The Scientific Bulletin of VALAHIA University
MATERIALS and MECHANICS –Vol. 20, No. 23

DOI 10.2478/bsmm-2024-0018

# VIRTUAL MODELLING OF THE STRESS-STRAIN STATE OF THE BAR THRUST SYSTEM IN THE CHROME PLATING TECHNOLOGICAL PROCESS

**Adrian PICU, Ivona Camelia PETRE, Alexis NEGREA, Elena Valentina STOIAN, Maria Cristiana ENESCU**

Valahia University of Targoviste, ,13 Sinaia Alley, 130004, Targoviste, Romania

E-mail:petreivonacamelia@yahoo.com

***Abstract:*** *Chrome plating of long bars in conventional batch plants proves to be challenging, requiring complex lifting equipment and considerable vertical space. Therefore, the use of continuous chrome plating plants, which allow controlled passage of the bars through the chrome plating bath, is preferred. The continuous hard chrome plating plant operates automatically, controlling the entire process from the loading to the discharge of chrome plated bars.*

*The feed and discharge mechanisms must allow the flow of electric current through the bars subject to the chrome plating. This calls for the design of some mechanisms capable of ensuring a constant feed of bars and their efficient discharge.*

*This paper presents a virtual study using finite element analysis (FEA) focused on the strength assessment of the mechanism including the drive pin, the levers and the sliding plates responsible for the movement of the bars.*

*As a result of the study, essential data on critical stresses, local deformations and factor of safety (FOS) for the whole mechanism were obtained, thus providing valuable information for the optimization of the chrome plating process.*

***Keywords:*** *virtual stud, local deformations, local deformations*

## 1. INTRODUCTION

The use of some metal parts in corrosive environments requires the coating of the metal surfaces with resistant protective layers. Various surface coating methods are available in today's industry [1-5]. The techniques currently applied to prevent and control metal corrosion largely depend on the shape and size of the object to be protected, the quality of the base material, the technological parameters for the plant operation and the possibilities for the execution of the corrosion protection. Special chrome plating plants are required for long bars or pipes, which require corrosion protection coating. In such cases, continuous chrome-plating plants are used for the chrome plating of the long bars, the operating principle of which is the continuous and controlled passage of the bars through the chrome plating bath. In these plants the volume of electrolyte used is much reduced, the bar moving horizontally through the solution.

The continuous hard chrome plating plant is a plant which operates in automatic mode, managing the process of charging and discharging the chrome-plated bars. The kinematic diagram of the chrome plating plant is shown in Figure I.1.

As a working principle, in the technological flow, the bars are manually placed on the feed table from where they are automatically loaded onto the supporting rolls by means of a system of successive steps carried out by means of the pneumatic cylinders. After loading, an optical system controls the movement of the trolleys which will push the bars along the entire chrome-plating length, passing successively through the degreasing, washing, anodizing and hard chrome-plating cell. At the exit from the last hard chrome-plating cell there are the end-of-bar signalling systems, so that the feeding and chrome-plating cycle can continue. The plant is equipped with an end-of-bar signalling system which indicates as it is indicated by the name the end of the chromium-plated bars and controls their discharge from the running lines onto the chrome-plated bars discharge bed. The number of chrome plating cells C1, C2 where the process of electrolysis and material coating takes place is given by the technological process of progressive coating in uniform layers on the chrome bars.

The present paper proposes a virtual study, with the help of FEA, of the strength of the drive pin-lever- sliding plate assembly in the bar thrust mechanism during the chrome plating process.

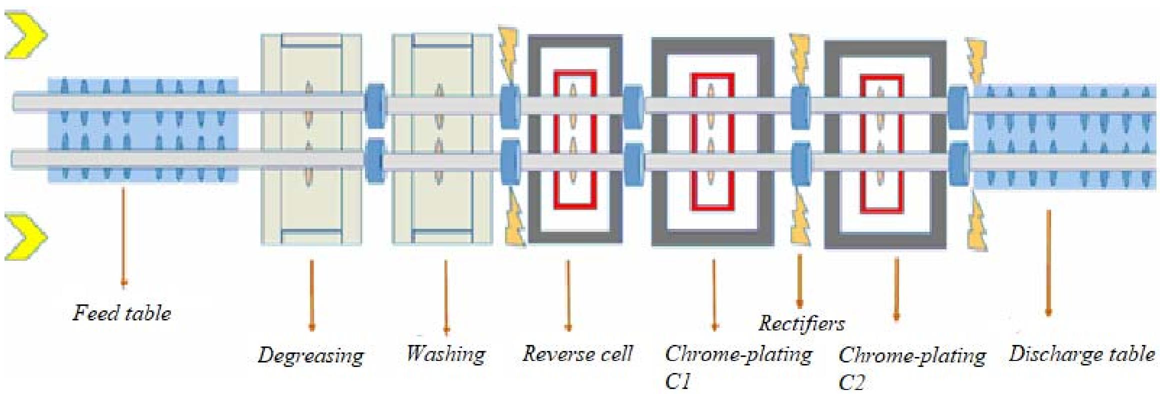


**Figure I.1. Kinematic diagram of the chrome-plating process**

## 2. DESCRIPTION OF THE DEVICE

The bar clamping and advance device is a lever mechanism which operates simultaneously and symmetrically in mirror image. It is provided with two plates made of copper alloy which clamp the bar between them. The mechanism is shown in Figure II.1.

The device consists of the lever mechanism, the sliding plate system, the connecting element and the pneumatic cylinder (Figure II.2).

The copper alloy plates have been removed from Figure II.2 in order to be able to show the drive mechanisms. The mechanism works as follows:

- the pneumatic cylinder axially actuates the drive pin which in turn axially moves the central part.
- the central part has a symmetrical design in order to be able to drive the L-shaped levers through the two recesses.
- the levers are hinged at the intersection of the long and short sides of the 'L'.
- when actuated by the pin these levers rotate, in a mirror image of each other.
- by rotating, the levers actuate the sliding plates, which have a transverse translation movement in relation to the axis of the bar.
- the movement is towards each other (tightening) or away from each other (loosening).

The two positions of the lever are shown in Figure II.3 - open position and in Figure II.4 - closed position.

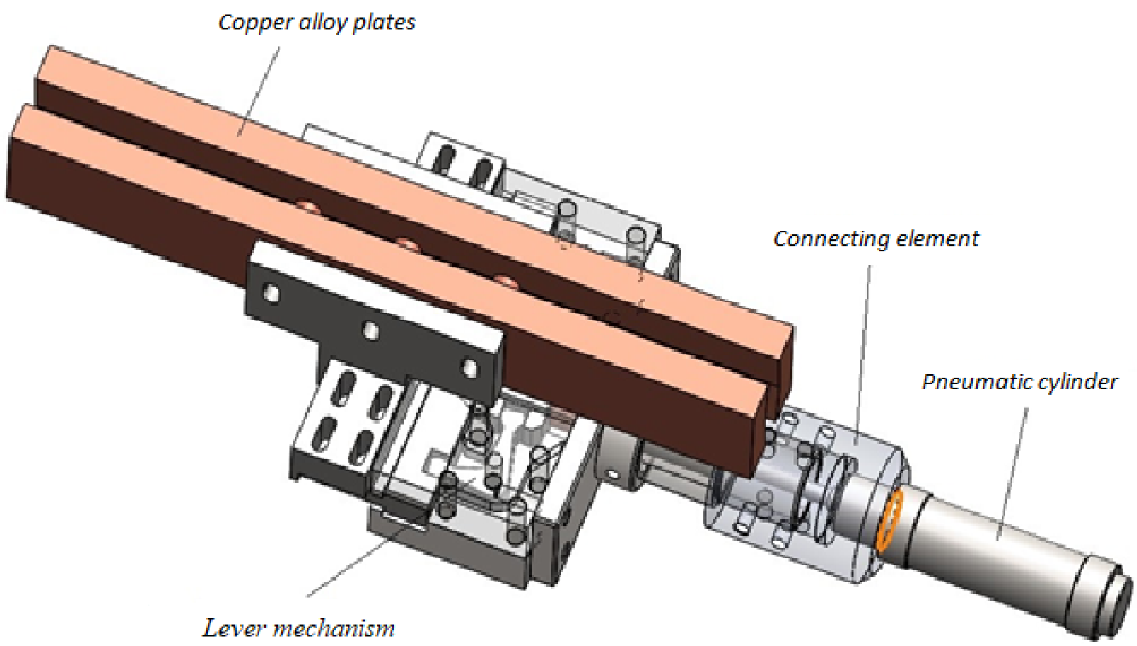


**Figure II.1. Electric current thrust/contact device**

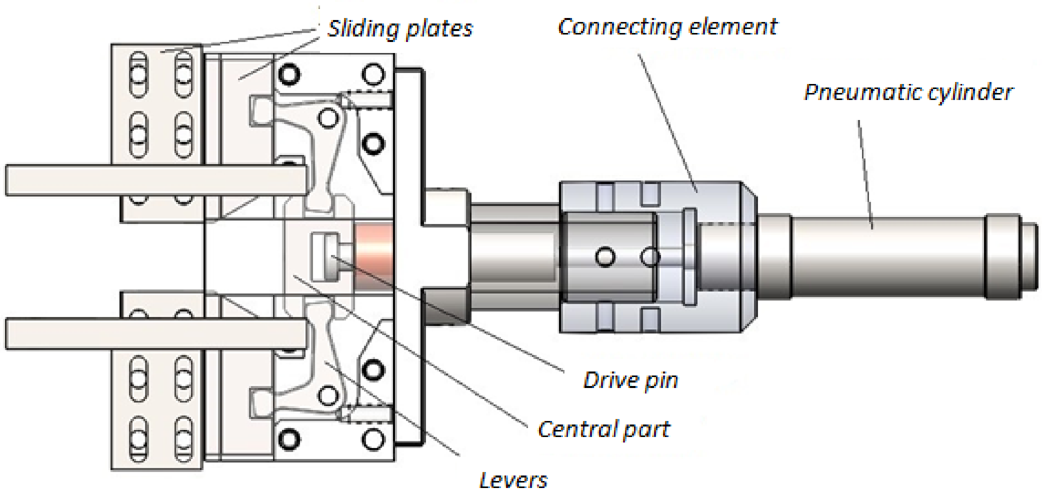


**Figure II.2. Electric current thrust/contact device**

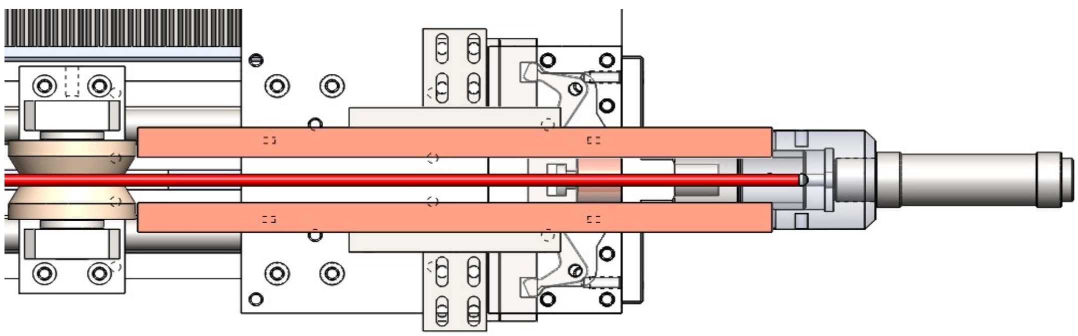

**Figure II.3. Open position of the thrust device**

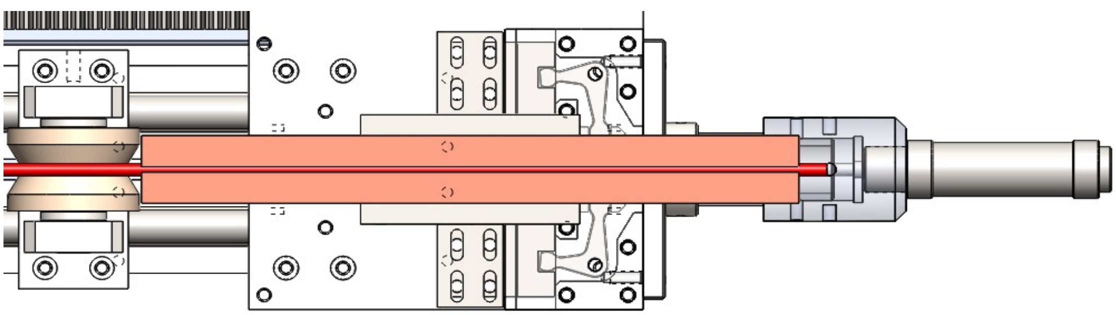

**Figure II.4. Closed position of the thrust piece**

## 3. VIRTUAL STRENGTH INSPECTION OF THE DRIVE PIN – LEVER - SLIDING PLATE MECHANIM

For a better assessment of the mechanical behaviour of the bar clamping mechanism during the chrome plating process, the behaviour of the three parts, analysed individually, under the stresses within the working system will be analysed [7-10].

For this purpose the mechanism composed of (fig.III.1) was modelled:

- the base plate, the support for placing and positioning the three parts;
- the drive pin;
- the levers;
- the sliding plates which support and move the two copper alloy plates.

For this analysis the sliding plates have been fixed in the clamping position of the bar (Fig. III.2). It is considered that when the copper alloy plates clamp the bar, the sliding plates become fixed.

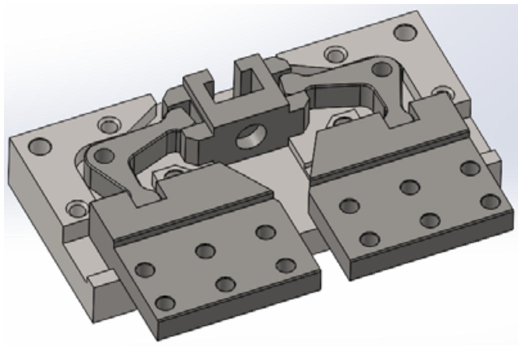

**Figure III.1 Drive pin - lever - sliding plate mechanism**

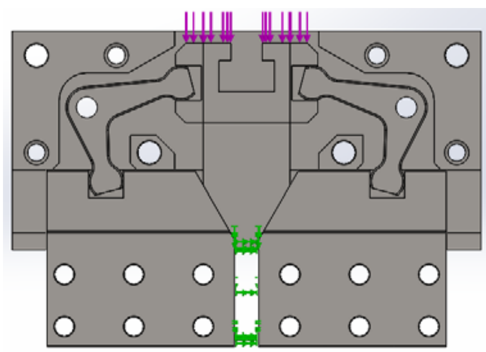

**Figure III.2 Fastening and applying stresses to the mechanism**

In order to highlight the most stressed areas of the mechanism, a force of 10,000 N was applied. This force is very high, but the results obtained show the transmission of the stresses between the three parts subjected to the mechanical analysis.

The von Mises stresses presented in Figure III.3 reach their maximum value at the contact between the pin and the base plate (168.64 MPa) of the mechanism. A point of interest is the lever head where the maximum stress is 54.76 MPa. This stress can provide us with a picture of the contact pressures occurring between the ends of the lever and the other two parts: the pin and the sliding plates.

The equivalent displacements corresponding to the applied force, shown in Figure III.4, are not large, the maximum value can be found within the pin and is 0.039 mm. The equivalent displacement on the pin head is 0.023 mm.

An illustrative picture is the distribution of the factor of safety FOS, shown in Figure III.5, which indicates the risk areas within the mechanism, i.e. the areas where potentially dangerous stresses occur. The lever head is a risk area because the value of 2.431 is below the safety value (3).

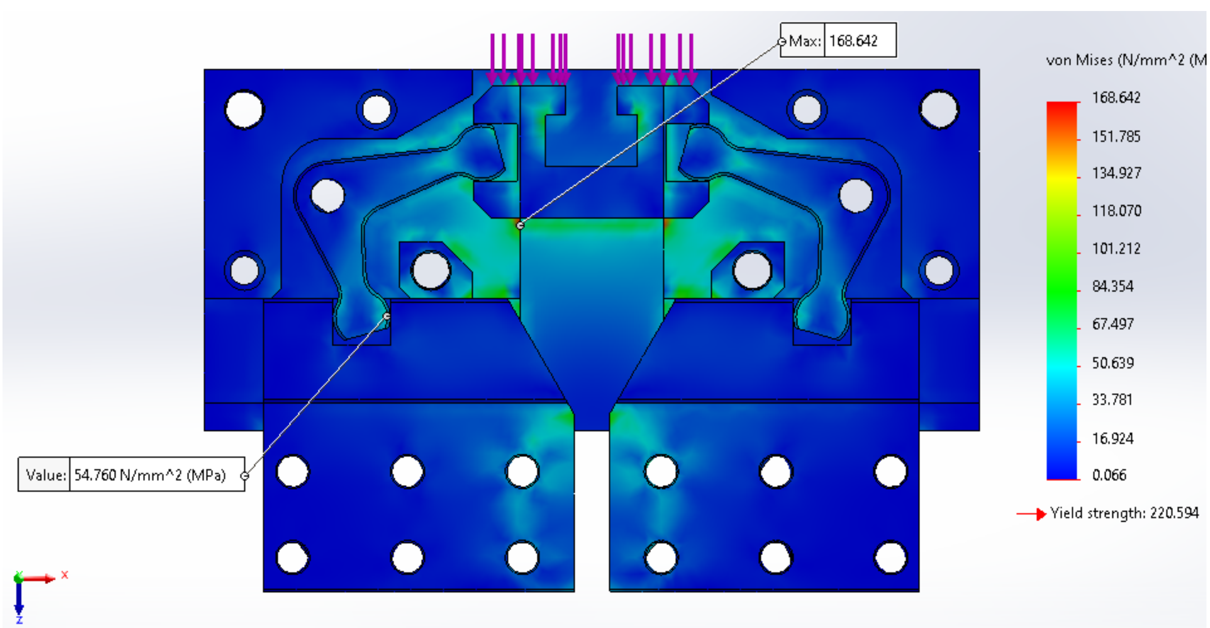


**Figure III.3. Von Mises stresses for the mechanism**

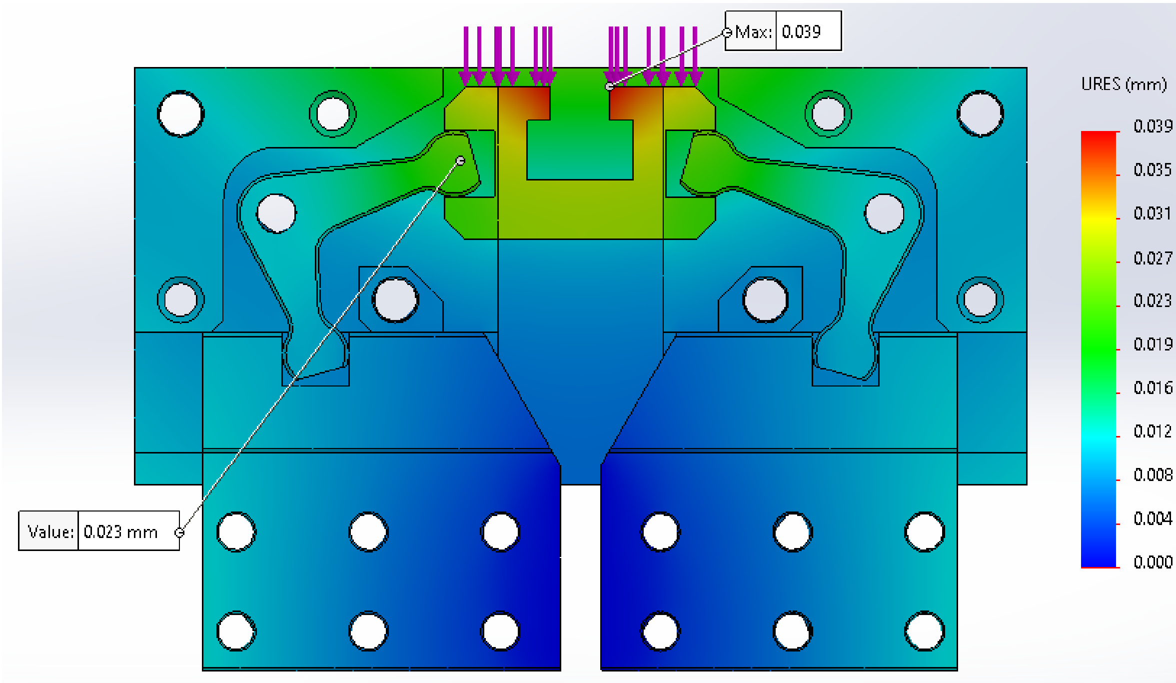


**Figure III.4. Equivalent displacements for the mechanism**

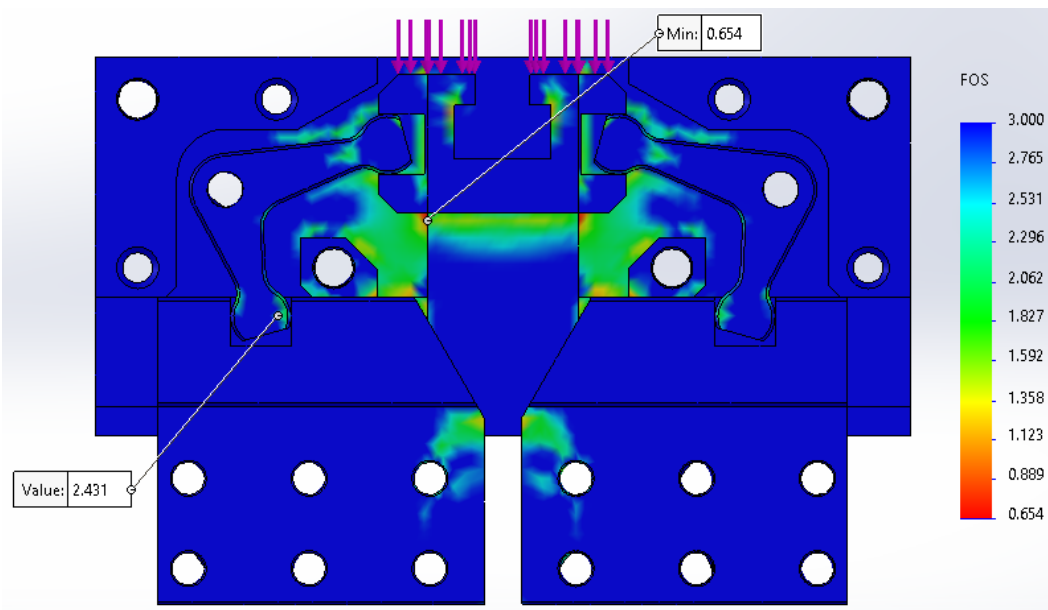


**Figure III.5. FOS factor of safety for the mechanism**

Another virtual analysis carried out assumes that the three parts of the mechanism are not closely connected. They are considered to have a contact clearance of 0.02 mm.

In this case, and for the same configuration of the base and the real stress force (300 N), the results below were obtained (Fig. III.6-Fig. III.8).

The obtained results are presented as follows: in Figure III.6 the von Mises stresses, in Figure III.7 the equivalent displacements for the applied force of 300 N, and in Figure III.8 the distribution of the FOS factor of safety.

A virtual analysis was also carried out on the pressures exerted in the drive pin - lever - sliding plate system which is shown in Figures III.9 and III.10.

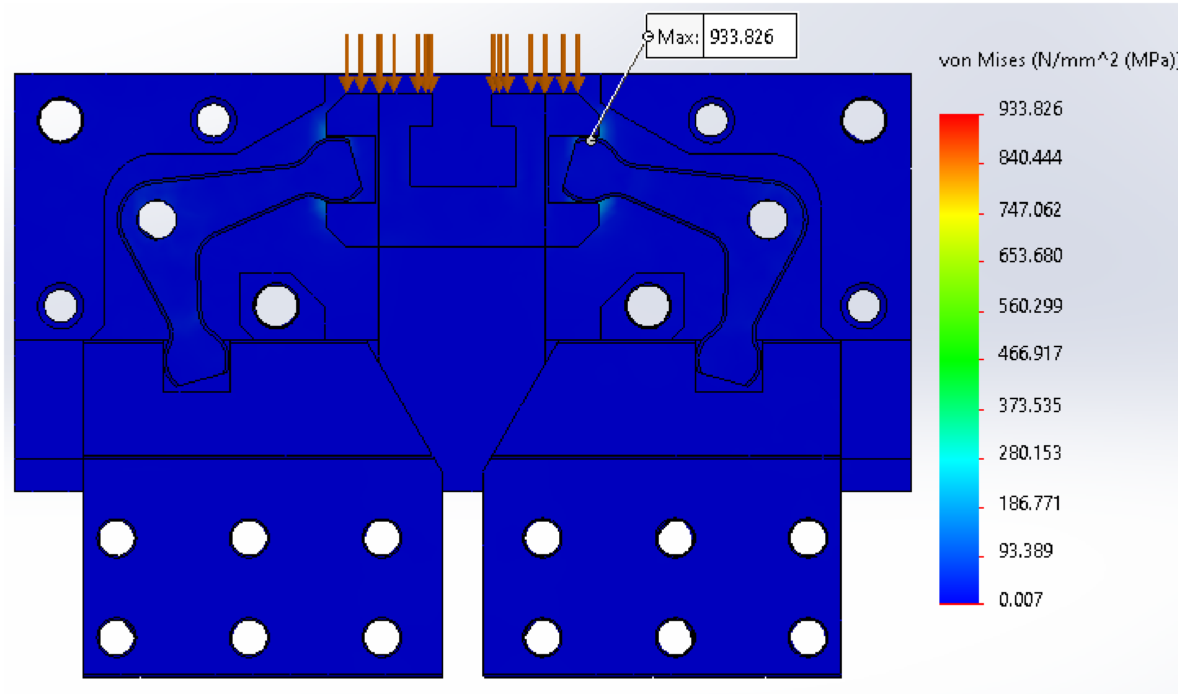


**Figure III.6. VonMises stresses for the mechanism, contact stress**

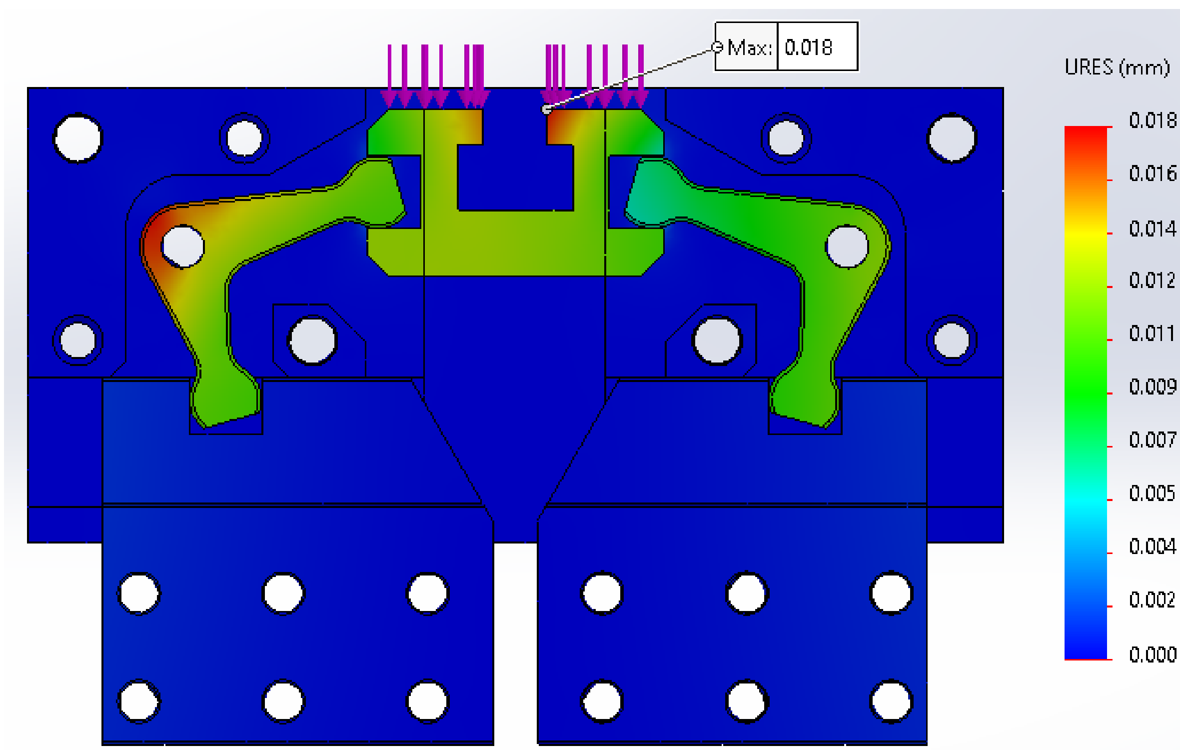


**Figure III.7. Equivalent displacements for the mechanism, contact stress**

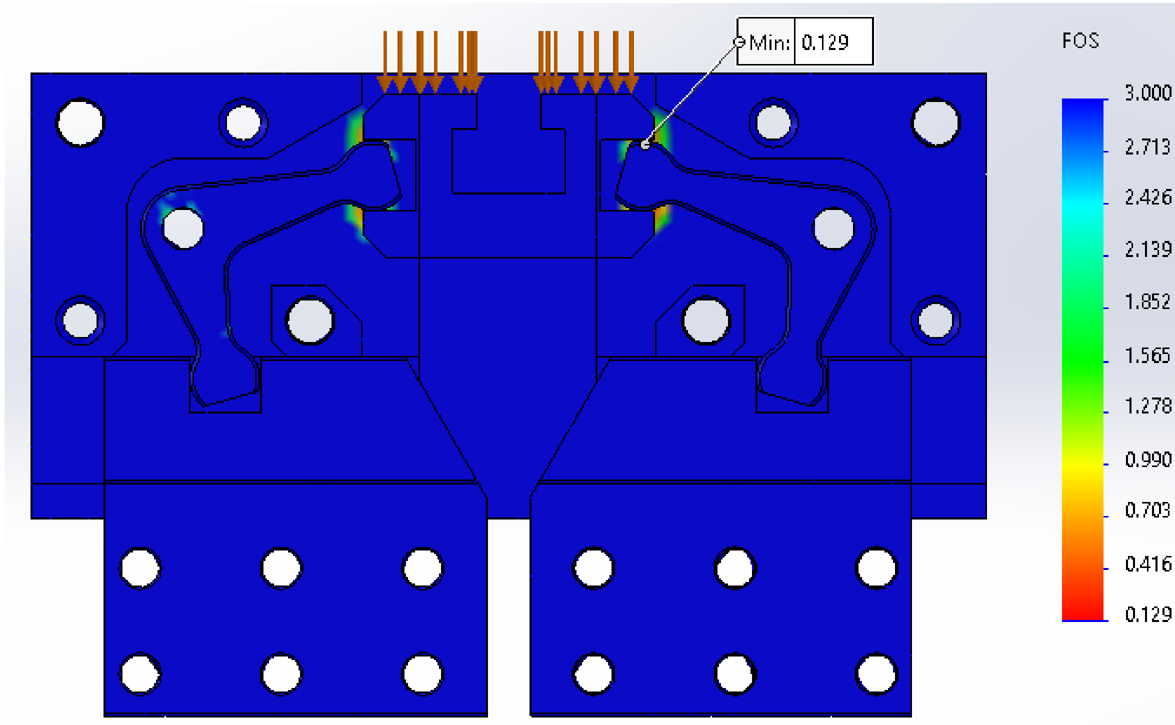


**Figure III.8. FOS factor of safety for mechanism, contact stress**

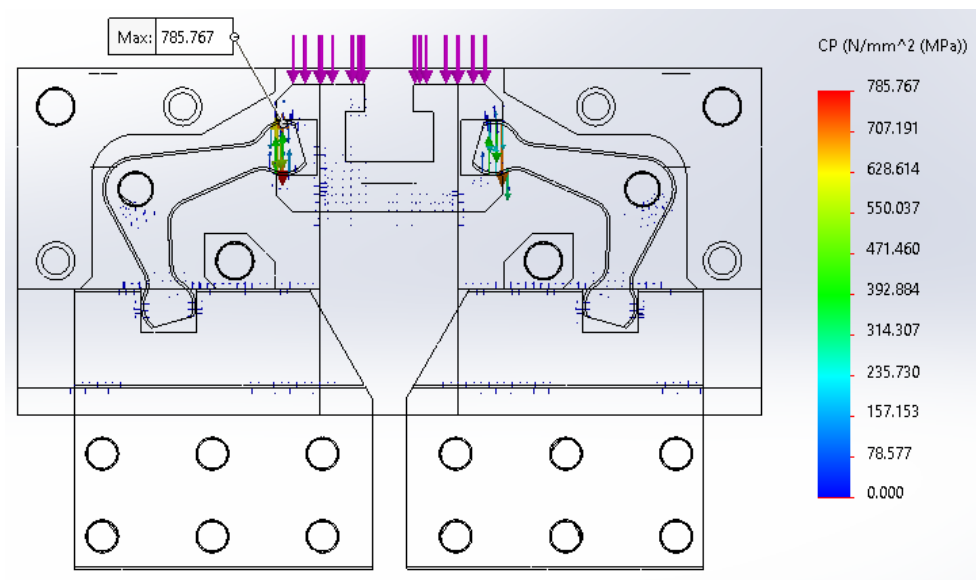


***Figure III.9. Contact pressure between the elements of the mechanism***

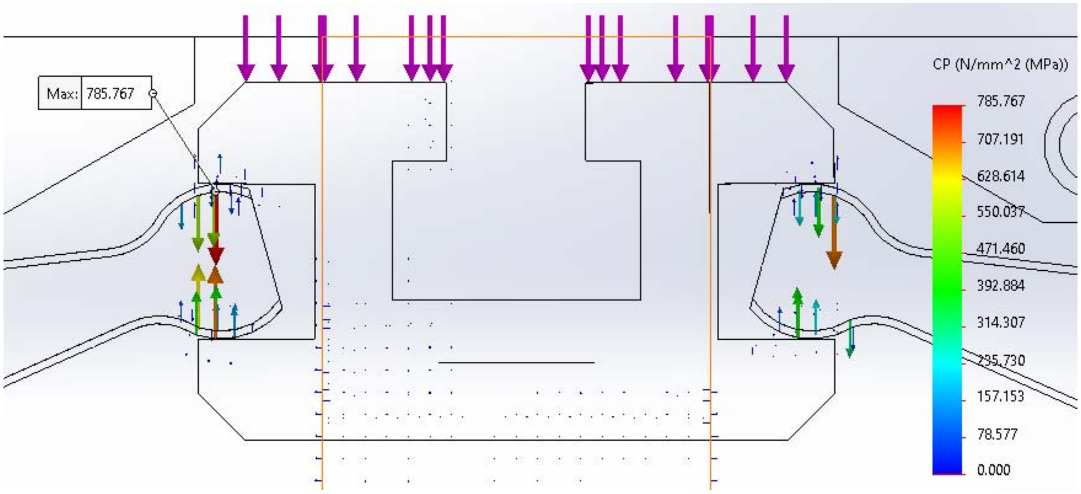


**Figure III.10. Contact pressure between the pin and the lever**

## 4. RESULTS AND DISCUSSION

In the case of the analysis where a force of 10,000 N was applied it was found that:
- the von Mises stresses reach the maximum value (168.64 MPa) at the contact between the pin and the base plate of the mechanism, and the maximum stress at the lever head is 54.76 MPa.
- the equivalent displacements corresponding to the applied force have a maximum value in the pin of 0,039 mm and in the head of the pin of 0,023 mm.
- the lever head presents a risk area because the value of 2.431 is below the factor of safety (3).

In the case of the analysis considering a contact clearance of 0.02 mm, the following was found:
- the von Mises stresses develop to very high values when the parts of the mechanism come into contact, which indicates that fitting or wear clearances are not beneficial;
- the equivalent displacements are smaller than in the case of the analysis in which the three parts are considered to be connected to each other; this leads to the conclusion that we have a better distribution of stresses between the parts due to contact;
- the clearances between the three parts make the factor of safety FOS with a value of 3 more present in all the contact areas, low values are obtained only in the case of the contact between the pin and the levers;
- high contact pressures (785,76 MPa) develop between the ends of the levers and the pin, at the contact between the flat surface of the pin and the cylindrical surface of the lever head.

Therefore, it is necessary to examine other types of materials, steels or steel torques that could mitigate the wear generated by these contact pressures.

## 5. CONCLUSIONS

Following the FEA analysis, important data on critical stresses, deformations at specific points of contact with other components of the bar clamping mechanism were obtained and the FOS factor of safety was investigated for the whole analysed component.

The individual loading of the parts subjected to the virtual loads, in conformity with the real ones, shows that they have a good behaviour, the stresses, deformations and the factor of safety are within the limits established by the characteristics of the materials of which they are made.

## REFERENCES

[1] Lidia Benea – Coroziune și protecții anticorozive de la teorie la practică, Editura Academica 2017

[2] Maria Cristiana Enescu – Tehnologii electrochimice, Ed. Valahia University Press, Târgoviște, 2016

[3] Veteleanu Ana - Protecțiaanticorozivă a materialelor, Editura LuxLibris,Brașov,2000

[4] Zamfir S., - Coroziunea materialelor metalice, EDP, București, 1981

[5] Maria Constantinescu – Protecţia anticorozivă a metalelor, Ed. Tehnică, Bucureşti,1979;

[6] Cristian Caizar – Utilizarea calculatorului în proiectarea constructivă. Solid Works. Universitatea Tehnică din Cluj-Napoca, 2000

[7] Ferguson, S – Practical Algorithms for 3D computer Graphics. AK Peters Natiek, Massachusetts, 2001

[8] Popa Ion Florin, Marin Cornel, FilipViviana – Modelarea și simularea sistemelor robotice, Editura Bibliotheca, Târgoviște, 2005.

[9] Marin, C., Hadar, A., Popa, F., Albu, L. – Modelarea cu elemente finite a structurilormecanice, Editura Academiei şi Editura AGIR, Bucuresti, 2002.

[10]https://www.academia.edu/26052570/Finite_Element_Method_a_practical_course, G. R. Liu, S. S. Quek - The Finite Element Method, A Practical Course,2003