3D Modelling and FEM Analysis on Die Clash Mint Error

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Abstract. During the last century, a large number of modern coins which wearing different error types were minted and released. In literature, there are known various error types, each is provided by some causes, as the coin metal, the coin dimension and also the manufacturing step where it could appear. The die clash error appears when the striking tools – the obverse and reverse negative dies - heat each other without the coin blank inside them. The paper presents the influence of some initial condition on the amplitude of this error, as the die size, the model flat field size or the model shape. In the first part of the paper, some introductive aspects of the die clash error are presented with some particular examples. Then, the obverse and reverse die 3D model is presented, followed by the finite element analysis, which is realized and achieved for considered initial conditions. In the final paper part, the analysis results and conclusions are presented.

1. Introduction

Striking metal coin currency is followed in most of the situations by a various amount of error types. These error types could appear on every coin's manufacturing step: at the coin metal alloy manufacture, on the blank coin manufacture, at the striking tools manufacturing, or at the properly coin striking. Usually, when the errors appear on dies, the model is slightly changed, and the pressed coins will result in the changed model with an error. As for collecting value, for increased spectacular error on coin or medal, the value for the subjected piece is increased [1, 2]. We consider that, from this point of view, it is important to know which of the initial coin strike conditions could influence some error to become more valuable.

The metal coins are manufactured by pressing at high loads the coin blank with hardened steel negative obverse and reverse dies. The both negative dies relief (composed by properly incused figures surrounded by flat field) forms a closed space to be filled by the coin material [3, 4]. These negative dies are obtained before hardening, by pressing with a hardened steel positive die with the relief model. Since the model on the negative die is incused, after the striking, result of the relief model on the coin.

If the coin blank fails to get into the striking space between negative dies, die clash occurs; then, the dies could hit each other. Generally, the dies are adjusted so that, at their closest approach, there is still a minimum clearance between them, even in the absence of a coin blank. There are a lot of situations when the dies are out of adjustment, and direct contact between them appears. In this situation, each die leaves a light or deep impression of some portions of its design on the opposing die. The die negative most vulnerable model's areas to the die clash are the closest areas from the die face. The flat face field around the model and the shallowest recessed on the die face are included; at striking, these led to the areas of lowest relief on the coin. The basic model, together with these impressions is pressed, as a mirrored image, to strike coins. These coins, which wear the incuse design elements are known as clash die error coins [2]. The most types of die clash errors coins have reduced diameter and especially thin blank; rarely, the die clash error could appear also at some increased size coins. Also, the die clash could appear once, when the traces impressed are single, or multiple, when the traces are also multiple. For multiple traces, these could be offset and close each other, when the dies maintain the same position during strike, or far each other, rotated, when major misalignments appear.

The dies clash error is known at various Romanian and foreign modern coins [2, 5]. As is presented in examples from figure 1, the negative impressions appear on the coin face flat field, which is the lowest relief on the coin. Most of these impressions could be observed near exterior coin rim, around the effigy or country arms, or inside the effigy or country arms, if there are some lowest than field relief portions as ears, eyes or shield hatches. It has to be mentioned that, these negative impressions are rarely on the entire coin face field, as is presented in figure 1, a, on a 2 bani coin issued in 1900. Usually appears on both coin faces, on a portion which is combined with the other face corresponding portion, as in figure 1, c, on a 500 lei coin, issued in 1944. Other found examples, where one face wears on a portion these impressions, are presented in figure 1, b, for 1 leu coin, issued in 1941, and, respectively, in figure 1, d, for a 3 lei coin, issued in 1966.

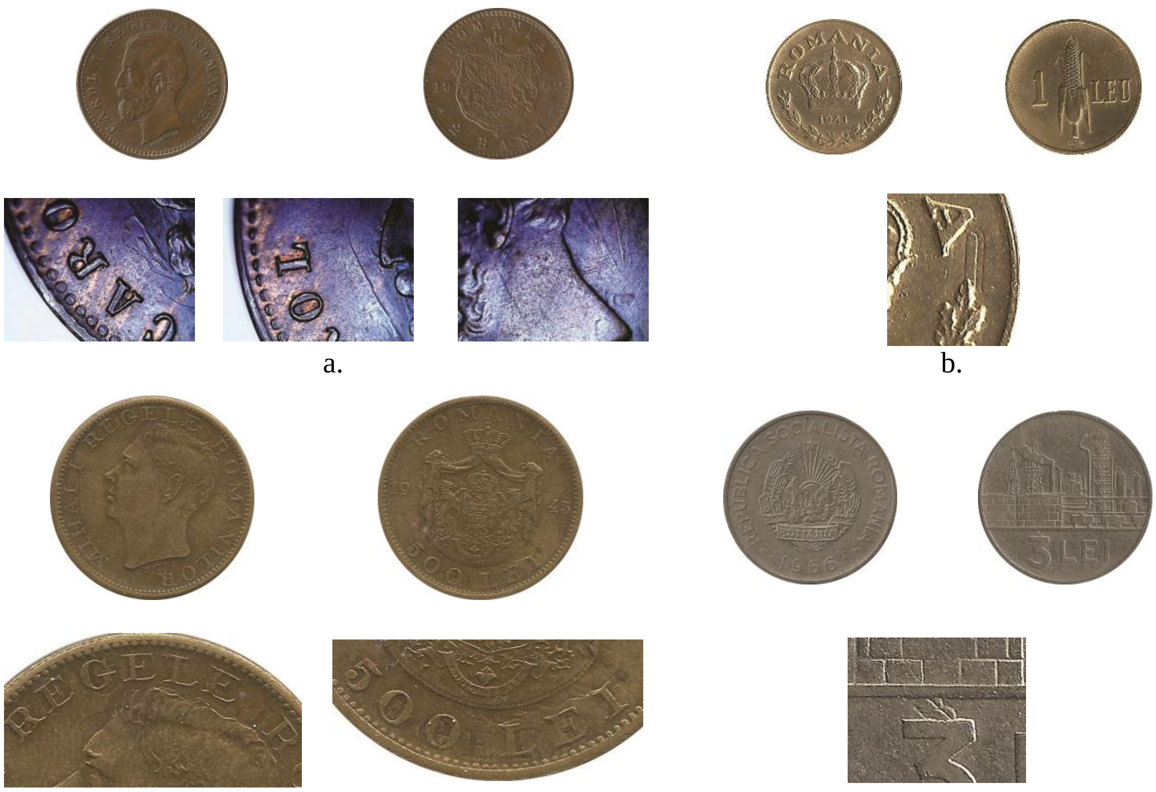


Figure 1. Various types of die clash error on coins

Some of the position of these negative impressions can be combined with the coin face basic design, resulting some interesting representation as effigy with wrinkles, tears, glasses and more others, desirable for private collections [6].

The traces left on the dies are given by the contour edges portion which touches each other. The combination of this traces are given by some design details, as the figures to be impressed on coin, but also by the dies position: medal position - when the obverse-reverse angle is 0^0 (example presented in figure 1, d), or coin position - when the obverse-reverse angle is 180^0 (the other examples from figure 1). In the literature, the side wearing the effigy face is considered the obverse and the side wearing the country arms, reverse [5, 6]. Another important detail consists in the flatness of the face field around relief contour edges. The reference case is to be considered as a plane surface; in the real case, due to some dies constructive reasons, could be slightly concave or convex [4]. In figure 2, there are presented the contours and traces defined by the dies model, for obverse-reverse medal position. In this example, the contact area between dies covers the full field common area, situation possible in the presumption when, there are no the misalignments inside of the pressing machine and the face field is plan [7]. Otherwise, the contact area is decreased. It can be observed that, depending by the coin design, the obverse flat field area (composed by red and green portions) is increased than the reverse (composed by red and blue portions).

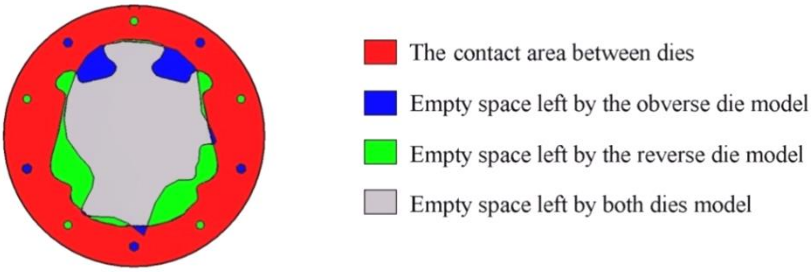


Figure 2. The clash dies contours and traces

2. The dies virtual model

As was presented, on a coin face, there are multiple complex details, as figures and also letter and number inscription. On a virtual model, these details cannot be faithfully reproduced. So, simplified models should be computed for study, using the CATIA software [8, 9].

a. b.

Figure 3. The dies 3D model

The each die simplified model consist in a cylinder with engraved model on top face. For obverse die model, presented in figure 3, a, an incused effigy contour is represented and some exterior ornaments; for reverse, presented in figure 3, b, an incused arms contour and also exterior ornaments. The considered exterior diameter for both dies is 30 mm. After the sketching of the parts, it follows the each part's virtual model computing, using the Part Design module. Using the Assembly Design module, the assembly is computed, following the corresponding constraints. As load, the dies will be pressed each other on the incused relief face. The dies model are presented in figure 3.

3. Finite element analysis, simulation and results.

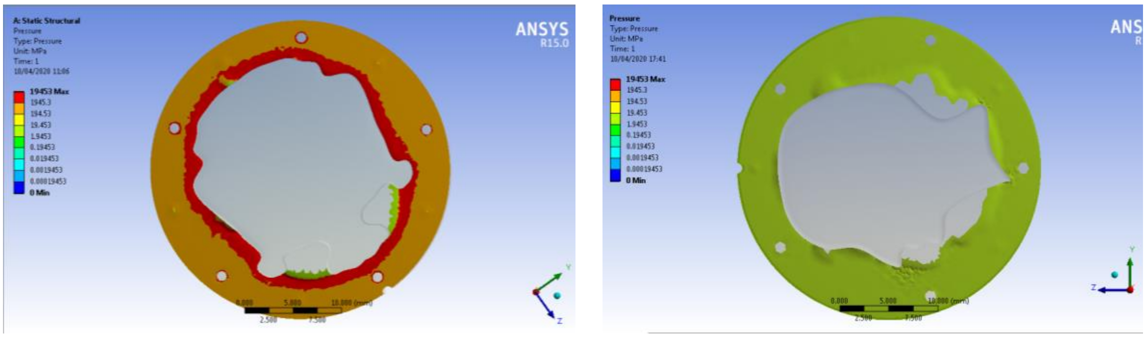
For the analysis, the ANSYS software is used. The analysis objective is to determine the pressed dies ensemble behaviour under the load. For the analysis, the simplified version of the virtual model is used, as is presented in figure 4, a, b. The considered material for dies is steel; the properties as Young modulus, Poisson coefficient, Tensile Yield Strength, Ultimate Strength should be defined [10, 11].

In the contact area it is chosen a smooth mesh with the minimum edge length equal with 0.001 mm. The applied normal force is equal with 650 KN, in order to obtain high contact pressures, over the allowable stress – 1600 MPa [3, 11].

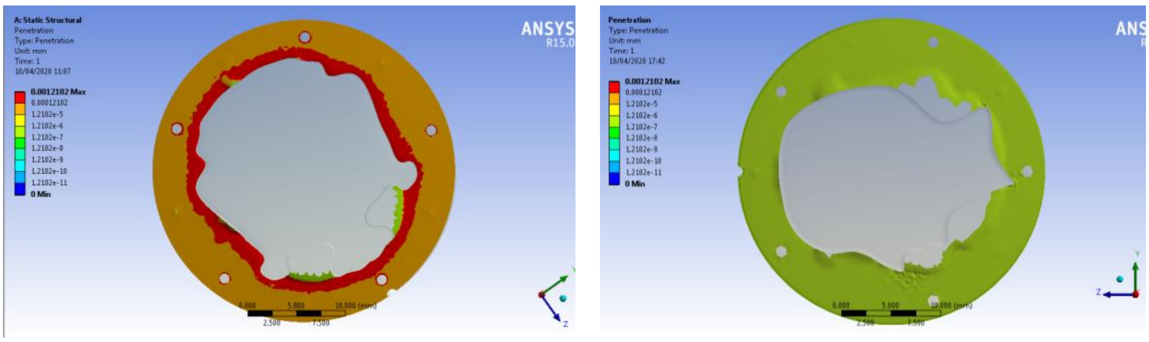
a. b.

Figure 4. The finite element model

The first studied case is when the negative dies contact is defined by entire plan face field common area. The results, presented in figure 5, a, b, and also in table 1, consist in the contact pressure maximum values and also the maximum values of the penetration in material.

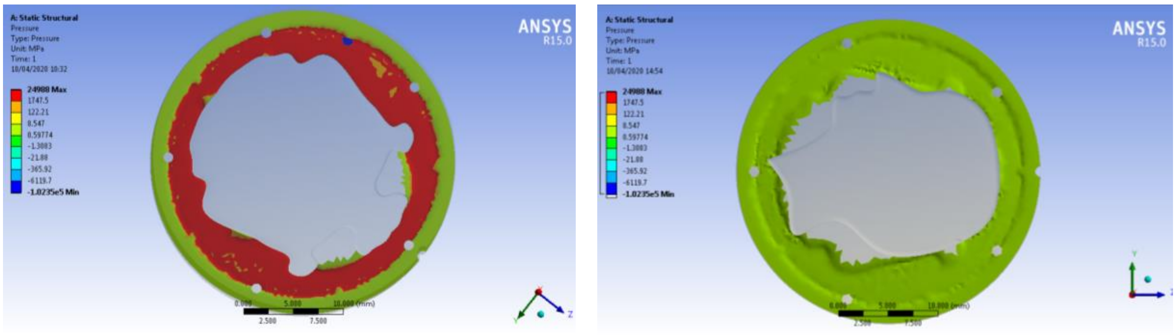


a.

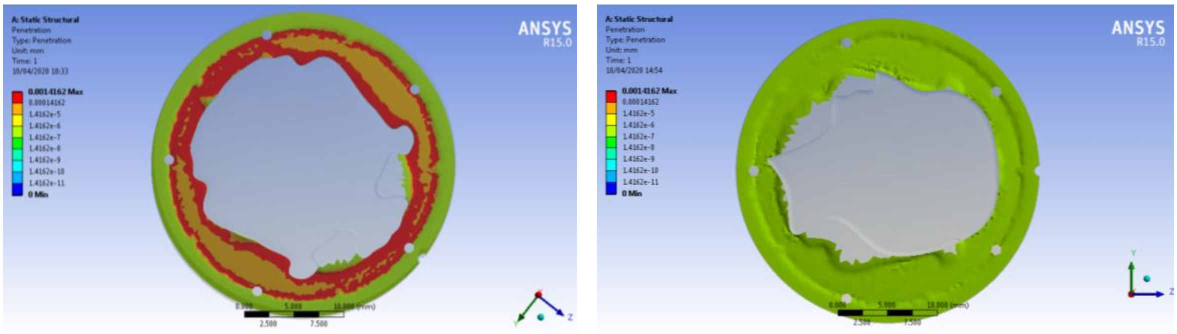


b.

Figure 5. Contact pressure and penetration in material, first dies contact case

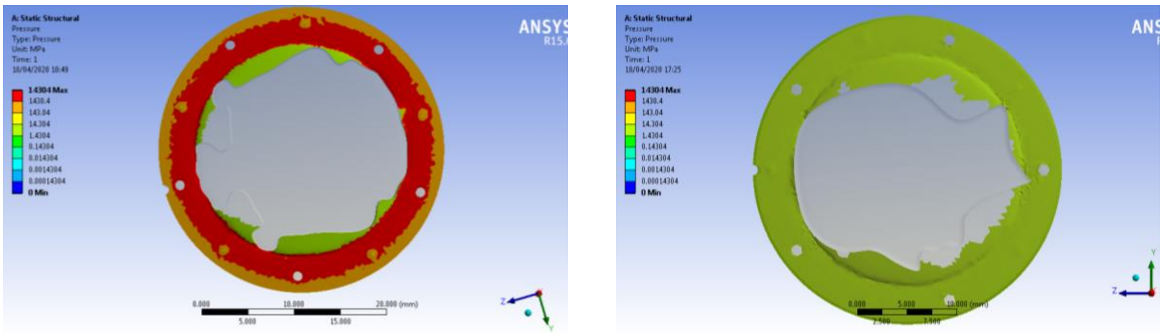


a.

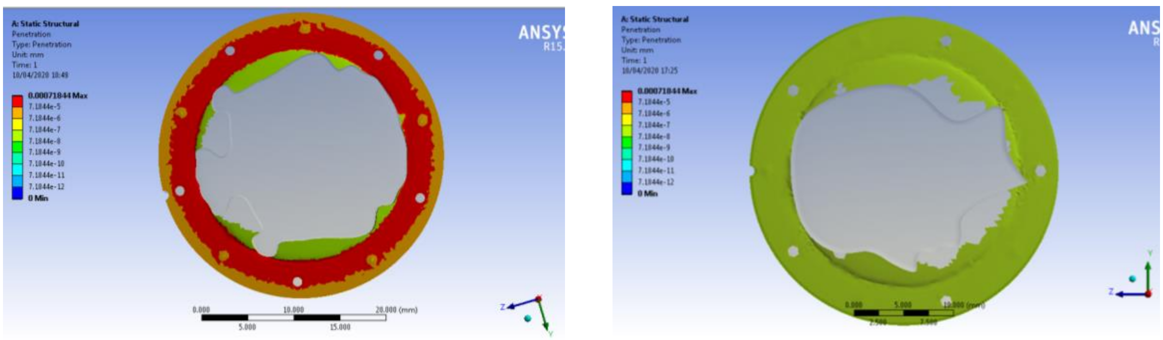


b.

Figure 6. Contact pressure and penetration in material, second dies contact case



a.



b.

Figure 7. Contact pressure and penetration in material, third dies contact case

The second studied case is when the face field is convex for both dies. The contact area is considered defined by common plan surface surrounding the relief contour. The results, the contact pressure maximum values and also the maximum values of the penetration in material are presented in figure 6 a, b, and table 1.

The third studied case is when the face field is concave for both dies. The contact area is considered defined by common plan crown circle surface, exterior bordering the die field surface. The results, the contact pressure maximum values and also the maximum values of the penetration in material are presented in figure 7, a, b, and table 1.

4. Conclusions

In the plane field case, when the dies are pressed each other, the first contact appears on the full field common area. The negative contours are impressed each other and the maximum contact pressure and penetration are on this contour edge. Due to the material rigidity, deformation and also the reverse flat field decreased area, the reverse side is more loaded than the obverse.

In the convex field case, the first contact appears on the incused model contour and surrounding plane area. The maximum contact pressure and penetration are on this contour. The each other impression begins on interior incused relief contour; the margin relief contours, close to the die exterior edge are not impressed. As in previous situation, the reverse side is more loaded than the obverse. This case has the worse condition on clash die, but for its behaviour at striking coins, in literature is considered the most desirable [4].

In the concave field case, when the first contact appears on the field exterior plan area, the maximum contact pressure and penetration are on this contour. The each other impression begins on this exterior contour, close to the die exterior edge; the interior relief contours are not impressed. Also here, as in previous situations, the reverse side is more loaded than the obverse. The maximum values of the contact pressure and penetration are lowest than to the previous cases; in literature is considered to be avoided for striking coins [4].

From the pressure and penetration variation it can be observed that, besides the traced contour on the die field, appear a deformation on the flat surface in the contact area. In all studied cases, due to the material rigidity, deformation and also to the flat field size, the effigy contact area resist better than the coat of arms contact area. This could explain the different die clash impressed traces: deep on one coin face and light on the other, in some coin cases and, respectively, both coin faces similar impressed, deep or light, on other coin cases.

If the appearance of this error is combined with some misalignments inside the pressing machine, this led to decreased die clash contact area and worse conditions. So, the obtained values presented in table 1 should be considered as relative values, to be used to compare the different studied cases.

Despite of the more or less spectacular traces impressed by dies on the coins at striking, repeated die clash could lead to the dies destruction.

Table 1. The contact pressure and the penetration in dies material, maximum values

The considered contact between dies	Contact pressure, MPa	Penetration in the material, mm
Full field plan contact area	19453	0.0012102
Convex face field, contact surrounding the relief contour	24988	0.0014162
Concave face field, contact on the exterior crown circle	14304	0.00071844

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