Comparative Study on Metal Coin Cancelling Methods, Using 3D Modelling and FEM Analysis

C C Gavrila[1] and M T Lates[1]

[1]Product Design, Mechatronics and Environment Department, "Transilvania" University of Brasov, Brasov, Romania

E-mail: cgavrila@unitbv.ro

Abstract. Along time, many minted coins were withdrawn from circulation, being replaced with new ones. The returned obsolete metal coins were melted in order to use the alloy for other purpose. Between the withdrawing and melting, some of the metal coins were cancelled by destruction of the original shape and dimension, using some adequate tools. The paper presents some aspects about the cancelling method used on the Romanian old nickel coins. In the first part of the paper, the introductive aspects about the used cancelling methods are presented; also, there are presented some examples. In the paper second part, the simplified 3D model computed for the cancelling dies, respectively the coin, are presented. Then, there are introduced the assembled models, corresponding to each cancelling case, which consist by the obverse and reverse cancelling dies, having the coin inside them. For the each model, the finite element analysis is realized and is achieved for different initial conditions. The final part of the paper presents the analysis results and also the conclusions.

1. Introduction

Many countries around the world have been cancelling the metal coins withdrawn from circulation. Mainly done to prevent the returning into circulation, the metal coin cancelling (or metal coin defacing) consisted in destruction by pressing the coin between different patterns dies [1]: lines, circles or other figures; this metal coin cancelling figures are also known in literature as waffle design [2]. Some of metal coins were canceled by perforating holes. Usually, the cancelling was followed by the melting, in order to recycle the coin metal content. But, for different reasons, some of these canceled coins had come to the collectors market: due to the piece state and rarity range, some are most valuable than other.

The literature indicates a lot of cancelled coins from different countries, as United Kingdom, Germany, United States, Malaysia, Philippine and others [2]. In Europe, the introduction of euro currency generated a large hoard of cancelled coins, provided by the former currency of the involved countries. For commercial purpose, some of them are presented in lots or sealed numismatic sets and are highly appreciated by collectors; as example, in figure 1, there is presented a coin set containing the canceled coins of Belgium former franc. After the euro currency introduction, some of its metal coins were defaced because of their inconsistent manufacture or eventually deterioration; these pieces are also recorded by the specialty catalogues or internet sources [3, 4].

In Romania, the metal coin cancelling was introduced by authorities in the interwar period, and was applied on some withdrawn coins, but also on the discovered coin fakes, to prevent their reintroduction into circulation [5].

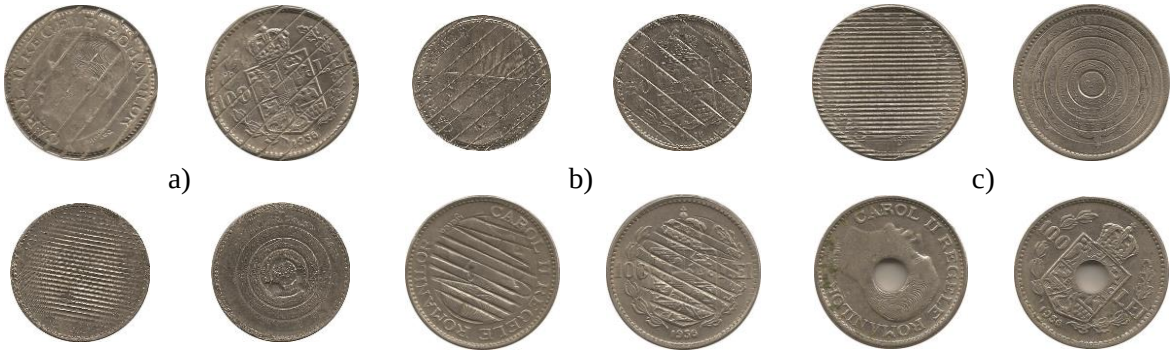
Figure 1. Canceled coin numismatic sets

In figure 2 there are presented some canceled Romanian coins: a counterfeit 100 lei from 1932 (figure 2, a, which imitates the original made by silver), a perforated withdrawn silver 100 lei from 1932 (figure 2, b), and also, silver 250 lei from 1935 (figure 2, c).

a) b) c)

Figure 2. Various cancelled Romanian metal coins

But the most known Romanian coins that have been canceled are the nickel coins of 50 and 100 lei, minted between the years 1936 – 1938. These coins were circulated until 1941 when, due to the country political changes and, also, the war out breaking, were withdrawn from circulation. Their metal, fine nickel was considered important to supply the war industry needs and these obsolete coins had to be returned and replaced by other currency [6]. In order to prevent the reintroduction into circulation, it was provided by the law their cancelling, supposed to be realized by those companies who indented to recycle the metal [6].



a) b) c)

d) e) f)

Figure 3. Various cancelled Romanian nickel coins

As a result, today the literature [1, 2, 7] records a large number of cancelled 50 and 100 lei nickel coins: having parallel lines impressed on both faces (as in figure 3, a and b), circles and fine parallel lines (in figure 3, c and d), inscriptions (in figure 3, e, on both faces “ANULAT”) or hole perforated

(figure 3, f). Some of those cancelling methods were previously used on other Romanian coins, as presented in figure 2. Also, it has to be mentioned that the recorded cancelling pattern fits both coin sizes, 24 millimeters for the 50 lei coin, respectively 27 millimeters for the 100 lei coin.

Following the coin cancelling cost decreasing, the same cancelling design was more or less deep manufactured: since on the well cancelled coins the original model is hard recognizable, on the less cancelled, the coin model is almost unaffected by the applied canceling method. Also, the coin position between the cancelling dies was random. It's also true that, the coins were canceled in different places, using different tools and pressing machines. The mentioned manufacturing conditions led to some questions about what caused some particularities of a cancelling pattern or another and which was the most productive. So, the real motivation behind one or another used cancelling pattern may be revealed and also, the subjected pieces market value can be adequate estimated.

2. Computing the virtual model

As previously presented, there are different types of patterns on cancelled 50 and 100 lei coins: the same parallel lines or inscription applied on both coin faces, respectively fine parallel lines applied on one face and concentric circles on the other face. Each studied model will contain as parts, the both coin face cancelling dies and also the coin. Since the cancelling dies have a simple pattern to be computed, the subjected coins present some multiple complex details which cannot be faithfully reproduced on the virtual model. So, a coin simplified model will be elaborated for the 100 lei coin, having represented on both faces just the main contour from the properly model. Taking account of this it follows, for all needed parts, the virtual model computing, using the CATIA software, module Part Design [8, 9].

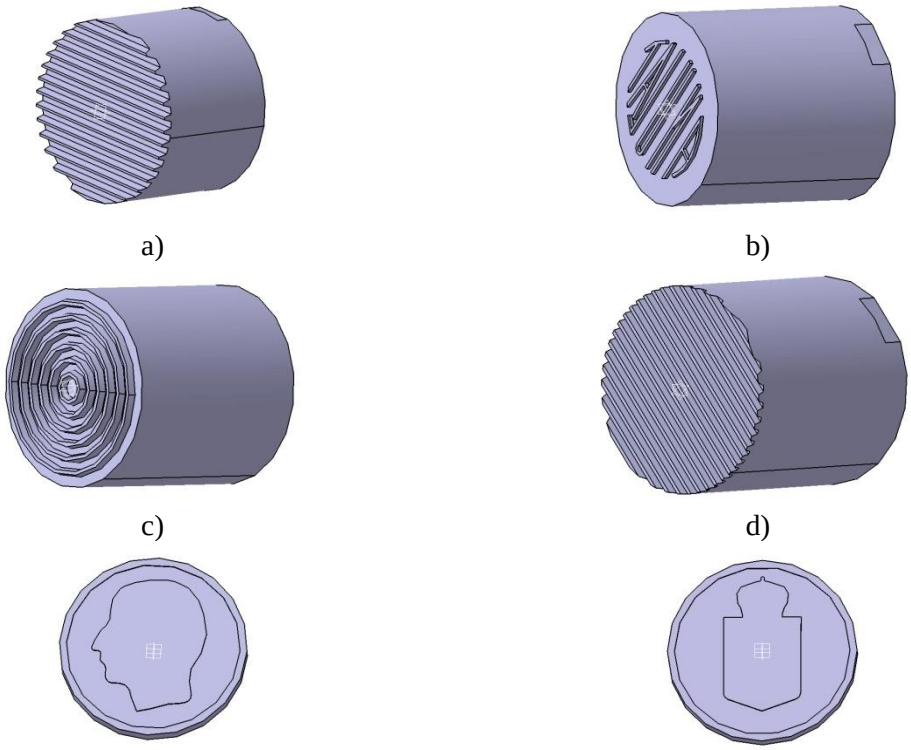
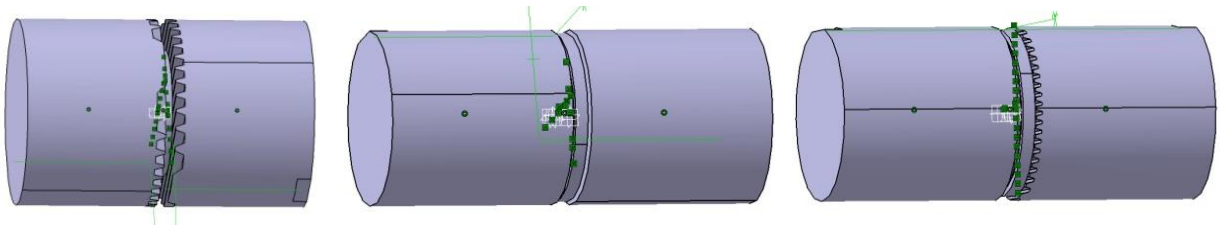


Figure 4. The 3D model parts



a) b) c)

Figure 5. The cancelling dies contact surface with coin

Each cancelling die model consist in a cylinder having engraved the pattern negative contours (figure 4, a, b, c, and d); between the dies the coin is introduced (figure 4, e, and 5). It has been noticed that, the coin obverse-reverse angle is 180^0.

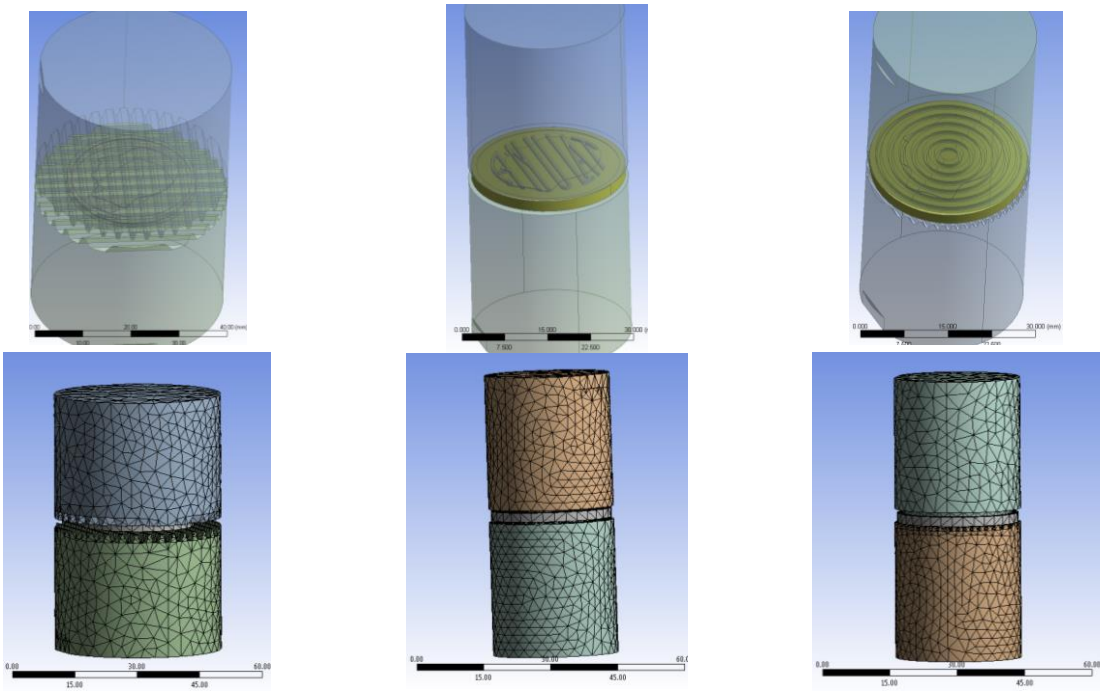
Then, using the Assembly Design module, the devices assembly are computed. Following the real first striking contact surface between the dies pattern and coin faces, the ensemble adequate constraints are defined. The defined contact area between the cancelling dies and coin covers the entire model highest common area, situation possible in the presumption when there are no the misalignments inside of the pressing machine and the relief is plan [10, 11]. For the first and second ensemble models (figure 5, a, and b), corresponding to the both faces parallel lines and, respectively, both faces inscription; the cancelling dies are positioned in the model to obtain the real pattern position, when the obverse-reverse angle between lines or inscription is 90^0. For the third ensemble model (figure 5, c), corresponding to the fine parallel lines on one face and concentric circles on the other face, the cancelling dies position in the model is not relevant.

3. Finite element analysis, simulation and results.

For the analysis, the ANSYS software is used. The analysis objective is to determine the pressed cancelling dies on the coin ensemble behaviour under the load. For the analysis, the previous virtual assembled models are used. In following figure, there are presented the obtained finite element model view and geometry, computed for all three studied cases (figure 7, a for the model having on both faces parallel lines cancelling pattern, figure 7, b for the model having on both faces inscription "ANULAT", and, respectively, figure 7, c for the model having as cancelling pattern fine parallel lines on one face and concentric circles on the other face).

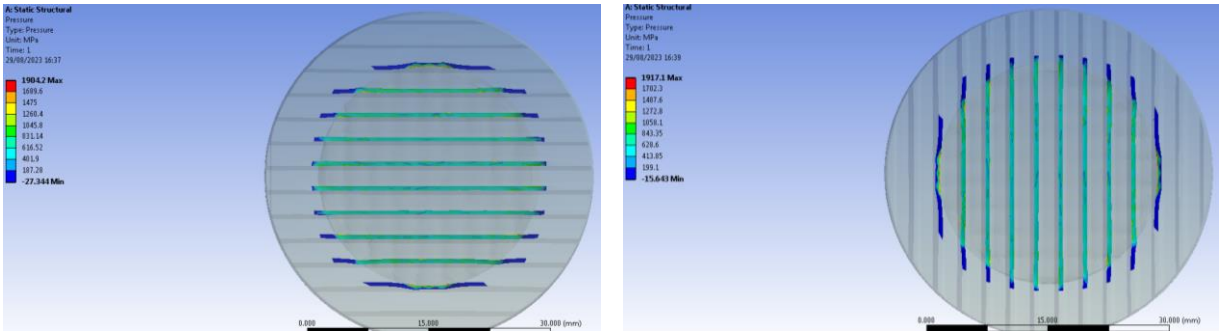
The chosen material for cancelling dies is hardened steel respectively, for the coin is nickel. The material properties as Young modulus, Poisson coefficient, Tensile Yield Strength, Ultimate Strength should be defined [12, 13]. In the contact area it is chosen a smooth mesh with the minimum edge length equal with 0.001 mm. Taking account that the cancelling dies doesn't form a closed space around the pressed coin, the literature indicates that, the chosen coin material allowable stress should be decreased by 30-50%, related to the value corresponding to the closed space coin striking [14]. The applied normal force is equal with 60KN, in order to obtain high contact pressures, over the coin blank material allowable stress – 1000 MPa [5, 14, 15].

The results, presented in figures 7 to 12 and also in table 1, consist in the contact pressure maximum values and also the penetration maximum values on the each cancelling die material. The obtained values presented should be considered as relative values, to be used to compare the different studied cases.



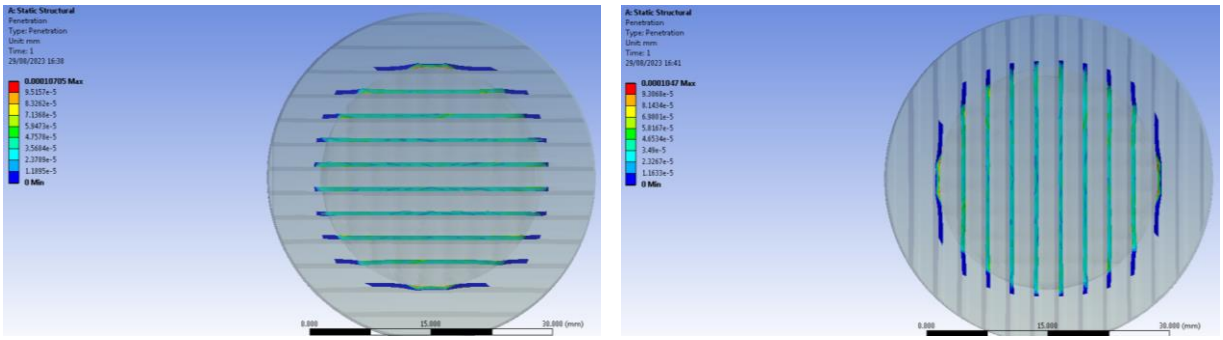
a) b) c)

Figure 6. The finite element model



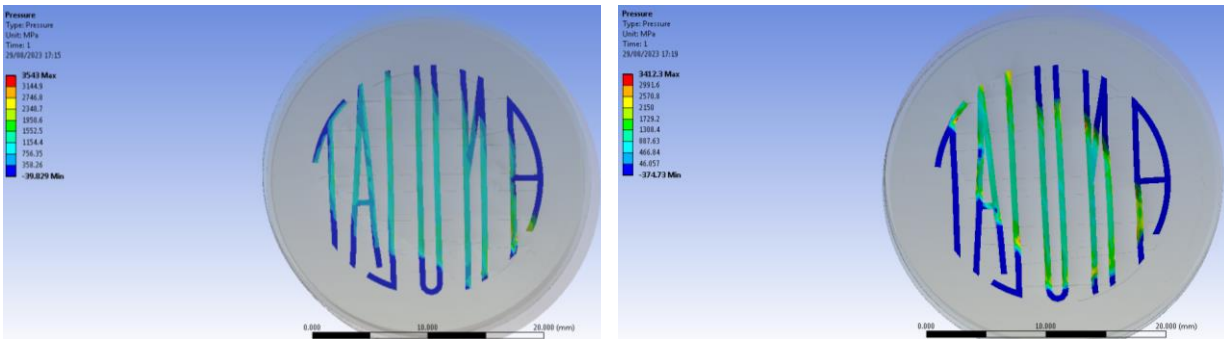
a) on coin obverse b) on coin reverse

Figure 7. The contact pressure on the parallel lines cancelling dies



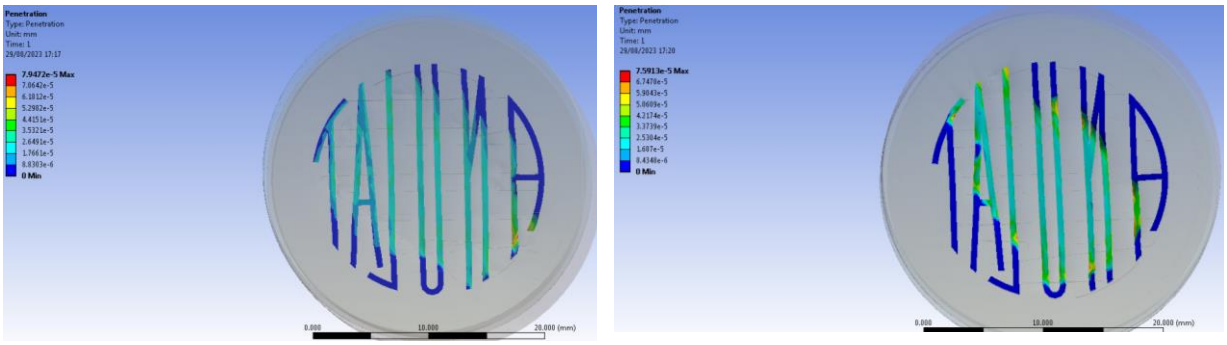
a) on coin obverse b) on coin reverse

Figure 8. The penetration on the parallel lines cancelling dies



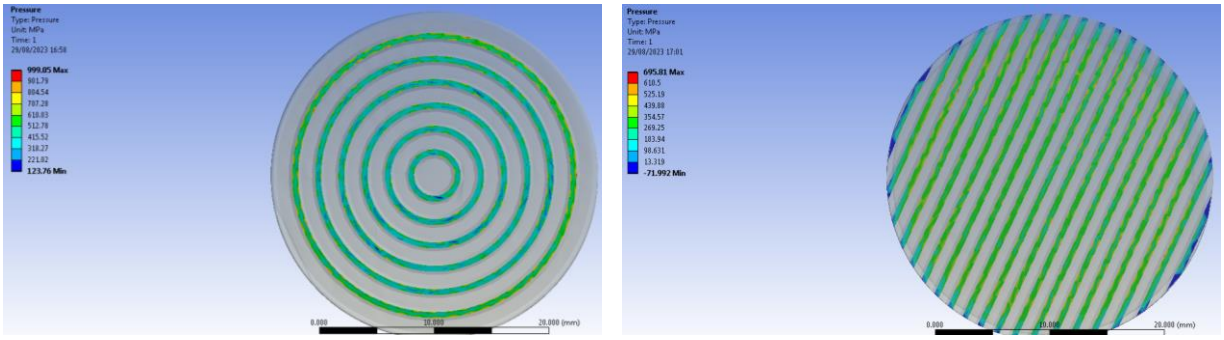
a) on coin obverse b) on coin reverse

Figure 9. The contact pressure on “ANULAT” cancelling dies



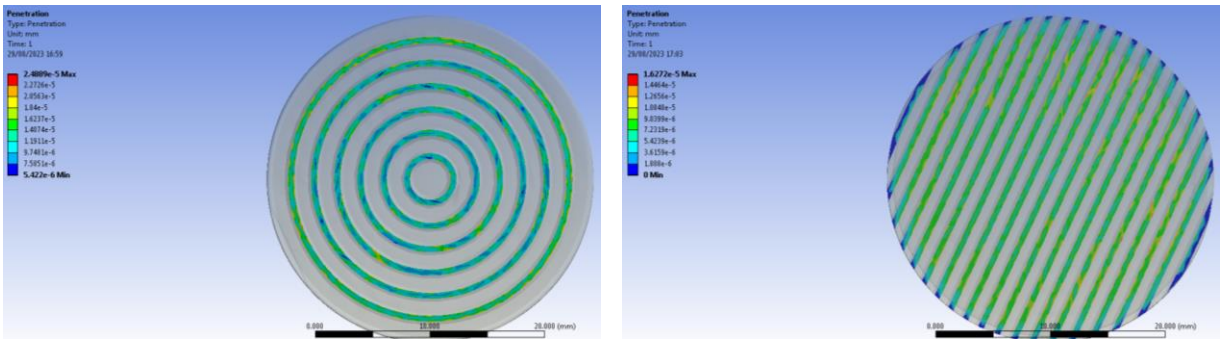
a) on coin obverse b) on coin reverse

Figure 10. The penetration on “ANULAT” cancelling dies



a) on coin obverse b) on coin reverse

Figure 11. The contact pressure on the concentric circles and fine parallel lines dies



a) on coin obverse b) on coin reverse

Figure 12. The penetration on the concentric circles and fine parallel lines dies

Table 1. The contact pressure and the penetration on cancelling dies, maximum values, for loading case 60 KN

The cancelling dies	Contact pressure, MPa		Penetration in the material, mm	
	Coin obverse cancelling die	Coin reverse cancelling die	Coin obverse cancelling die	Coin reverse cancelling die
On both faces, parallel lines	1904.2	1917.1	0.00010705	0.0001047
On both faces, inscription “ANULAT”	3543	3412.3	0.000079472	0.000075913
Concentric circles on coin obverse combined with fine parallel lines on coin reverse	999.05	695.81	0.000024889	0.000016272

4. Conclusions

For the first studied model, having on both faces the similar parallel lines cancelling pattern, the related contact pressure maximum values are close each other; small differences are caused by different represented contours shape on the coin obverse and also reverse. For slightly increased contact area, the contact pressure maximum values are slightly decreasing. It can be observed that, those maximum values are recorded close to the coin outer edge. The other values appear in the main contact area and exceed the coin material allowable stress. The penetration maximum values are also recorded near the coin outer edge and are close for both obverse and reverse cancelling pattern dies.

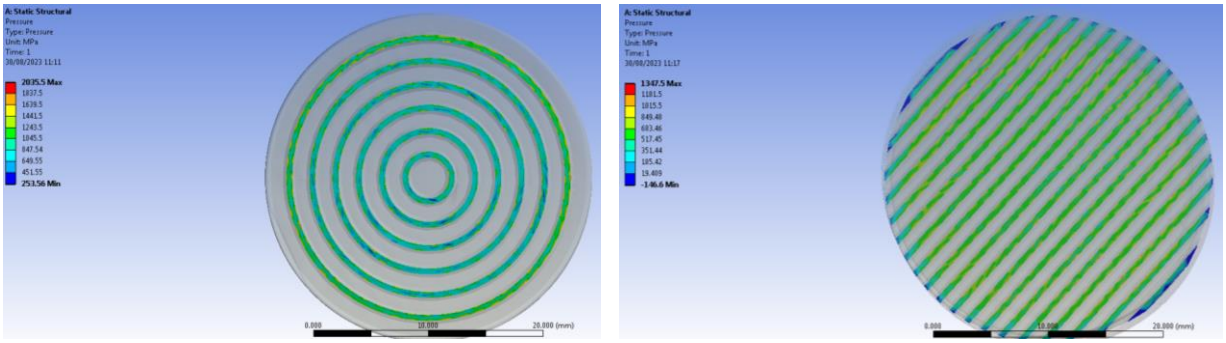
For the second model, having on both faces on both faces inscription “ANULAT”, the related contact pressure maximum values are close each other; also here, small differences are caused by different represented contours shape on the coin obverse and also reverse. Because the cancelling dies are smaller than the coin outer ring, it can be observed that, the maximum values are recorded close to the each face model edge contour; due to the coin material stiffness along the applied load direction, the faces contours are influencing each other the contact pressure in the contact area. The other values appear in the main contact area and exceed the coin material allowable stress. But some of the contact pressure values exceed also the dies material allowable stress; so, the dies are damaged. This led to the conclusion that, this type of cancelling was applied on small pressing machines manually operated. The penetration maximum values are also recorded near the coin outer edge, and are close for both obverse and reverse cancelling pattern dies.

The third model has as cancelling pattern concentric circles applied on coin obverse and fine parallel lines applied on the coin reverse. The different pattern applied on coin faces has as main result important differences given by the contact area; in this case, the coin faces model differences are less important. The decreased area under the circles pattern led to increased contact pressure maximum values and, also, the increased area under the fine lines pattern led to decreased contact pressure maximum values. Since the circles pattern is close to exceed the coin material allowable stress, the fine lines pattern is so far lower than this. The penetration maximum values have the same trend: for circles pattern the value is higher than for fine lines pattern. It can be concluded that, the load value, 60 KN, was not adequate for this cancelling method. The needed had to be obtained from a different bigger pressing machine.

Consequently, this model was again simulated for an increased load, 120 KN [5, 14, 15]. The results are presented in figures 13 and 14 and also in table 2. The increased load led to increased contact pressure and penetration maximum values, but, due to the different contact area, the differences between the obverse and reverse values are maintained. The contact pressure on the fine line pattern finally reaches the level to exceed the coin material allowable stress. But in the same time, on the circular pattern die the values are more increased, over the dies material allowable stress. So,

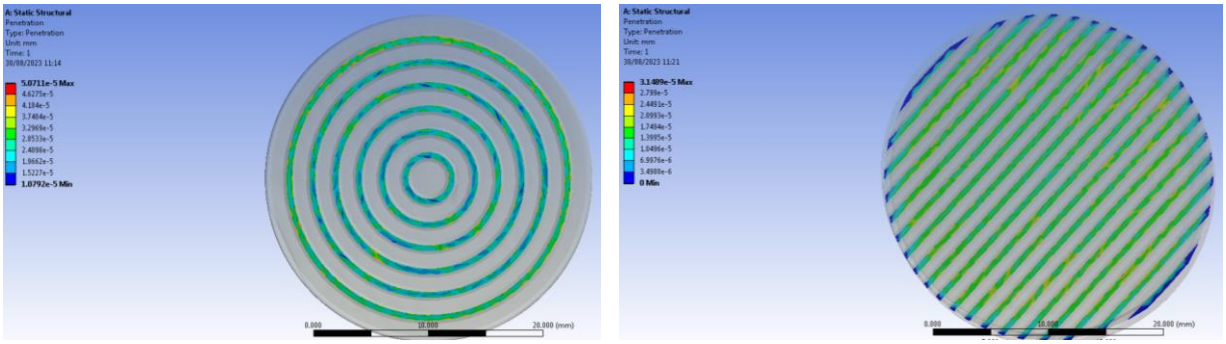
the circular pattern die is subjected to be damaged. This explains why some of the coins cancelled with this pattern type present die cracks on circles devaluated face.

Overall, the studied models indicate that, the coin cancelling was made on different pressing machines type. These generated different load, not necessarily well adapted to the used cancelling method. Since the similar used pattern used for both coin faces assured a longer dies lifetime, the different patterns used on the coin faces led to the destruction of the overloaded die.



a) on coin obverse b) on coin reverse

Figure 13. The contact pressure on the concentric circles and fine parallel lines dies



a) on coin obverse b) on coin reverse

Figure 14. The penetration on the concentric circles and fine parallel lines dies

Table 2. The contact pressure and the penetration on cancelling dies, maximum values, for loading case 120 KN

The cancelling dies	Contact pressure, MPa		Penetration in the material, mm	
	Coin obverse cancelling die	Coin reverse cancelling die	Coin obverse cancelling die	Coin reverse cancelling die
Concentric circles on coin obverse combined with fine parallel lines on coin reverse	2035.5	1347.5	0.000050711	0.000031489

References

[1] Buzdugan G Luchian O and Oprescu C C 1977 Romanian Coins and Banknotes (Monede şi bancnote româneşti) *Editura Sport Turism* Bucureşti (in romanian) pp 256 - 259.

[2] Snyder B 2004 World Mints Deface Coins With “Waffle Designs” *Mint Errors News* ***5*** Mike Byers, USA p 10.

[3] *** 2007 Euro 4, Coins and Banknotes (Euro 4, Monnaies et Billets), *Edition Les Chevau-Lègers* Paris France (in french) p 205.
[4] https://www.error-ref.com/canceled-waffled/, accessed on 20.09.2023.
[5] *** 1945 Finance Ministry, National Mint, Ten Years of Activity (Ministerul Finanţelor, Monetăria naţională. Zece ani de activitate) *Monitorul oficial şi Imprimeriile statului* Bucureşti (in romanian) pp 81 - 87.
[6] *** 1941 The Official Monitor of Romania (Monitorul Oficial al României), no.189, part I. *Monitorul oficial şi Imprimeriile statului* Bucureşti (in romanian), pp 4708-4709.
[7] https://romaniancoins.org/, accessed on 20.09.2023.
[8] Ghionea I G 2009 CATIA v5. Application in Mechanical Engineering (CATIA v5. Aplicaţii în ingineria mecanică) *Editura Bren* Bucureşti (in romanian).
[9] Ghionea I G 2021 CATIA v5. Parametric Design and Programming Applications (Aplicaţii de proiectare parametrică şi programare), *Editura Printech*, Bucureşti (in romanian).
[10] Gavrilă C C and Lateş M T 2020 3D Modelling and FEM Analysis on Die Clash Mint Error *IOP Conf. Ser.: Mater. Sci. Eng.* **898** 012040 pp 1 – 7.
[11] Hilbert H 1938 Punching technique (Stanzereitechnik) Part I *Carl Hanser Verlag* Munchen (in german) p 14, 196.
[12] Lateş M T 2008 Finite Elements Method. Applications (Metoda elementelor finite. Aplicaţii) *Editura Universităţii Transilvania Braşov* (in romanian).
[13] Lee H H 2012 Finite Element Simulations with ANSYS Workbench 14. Theory, Applications, Case Studies. *Schroff Development Corporation* Kansas USA.
[14] Iliescu C and Tureac O 1987 Cold Pressing Technology (Tehnologia presării la rece) *Editura Universităţii din Braşov* (in romanian) pp. 262 - 267.
[15] Gavrilă, C. C., Lateş, M. T. 3D Modelling and FEM Analysis on Holed Metal Coin Striking Die Mint Error, *IOP Conf. Ser.: Mater. Sci. Eng.* **1256** 012001, 2022.