON
6	Tap	2	Inlet diameter : 0.75 inch Output diameter: 0.5 inch Maximum working pressure : 10 bar		166 RON
7	Guide wedge	4	Dimensions : 10x20x10 Material: Steel		160 RON
8	Forks	4	Dimensions : height 47mm, length x width : 47mm Colour: white		50 RON
9	Gasket	1	Length: 1000,00mm Net width: 6,50mm Height: 10,00mm Net mass: 0.07kg		50 RON
10	Part fixing plate	1	Dimensions: 50x50x5 Material: steel		360 RON

11	Blocking element	4	Dimensions: 20x20x20 Material: steel		240 RON
12	Cock	1	Ɵ20x80		400 RON
13	Electrolyte liquid	1	Composition UNI805: Phosphoric Acid + Additives DOES NOT CONTAIN: toxic substances such as Hydrofluoric Acid and Azotic Acid Container: 1 litre		211 RON
	TOTAL				4868 RON

8. Conclusions

This paper deals with the state of the art of electrochemical polishing. The main details of the polishing process are the dimensioning of the electrode-shell, the choice of the type of counter-pressure chamber, the choice of the type of flow of the electrolytic liquid, the type of surface to be polished and the establishment of a type of process that will improve the quality of future polished surfaces. The aim is to rebuild a modular electrochemical polishing equipment in order to obtain the highest quality surfaces with the lowest roughness in the shortest time. Thus, the present work will provide information about the process and the existing equipment on the market with the help of patents, to be developed in the dissertation. Finally a concept proposal for the future equipment will be presented.

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