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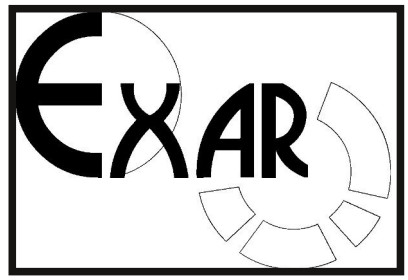

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About the relationship of the coin image and the engraving tools

Matthias Bruestle

Zusammenfassung – Über den Zusammenhang zwischen Münzbild und Gravurwerkzeug. *Durch praktische Stempelgravur und den Vergleich mit originalen vor-neuzeitlichen Münzen wurden Erkenntnisse über den Zusammenhang von Werkzeug und Münzbild gewonnen. Werkzeuge hinterlassen charakteristische Spuren auf dem gravierten Stempel und damit der Münze, sodass man von der Münze auf das Werkzeug schließen kann. Dies sind z. B. Stufen in gemeißelten Linien oder Materialverdrängung und das Wiederholen von Mustern bei der Verwendung von Punzen. Außerdem hat es einen Einfluss auf das Münzbild, ob der Stempelschneider den Münzstempel direkt bearbeitet oder diesen indirekt durch die Verwendung von Punzen fertig.*

Schlagworte: Münzen, Stempelschnitt, Gravurwerkzeug
Key words: coins, die engraving, engraving tools

Experimental numismatics

Numismatists normally do not have practical experience in minting, so they have only common sense and general technical knowledge to answer technological questions. Experimental numismatics adds to this hands-on experience. This is necessary as physics and technology are often surprising. Experiments can provide patterns, which can be compared to ancient objects, as numismatists are fortunate to be dealing with rather durable materials. Experiments can also help to examine work flows for their practicability or resource requirements, and they can explain the use of tools. The topic of this article is the connection between the tool marks we can see on the coins and the tools, which are used to create the image in the coin die.

The beginning of the research presented in this paper was the death of my cat Kitty in February 2008 at the good age of 18 years. This was the occasion to start making medals and copies of coins and pursuing experimental numismatics with the focus on ancient and medieval minting. The first pair of dies was for a commemoration medal for Kitty in the style of a Roman denarius (*Fig. 1*). The skills for practical minting were acquired as an autodidact by closely looking at coins and basic tool knowledge from my father. This self-teaching was a kind of fundamental research, also providing information about the correlations between die manufacturing and coin appearance.
People whose work and information is included in this article are Alfred Brand and Greg Franck-Weiby. Brand is a retired master of engraving and head of craft

Fig. 1: Kitty memorial medal. The consecratio reverse minted on Roman denarii to deify an emperor seemed to be a very good choice for a deceased cat, as a cat can be like an emperor. – Kitty-Gedenkmedaille. Die Consecratio-Rückseite, die auf römischen Denaren zur Vergöttlichung eines Kaisers geprägt wurde, ist für eine Katze eine gute Wahl, da sie sich wie ein Kaiser benehmen kann.

guild in Annaberg-Buchholz (Erz Mountains) and passed on some of his knowledge, which I have quoted here. Any references to him in this article are based on personal communication. Franck-Weiby was an US artist living in Washington. He engraved dies for hammered coins for over 20 years. Due to his technique, he produced quite interesting samples. Sadly he died in the middle of me writing this article.
In this context, it is especially worth mentioning publications about historic minting technology: Cooper (1988), Hill (1922) and Stannard (2011). More publications relevant to the topic are (Casson 1938; Kleeb 1982; Kleeb 1984; Kühn 1989; Schwabacher 1958; Schwabacher 1965; Schwabacher 1966; Schwarz 2000; Sellwood 1962; Sellwood 1963).

Tools and tool categories

Only tools made of iron/steel were used in the research and hence are discussed here. Bronze has different properties, e.g. it is less hardenable, most easily deformable at lower heat (for bronze with 20% tin the best temperature for deformation is

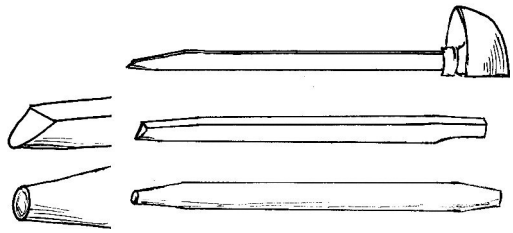

Fig. 2: Tools (from top to bottom): Graver, chisel and punch with details of the tips of a round chisel and a hollow pearl punch. – Werkzeuge (von oben nach unten): Stichel, Meißel, Punze mit Vergrößerungen eines Rundmeißels (Bollmeißel) und einer Hohlperlpunze.

in the range of 587-798°C; [Bauer, Vollenbruck 1925]) and it is easily castable. Because of this, some working techniques are more difficult with bronze and others with iron, e.g. casting. The working techniques shown here are normally used with bronze dies and in any case iron tools probably dominated in Roman times. As a first step to understand the tools they shall be categorizsed according to their working properties. The working properties are not only defined on how the tools shape the die, but also on how the tools themselves are made, as this has also an influence on the image of the coin.
The historical tools (*Fig. 2*) – modern tools would be pantographs, reducing chipper, motorized or computerized machines – suitable for making coin dies are:

Abrasives
Abrasives can be used in many different forms, e.g. as a natural stone, as loose powder with a wooden stick for application or glued onto an emery paper.

Chisel
The chisel is driven with a hammer. Small chisels (8-16 cm long) can be used for die engraving. The tip of the chisel can have

Fig. 3: Top row, from left to right: a) Penny, Nuremberg, 1138-1152, Erlanger 9 (Erlanger 1979); b) Penny, Nuremberg, 1240-1268, Erlanger 67. Bottom row, from left to right: c) Copy of lower die of Erlanger 9; d) Copy of lower die of Erlanger 74 made with a large picture punch and a smaller star punch. – Obere Reihe, von links nach rechts: a) Pfennig, Nürnberg, 1138-1152, Erlanger 9 (Erlanger 1979); b) Pfennig, Nürnberg, 1240-1268, Erlanger 67. Untere Reihe, von links nach rechts: c) Kopie eines Unterstempels von Erlanger 9; d) Kopie eines Unterstempels von Erlanger 74, der mit einer großen Bildpunze und einer kleineren Sternpunze gemacht wurde.

many different shapes (pointed, rounded, flat) in different angles and sizes depending on the desired image and the material to be engraved.

Graver

The graver or burin (Theopilus describes gravers in De diversis artibus [written in the decades after 1100] in book 3, chapter 11 – ferri fossorii; Brepohl 1987) works basically like a chisel, but it is moved by hand pressure using the normally present bulbous handle. But even a chisel can be used as a graver and pushed by hand.

Fig. 4: Details with incuse letters. Top row from left to right: a) Roman quadrigatus, ca. 225-214 BC, Crawford 28/3 (Crawford 1974); b) Roman denarius, ca. 112-111 BC, Crawford 297/1a. Bottom row from left to right: c) British cartwheel twopence, 1797, Seaby 3776 (Seaby); d) Letter R when chiseled into die and into a square punch. – Details inkuser Buchstaben. Obere Reihe, von links nach rechts: a) Römischer Quadrigatus, ca. 220 v. Chr.; b) Römischer Denar, ca. 110 v. Chr. Untere Reihe, von links nach rechts: c) Britischer Wagenrad-Twopence, 1797; d) Beispielbuchstaben. Buchstabe R direkt in den Stempel gemeißelt und indirekt in eine Punze.

Punch

The punch is driven – more or less – vertically into the work piece using a hammer. The material is not cut away but merely displaced to the side. Common punches today are centre and number/letter punches. Punches for making coin dies range from very simple to very complex. As the die bears the inverse image the punch used on the die bears the positive image like the coin. The term punch is used in this article for all tools working with this mechanism independently of where it is driven into and if the image is positive or negative and more or less complex.

From this list there is already an obvious categorization into cutting: abrasive, chisel and graver – and non-cutting: punch.

The tools can also be categorized by their complexity:

Simple tools

In this category are abrasives and tools which can be produced just by the use of abrasives, i.e. chisels, gravers and very simple punches (centre punch, lines, ...). With multiple applications of these tools, very complex designs can be created on the die.

Complex tools

With the help of chisels, gravers and punches, complex punches can be created, which contain details or large parts of the coin image. When a punch for the die is produced using another punch, the later is negative on the coin.

Fig. 5: Drachm, Lukania, 540-510 BC. From left to right: Main coin side. Incuse coin side. Impression of the incuse side showing how the die would have looked. – Drachme, Lukanien, 540-510 v. Chr. Von links nach rechts: Vorderseite. Inkuse Seite. Der Abdruck der inkusen Seite zeigt, wie der Stempel ausgesehen hat.

Fig. 6: Coin showing field deformations from punching: Copper coin from Bela III. from Hungary, 1172-1196. The deformations are much more local than the field deformations shown in Fig. 7,a. From the deformations done by the arc in the lower left corner it can be deducted that the beaded circle was done first. – Eine Münze mit Felddeformationen durch die Verwendung einer Punze: Kupfermünze von Bela II. von Ungarn, 1172-1196. Die Deformationen sind näher am Punzabdruck als die Deformationen in Abb. 7,a. Aus der Verformung durch den Bogen links unten erkennt man, dass der Perlring zuerst punziert wurde.

Influence of the tool types on the design of the image

There are relations between the tools and the created image. With engraver's tools, there are things, which can be done more easily and things which are more difficult. Hence the desired image can make the engraver choose the appropriate tool or the available tools restrict – or at least strongly suggest – how the image looks. An example to illustrate the connection between tools and product: It is easy to do a blue cross-hatching on paper with a blue ball pen, but it is difficult to do white cross-hatching with blue background.

Designs in the positive and the negative image

A very similar situation to the previous example is the engraving (“drawing”) with a chisel onto the (negative) die and onto a (positive) punch. This has also a strong influence on what is easy and difficult. The first case can be seen on earlier medieval frontal portraits (*Fig. 3,a*). The face consists of embossed lines and dots, which form the edge of the face, the nose, the mouth and the eyes. The lines are knife-edged on the die, which can most often not be recognized on the coin due to minting weaknesses.

Fig. 7: From left to right: a) Copy of an upper die of Erlanger 74 showing field deformations before the nose of the lion; b) Result of a big punch driven in a flat die. Half of the line is below the die field even so the punch is still not filled there. – Von links nach rechts: a) Die Kopie eines Oberstempels eines Erlanger-74-Pfennigs zeigt Felddeformationen vor der Nase des Löwen; b) Ergebnis, nachdem eine große Punze in einen ebenen Stempel geschlagen wurde. Die Hälfte der Linie ist unterhalb des Stempelfeldes, obwohl die Punze an dieser Stelle noch nicht ausgefüllt ist.

Fig. 8: A very unevenly minted Bohemian groat (John I. from Luxembourg). As the cross and the surrounding area a higher profile than normal has the general image is most probably higher and normally not fully minted. – Ein sehr ungleichmäßig ausgeprägter Prager Groschen (Johann I. von Luxemburg). Da das Kreuz und die Umgebung ein deutlich höheres Profil hat als bei normal geprägten Groschen, ist davon auszugehen, dass allgemein das Bild im Stempel höher und normal nicht ausgeprägt ist.

The second case – using a complex punch – can be seen on later medieval frontal portraits (*Fig. 3,b*). The face is an inversion of the first style. It is an embossed, flat area where the details are defined by sunken lines and circles, which are level with the field of the coin. So while it is difficult to create embossed flat areas with sunken decorations using simple tools (c.f. *Fig. 4*), it is very easy to do so with a complex punch because the punch can be easily given a flat face just like a die. In Nuremberg the minting starts with the line style. The flat punch style starts with Friedrich I. (1152-1190) and gradually changes to the use of better-sculpted punches at the end of the 14th century, but it is difficult to define this exactly as the images are not fully minted.

Experiments have been performed to copy coins of Nuremberg with both styles – Erlanger 9 and 74 (Erlanger 1979) – to verify the die production (*Fig. 3*). For Erlanger 9, only one chisel and one bead punch were necessary. Although the chisel was pointed, the lines look flat due to a minting weakness caused by the thin blank. For Erlanger 74, multiple complex punches were made: For the upper die (*Fig. 7,a*) a rosette punch and a lion punch, for the lower die (*Fig. 3,c*) a star punch and a big punch with two lions and a staff. That the image on the lower die from these types of pennies was a single punch was shown in (Bruestle 2012), although it differed a bit from the punch used in the experiment. The size of this big punch requires a lot of force to drive it into the die blank. Therefore it really makes sense that on genuine coins, the punching is not as deep as if using the lion punch.

Coin images where the usage of such a complex punch would have made life much easier is the Roman didrachm with incuse ROMA (*Fig. 4,a*) and denarius with incuse D.S.S (*Fig. 4,b*). The letters are thick and clumsy. The embossed field is also often without good straight edges. If they had used a punch for this, then the

Fig. 9: Beaded borders from Roman coins. Top from left to right: a) Denarius, 47/46 BC. Beads too far apart to interfere; b) Denarius, ca. 150; c) Denarius, 223. Bottom from left to right: Experimental beaded lines, d) Beads showing extreme D-effect because of missing precut line; e) Some D-effect with precut lines. – Perlränder römischer Münzen. Oben, von links nach rechts: a) Denar, 47/46 v. Chr. Ohne Beeinflussung wegen zu großem Abstand; b) Denar, ca. 150; c) Denar, 223. Unten, von links nach rechts: Experimentelle Perllinien, d) Mit extremen Verformungen, da keine Linie vorab graviert wurde; e) Geringer D-Effekt mit einer vorgravierten Linie.

field edges would have been straight and the letters could have the same fine style as their normal letters with the dots at the end of lines. A sample of the letter R is shown in *Fig. 4,d*. On the left it is in the normal style directly engraved into the die. On the right the same letter is engraved into a square punch, which has then been driven into the die. The result is very different from the Roman incuse lettering. Considering their difficulties to sculpt this without a punch, the engravers did a very good job. Thus it is obvious why the Romans did not continue using incuse lettering.

An example where an image is on the same coin as a positive and as a negative is shown in *Fig. 5*. Normal image and incuse images differ in style and form, so it was not just one die imprinted onto the other. On the impression, it can be seen that the field of the coin had to be removed while the border decoration and the man had to be left standing. The man on the incuse side is coarser and has a flat surface somehow similar to the penny on the right in *Fig. 3*. The folds of the cloth are engraved on both sides into the die thereby having them projecting on the coin. The delicate spear is missing on the incuse side completely. Also the beaded circle has been changed to a wreath for easier engraving.

Designs with punches

The knowledge about punches and then their usage leads to certain image styles. Besides the flat picture punches shown above (*Fig. 3,c-d*) smaller punches can also be used to assemble a die image. Making such a punch is especially worthwhile when many dies shall be made or an element is used multiple times in an image, e.g. letters or the hair locks of the lion on the Bohemian groat (*Fig. 8*). So images with repeated features can lead to the production of punches and the wish

Fig. 10: Chisel marks on letters. Top from left to right: a) Tetradrachm; b) Denarius; c) Solidus. Bottom from left to right: Experimental letters, d) Carefully chiseled P; e) Coarsely chiseled P; f) Coarsely chiseled O made in one turn. Ps and O showing steps, even in straight lines; g) O made with graver. Just a little scratching on the outside edge. – Meißelspuren bei Buchstaben. Oben, von links nach rechts: a) Tetradrachme; b) Denar; c) Solidus. Unten, von links nach rechts: Experimentell gravierte Buchstaben, d) Sorgfältig gemeißeltes P; e) Grob gemeißeltes P; f) Grob gemeißeltes O. Ps und O zeigen Stufen; g) Mit Stichel graviertes O. Man sieht nur leichte Kratzer an der Außenkante.

for faster die creation or more uniform coins can lead to designs suitable for punches.

Because the image of a punch is mostly constant (including defects which can increase by usage) punches can be identified by comparing image parts on the same coin or on different coins from different dies. Letters can be made with a single punch or with multiple applications of one or more simpler punches. In the first case, the relative position of the parts of the letter must always be the same. In the second case the parts of the letter are moving relative to each other. However, comparing elements can be difficult because punches are not always driven into the die with the same depth and the coins are not struck equally well. The same punched element can have different sizes and slightly different forms on the coins.

Non-specific texture punches (matte punches) can be used to give an engraved tree a texture like small leaves or a roof the texture of tiles. This is normally done by applying the punch multiple times over the area to be textured. On a well-minted coin, this can be identified by closely looking for repeating patterns. The images suitable for texture punches appear around 1700. Because of their fine and irregular structure, they are difficult to be identified on coins.

Tools marks of punches

Punches are driven into steel e.g. with a hammer and displace material to leave an impression of its image in the negative. The displaced material is moved to the side, depending on the form of the punch, more or less evenly to all directions. This can be seen on a coin as a depression around the image (as shown in *Fig. 6*), unless the die is not again ground for a flat field before minting what seems to be the normal case. However, not grinding away these distortions can make minting

of a thin coin blank easier. Even when the coin is weakly struck, the displaced material helps that the image remains visible. The use of a punch does not create stepping like when using a chisel. This characteristic was used in (VAN ARSDELL 1986) to distinguish original celtic coins from forgeries.

When punches with cavities are set into a flat surface, the cavity is filled less than when the punch was driven into the material, because the displaced material is flowing more to the outside of the punch than to the centre. When the lion punch (die in *Fig. 7,a*) was driven into the die blank as deep as on the coin, the space between the legs and head and tail were not filled very well. For this the punch had to be driven in further and then the superfluous metal removed. So this die did not show any metal displacement from the punch anymore. The result of punching with an experimental big punch is shown in *Fig. 7,b*. To get a line level with the die surface, part of the die surface would have to be removed.

After minting a dozen coins, a die that has not been hardened showed deformations in the field (*Fig. 7,a*), which can be confused with the metal displacement from a punch. The reason for this is the high force needed to mint this coin type with a hard silver alloy and a thin blank. This leads to high friction forces between blank and die, thereby greatly increasing the pressure on the dies.

Lines – straight and variably curved, e.g. the shield for a coat of arms – can be made with either big punches or after pre-engraving with short straight and differently curved short punches to achieve an even line appearance, which is a currently used technique (pers. comm. Alfred Brand). A general indication for punched lines is their flat face, which could have been chosen to match style with other flat faced elements like letters. However, a minting weakness can also be

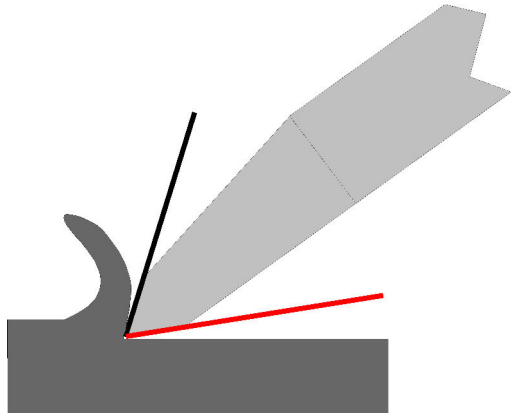

Fig. 11: Operation of the chisel or graver tip showing the formation of the bur. – Die Entstehung des Spans an der Meißel- oder Stichelspitze.

the reason for flat faces lines on a coin.

An indication for short punches is the visibility of the ends of the punch on the brinks of the line, as it happened in my experiments. The arm on one barbarous radiate is probably an extreme case of marks with this technique. Admittedly, I was not able to find other coins showing these marks and also the medals made by Alfred Brand do not show any. A better way to determine whether large or small punches are used is to compare the images of different coins, i.e. if the lines change or stay the same.

Beaded lines

Beaded borders are a special, but standard element of coin designs from Greek and Celtic times until now. The size of the beads matches about the size of the dots made by centre punches. The bead punch is examined first to see if the marks match these on coins.

Roman coins often show a precut line (*Fig. 9,a-c*). Its influence on the punching can be seen in *Fig. 9,d-e*. Without a line, all the material of a punched bead lying in the direction of the previous bead is displaced into that and leaves it greatly de-

formed. A precut line helps to position the punch and also removes the material between the beads. As a result, the deformation is reduced. If the line is to deep compared to the depth of the beads the line is still nastily visible at the top of the beads as seen on many Roman coins. This effect is to be called D-effect, because the deformed bead looks like a D. So the tool marks of the bead punch in the experimental sample and on the Roman coins clearly match.

Deformations on a coin can show the history of die production steps as the later punch impression displaces into the earlier one. It can tell us if e.g. the letters are punched before or after the beaded border as in *Fig. 6*.

Another possibility to make beaded lines is using a punch that has not a single but two beads or – in case of 17th/18th century coins – sticks. A double-bead punch is used to advance each stroke of a single bead by placing one bead into the previous one. This ensures an even spacing between the beads. A circle with an all around even spacing can be obtained by doing multiple rounds with light hammer blows. The punch synchronises itself for the full circle. When done well, this can hide a precut circle. The disadvantage of this method is the higher difficulty to make the tool and the increased time to make the circle. Clearly the Romans did not use such a tool. The coins from the 17th/18th centuries with all around evenly spaced sticks on the edge do suggest the use of double-stick punches. However, many coins of that time still show the irregularity of a single stick punch with differently tilted sticks of varying distance.

Tool marks of the gravers and chisels

The graver and the chisel have a heel at the bottom (marked red in *Fig. 11*), which can make contact with the die where it should not. This is at the end of mostly short lines because of the limited space, e.g. at the stem of a letter, where the tool has to be moved away from the line ending (*Fig. 10,e*). Here the bottom of the tool can leave a needlelike mark. The heel of gravers can also scratch the die surface at the outside of narrow curved lines (*Fig. 10,g*). Chisels create more coarse marks (*Fig. 10,d-f*) because the chisel is not smoothly pushed but driven with hammer strokes. This creates steps in the line, which are most noticeable at the outside of curved lines, but can sometimes be seen even on straight lines (*Fig. 10,d-f*). They can be so prominent that they are still visible on coins from well-used dies.

The tip of the tool must be at a relatively obtuse angle (60-70°) for engraving steel – for softer metals like tin and copper smaller angles are used. Because of this steep angled tip, the chisel piles up material in front of it where the bur is formed

Fig. 12: Heights of letters and portraits. From left to right: a) Ancient radiate, Philippus I., ca. 245; b) Modern engraved radiate made by Franck-Weiby; c) High relief engraved with graver made by Franck-Weiby. – Profilhöhen von Buchstaben und Portraits. Von links nach rechts: a) Antiker Antoninian, Philippus I. 248; b) Modern gravierter Antoninian von Franck-Weiby; c) Hohes Relief graviert mit einem Stichel von Franck-Weiby.

Fig. 13: Serifs on roman coins. Top from left to right: a) N/V on denarius. Top right of the N is a light first strike of the triangle punch; b) T/V on denarius. Bottom from left to right: c) S/T from denarius. S has a double punch strike on the bottom serif. T shows very precise planes of a punch; d) S from radiate; e) Modern E/L with serifs made with a graver which form never a straight line (by Franck-Weiby). – Serifen römischer Münzen. Oben, von links nach rechts: a) N/V, Denar. Oben am N ein kleiner Abdruck einer Dreieckspunze; b) T/V, Denar. Unten, von links nach rechts: c) S/T, Denar. Am S links ein Doppelschlag einer Dreieckspunze. T zeigt deutliche Flächen der Dreieckspunze; d) S, Antoninian; e) Modern E/L mit einzeln gravierten Serifen. Diese zeigen niemals eine gerade Linie (Franck-Weiby).

(*Fig. 11*). When the bur is not ground off fully, it creates a depression on the coin in the form of a half circle, which can be confused with the mark of a punch. The difference to the punch mark is that it is only at the end of a line. This bur is formed much more intensely with the chisel than with the graver, because more material is moved in one step. The graver has to be used repeatedly to gain the same depth.

Although it is possible to remove much material by multiple passes, graver work is normally not as deeply engraved as chisel work. *Fig. 12* shows angled views of a modern coin made in the style of a Roman Radiate coin with gravers (*Fig. 12,b*) and a genuine Roman radiate made with chisels (*Fig. 12,a*). The letters and image are much higher on the chiseled coin. But as Franck-Weiby has very well proven with his engraved Athena's head in the style of the Corinthian stater (e.g. Calciati, Pegasi 11) that it is possible to make high profile coins with a graver if desired.

Common difficulties in determining tools

Not every coin shows tool marks and even when marks are present, they can sometimes be misleading. Reasons for this are:

High quality engraving

A skilled and careful engraver produces less visible tool marks. Most times he has well maintained tools and a smoother handling of a chisel or graver leaves less marks that, in addition, can be removed afterwards e.g. by tracing a line with a line punch. If punches are used, the displaced

Fig. 14: Victoria on a denarius, Maximinus I., 235-238. Right detail. – Victoria auf einem Denar, Maximinus I., 235-238. Rechts im Detail.

and piled up steel can be ground away to leave a flat die face.

Wear of the die
The wear of the die softens the image and removes fine marks. A good example for this are the often heavily used reverses of the third century AD roman coins. From usage, the field can also be deformed by the minting pressure. This is most likely to happen on thin coins made of hard alloys, e.g. coins like thin medieval pennies, because here the friction between the blank and the die causes a particularly high minting pressure. The sunken field on such a die can create the impression that material was displaced by punches. This can be seen in *Fig. 7,a* in front of the nose of the lion.

Double strikes
Striking an image multiple times slightly shifted (often seen on medieval coins struck with multiple hammer blows) usually obliterates any meaningful tool marks. Instead misleading artefacts could be created, thus such parts should be disregarded when analysing a coin.

Not fully struck coins
If a coin is not fully struck, the parts that did not touch the die are flat or rounded. This effect is difficult to determine and can be mistaken for the usage of flat faced punches. In the medieval ages this is quite common. A sample is given in Fig. 8. A coin that is not fully struck can be identified by comparing multiple coins or better dies of the same type where the images are filled unequally.

Wear of the coin
The circulation of a coin softens the image and removes tool marks.

Corrosion
An even worse effect can have corrosion – most of all on copper coins. Even light corrosion can remove fine tool marks.

Effects of ageing
Especially silver coins can recrystallize. The coins get brittle and develop a grainy surface structure hiding tool marks.

Because of these influences the best coins to be examined for their die production are the best-preserved well-struck coins from good dies. However, also minting errors can help to identify die making techniques, e.g. off-centre strikes can show the die edge or tilted strikes can fully strike parts where normally the coin is nowhere fully struck (*Fig. 8*). A coin where a tilted strike proved to be useful to determine its production is the Aeginean stater (Bruestle 2010).

Example tool marks on ancient Roman coins

In this section, the tool characteristics discussed above are shown on Roman coins. The three main parts of the die image are the beaded border, the letters and the other images like the portrait and the reverse figures. These will be discussed in this order.

Letters
Two types of letters were used, which differ at the end of the lines: beads or serifs.

The very exceptional incuse letters have already been mentioned and are not discussed further. The beads have been used since the beginning of the first Roman hammered coins. At the time of Augustus, the larger coins start to bear serifs. STANNARD (2011) has already shown that letters were not punched because the form of the same letters on a single coin differ. Hence a graver or chisel has been used. The curves have a coarse stepping (*Fig. 10*) and the height of the letters is comparable to the letters on my chiseled Kitty medal shown in *Fig. 1*. This is a strong indication that the letters have been engraved with chisels.
The beaded end is easily made with a bead punch, the same as is used for the beaded borders. For the serifs, the bead punch was replaced with a triangle punch, narrow at the beginning and getting wider later on to form long serifs. The small, narrow serifs could have also been made by using the chisel as a punch. For the other serifs, a dedicated punch had to be used. *Fig. 13,a-d* shows some sample letters with serifs from different times. As can be seen, both serif sides on a line ending form always a straight line, which would not be the case if the serifs were cut from both sides (*Fig. 13,e*). Sometimes the separation from the line and also the clear planes of the punch can be seen. Evidence for the engraving of serifs with a chisel have not been found.

Images

When looking at portraits, figures and other types of images, the frequent usage of the bead punch can be observed, e.g. for knee, eye, breast and nipple of Victoria on the denarius shown in *Fig. 14*. As a very rare case – in fact this Victoria is the only case where I have ever seen this – the texture of her wings has also been made by punching. The form indicates that perhaps the tip of the chisel has been used.
Otherwise these types of images are very much based on freely flowing lines as the folds on Victoria's clothes, the arms and legs or the palm branch. These are all very likely made with chisels (pointy as in the case of the branch and rounded for the arms). So on this type of image we see mostly chisel work, punched beads and extremely rarely also other punch work.
The portraits have a large main part and some lines forming nose, eyelids, hair and ear. The lines are very easily made using a chisel. A modern engraver would also make the large part of the relatively flat head with chisels and clean it up by scraping. However, at least large parts of the portrait could have also been punched. The forgers of this time knew about punching and made transfer dies. Thus also the Roman mint officials must have been aware of this possibility. STANNARD (2011) argues very well against the use of image punches by the mint officials. I have also found no evidence for their usage and even the Roman coins with portraits of the emperor on both sides show significant differences in parts that could have easily been punched.

Summary

In this article the old tools were defined and categorized and their properties and possibilities were shown. The tool marks were compared to experimentally produced new dies to verify the assumptions about die engraving. Also the difference of working in the positive and the negative image was described. This fundamental analysis was then applied to Roman coins to get more understanding of die engraving.

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