

10th Century Danish Brooches with Necklace Hooks

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Summary

On a trip to Denmark in 2001, I saw two pairs of necklace hooks in the Danish National Museum. These hooks answered a question I had pondered for some time, which was how Norse women attached their necklaces between their brooches. I decided to make some necklace hooks, and learned a lot about fire-polishing wax and casting bronze in the process. The result is a beautiful and practical form of jewelry.

The "turtle" brooch was a basic item of jewelry for Norse women. I have wanted to make some for a long time. My past casting experience is with sand-casting, and someone suggested that it was not possible to make a brooch by this method. I like challenges and, with some suggestions from my teacher, we determined a way that it could be done, in theory. These brooches are an experiment to prove that it is possible to make turtle brooches, using the sand casting method and tools available in period.

I designed and made these items separately, designing them for different people, but decided to enter them together to reduce my number of entries this year.

Historical Documentation

Norse Women's Turtle Brooches

Norse researchers generally agree that Norse women often wore a pair of brooches to pin the dress and/or apron together. The photo to the right shows a reconstruction of a Norse female costume with brooches and hanging necklace.



Turtle brooches, named for their oval convex shape, were worn in pairs, and each had a fibula-type pin on the back to attach them to the

garments. The archeological evidence for such brooches is extensive, as illustrated by the many brooch artifacts pictured further into this document. Brooches could be simple (cast in one piece) or composite (made of 2 layers of sheet metal, with decoration on the top layer).

Brooch-hung Hanging Necklace

The idea that wealthy Norse women would wear necklace segments strung between their brooches is based on physical placement of beads, brooches, chains, and tools in many grave finds, because the strings on which the necklaces were hung have not survived. During my visit to the Danish National Museum, I saw many necklace artifacts, many of which only had enough beads and pendants to be 10-14 inches long. This would be the right distance to dangle between the brooches. My own research has also found many examples of brooches with loops near their

bottom edge, which further supports this theory.

Shown to the right is WOV 2013, the back of a bronze brooch found at the Nygaard site at Nord-Troendelag, Norway. It shows the structure of the pin, though the decoration on the pin holders is a rare thing for brooches. Such decoration would not be visible when the brooch was in use, and may have been some kind of artist's signature.

At the bottom of the brooch can be seen a small loop that may have been used for hanging necklaces. However, as with many museum photos and displays, the brooch is shown upside down, so the loop is at the top of the photo.



My assertion deserves some explanation. The brooch pin is attached at the top of the photo, with the pin end and its keeper at the bottom of the photo. Anyone who has worn Norse female garb, such as my lady, can attest that the brooch is much easier to put on and take off with the pin pointed

upward. Thus, I conclude that the museum has the brooch upside down in the photo, and the loop shown could be used to hang a necklace. It is not uncommon to find such errors in museum photos and reconstructions, where information gathered later supersedes an earlier interpretation.

Shown to the near right is WOV 2015, a pair of composite brooches from Viking Age Norway. They have animal-head lugs at the bottom, which could be loops for the attachment of a hook. It is difficult to be certain in this photo. The far right shows WOV 2882, a brooch from Lindholm, which has a large loop.



To the right is WOV 4118, a brooch set from Viking Age Finland, which has twin round brooches, a single bar brooch (used to pin the shawl, worn over the dress), and some tools, all permanently joined by bronze chains. This sort of arrangement was undoubtedly more expensive than using hooks, which are more versatile to meet the needs of changing fashions.



Necklace Hooks

While I took photos of two pairs of necklace hooks in the Danish National Museum, they did not come out well, so I must describe them from memory and the poor-quality photos shown to the right. The hooks are bronze but may once have been gilded. As with all the Norse jewelry pairs (brooches, hooks, etc.) that I have seen, the left is identical to the right, rather than the mirror image that the modern artistic eye expects.



Each hook is shaped vaguely like a tall triangle, covered with a zoomorphic animal design. The design used on both the museum artifacts was the Jelling style, though this is difficult to tell, even with the enhanced close-up shown here. Each had a hook at the apex of the triangle, and four or five necklace strands were tied to the back, probably to loops or hooks, though the museum display make this impossible to see. The hook with five strands also had a small "spreader" bar at each end of the necklace, with holes through which the strands went to keep them spaced apart and orderly.



Clearly, the archeologist's interpretation of these objects as necklace hooks is speculation. I have seen other similar hooks interpreted as garter hooks. It is also possible that these hooks were chatelaines to hold the small tools that Norse women suspended from their brooches. However, the museum artifacts interpreted as hooks were found in pairs, each with a quantity of beads, and one pair of hooks had spacers (small bits of wire with holes in them). The presence of beads and spacers suggests these objects were hooks for a necklace set.

I was not able to accurately pinpoint these hook artifacts to a date and location, though the Danish National Museum included them in the Viking Age section, and the Jelling art style dates them to the late 10th Century or early 11th Century.

Jelling Style Art

The Norse art known as the Jelling style, named after the Jelling cup, is characterized by ribbon-like animals knotted together, with different body parts of varying thickness. The thicker body parts are generally covered with stylized patterns that may represent scales, fur, or feathers. The animals usually have round eyes, with or without a pupil, and curls or spirals on the nose and sometimes at hip and shoulder joints. The overall animal is difficult to identify as to its intended species. The shape of the ears and jaws and the number of limbs are the only clues to the type of animal. Unlike Celtic knotwork or the zoomorphic designs seen in the Lindisfarne Gospel or the Book of Kells, the knotted pattern of a Jelling style animal is not usually symmetrical, but flows gracefully and generally fills the available space. When more than one animal is used to fill a space, the overall pattern could have radial symmetry, bilateral symmetry, or no symmetry at all.

Here are two examples of the Jelling style of art used on brooches. To the lower left is WOV 2836, a bronze brooch found in Hedeby. To the lower right is WOV 71323, a bronze brooch found in Iceland. Each has 4 intertwined beasts in a radially symmetrical pattern, surrounded by a simple border. These are composite brooches. The cutouts in the decorated top layer of metal give the pattern great depth.



These brooches not only illustrate the Jelling style very well, but are exciting because they are so identical in their artistic design that they must have been made by the same craftsman, despite the geographical distance between where they were found. These artistic design of these brooches was the inspiration for the brooch that I created.

Bronze Casting

The archeological evidence for metal casting in 10th Century Denmark is extensive. However, some question remains as to whether the Norse craftsmen employed sand casting, or exclusively used fired clay molds.

Evidence of casting in hard-clay molds is widespread. At the museum in Ribe, I saw hundreds of clay molds that had been pieced back together, some of which are shown in the photo to the right. These reassembled mold fragments showed that the craftsmen of Ribe could cast metal in many types of tools and jewelry, including brooches. Traces of metal in clay crucibles found there show traces of bronze, brass, lead, silver, and gold (Jensen 31). Furthermore, the mold fragments found in any one location show that craftsmen routinely cast the entire variety of objects, rather than specializing in keys, brooches, and so on (Jensen 33).



The archeological digs at the Coppergate site in York, England, dated to Viking Age, also provide information about clay casting. These included many crucibles, ingot molds, and cupels (Bayley, 799). The crucibles show evidence of being used to melt all manner of copper alloys (Bayley 803), including brass and bronze, as well as silver (Bayley 799). Likewise, a wide variety of copper-alloy items were found in York, including strap-ends, buckles, brooches, and finger-rings (Hall 103-105).

The process of clay casting is, in theory, simple. A "master," or original, is carved from wax, including a wax sprue or gate to pour the metal, lugs to hold pins, or other hardware features. This master is carefully packed in clay, which is fired to pour out the melted wax and harden the clay. While the molds are hot, the metal can be melted and poured in. Finally, when the casting has cooled, the clay mold can be broken apart to free the metal item for finishing (Theophilus, 106). Clay mold casting can create nearly any shape including intricate shapes with undercuts, but requires one wax master for each item cast. However, my experiments with this technique have been only marginally successful, and I am still seeking to find the correct clay mixture.

The use of the sand casting technique is more difficult to document, because a mix of fine sand and clay would not be recognizable in an archeological dig as a casting component. However, sand casting produces a rougher surface on an unfinished piece than clay mold casting. A sand-cast piece has tiny pits and bumps which, in my own experiments with clay versus sand casting, do not occur with a fired clay mold. Some artifacts show this type of bumpy surface and could, therefore, have been cast in sand. Sand casting is documented by Biringuccio in the 16th Century (324-328), but Theophilus in the 12th Century makes no mention of it. It is possible that it was available to 10th Century Danish metalsmiths, but I have not been able to prove it.

Sand casting is different from clay casting, in that the mold is made from two halves of packed sand, mounted in frames that fit together. One half of the mold is packed and dusted with powder to prevent it from sticking to the master or the other half of the mold. The original is pressed into the mold and dusted again. Then, the second frame is set in place and the second half of the mold is packed down, around the master model. Finally, the two halves are pulled apart to extract the master and cut sprue, gates, and vents. Sand casting can create any shape that does not have undercuts, can make many castings from the same master model, and usually requires more finishing work because of the parting line left between the mold halves. However, the effort of packing the sand can gradually damage a master made from soft material, like wax.

In either case, it is believed that the mold masters were usually made from wax originals, because beeswax was readily available, easy to carve, and has an advantage over wood or bone in that its lack of grain makes detailed carving easier. A copy of the wax master, of clay, lead alloy, or other durable material, was usually made as a basis for future castings (Jensen 33). Such a lead master could be used with clay to mold wax masters for clay molds, or directly in sand-casting.

Metal Working

At the Danish National Museum we saw an assortment of tongs, pliers, hammers, chisels, files, gravers, and other tools that were likely to have been used in carpentry but some of which could also be used in metalworking. The museum display did not provide any information as to where these tools were found, but the display was in the Viking Age wing of the museum. The Mästermyr find, from Sweden, also has similar tools (Arwidsson 12-17).

Works from later time periods, such as the writings of Theophilus and Biringuccio, can fill these gaps in our knowledge. The technology of metalworking is believed to have changed little during the Middle Ages. The main advances during that time were in the use of chemicals for parting, assaying, and pigments (Agricola 354), so it is likely that most tools and techniques from later periods could be applied to the Viking Age.

Forming, or bending, is an important step in many types of jewelry, including the pin holder on brooches and the hook portion of a necklace hook. The craftsmen had various types of pliers to accomplish this. Working metal this way causes it to become hard and brittle. The hardening varies with the type of metal. To restore malleability and ductility to the metal, a metalworker can conduct a process called annealing. Theophilus mentions annealing as being done at each stage of working silver (102, 138). His failure to define or describe the annealing process in a work that is otherwise very detailed is evidence that the concept of annealing was commonly known to metalworkers in the 12th Century. Biringuccio describes the process of annealing copper-silver alloy using a charcoal fire (362), and reiterates the importance of annealing after hammering (367). Alloys of gold, silver, and copper are quite different from ferrous metal in their reaction to heat. Annealing consists of heating the metal to a faint orange glow and quenching it to cool quickly, which softens the metal, allowing it to be further worked.

Finishing jewelry consists of shaping, smoothing, and polishing. There were many abrasives available in period, chosen by their availability and relative effectiveness on the material being worked. Theophilus describes the process of shaping with a flat hone (102) or flat sandstone (189). He describes a variety of files (93) and wire brushes (86) for shaping and smoothing harder metals such as brass and bronze. He describes smoothing as done with a piece of oak covered in ground charcoal (102) or fine sand and cloth (152). He describes polishing with a cloth covered in chalk (102) or powdered clay tiles and water (128), or saliva-moistened shale followed by ear wax (115). Biringuccio describes shaping as done with files, smoothing with cane dipped in powdered pumice (366) or sand and water (390), and polishing using tripoli powder (366, 374), or a wheel of copper or lead coated with powdered gems (122), emery (123), or lime (372).

Materials and Tools

I used bronze for this project, because it is affordable and has a beautiful appearance. Its hardness and casting properties that make it just as challenging as silver or brass. I purchased the bronze from a jewelry supply outlet, because I lack the necessary experience to safely alloy my own bronze. I carved the original necklace hook from beeswax, which is cheaper than modern carving wax, and is likely to be the wax used in period. I carved the brooch pattern from a sheet of carving wax, because I needed a stable, hard, thin sheet of wax for the brooch design.

The tools needed are:

- Carving tools to carve the original or "master" model (I made some from 10-gauge wire and also used some small (1 mm wide) woodcarving tools)
- Casting sand, talcum powder, mold frame, and palette knife, to make the molds
- Crucible with tongs and a heat source that can keep the crucible at 2000° F
- Brass, bronze, pewter, or silver to cast, and flux (boric acid crystals)
- Graphite spoon and/or rod for stirring molten metal in the crucible
- Oven or kiln with controllable temperature capable of 300° F
- Fire extinguisher, fire-resistant apron, and safety glasses
- Dapping block (piece of 2x6 wood with an oval depression carved into it)
- Ball-peen hammer for dapping the brooch master on the dapping block
- Small bolt cutters or jeweler's saw to remove the sprue, wire cutters to remove the vents
- Drill with 1/32nd and larger drill bits; a drill press is the safest form of drill for this
- Tools to file and polish the cast piece
- Carved wooden jig to hold the hook for drilling
- Round-nose pliers to bend the hooks and pin holder
- Dust filter mask and light leather gloves for polishing
- Heavy welding-type insulated gloves for handling crucible tongs, hot molds, and metal

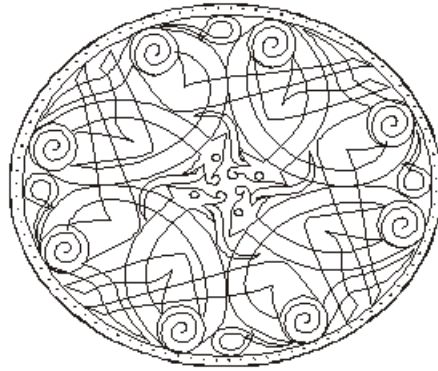
Method of Construction

Brooch

Designing and Creating the Master Model

I created a design based on the artifact brooches shown previously.

First, I drew a rough draft to create my own version of the artwork. Then, I diagrammed it out as a round brooch on graph paper to get the radial symmetry and placement of the creatures. Then, I elongated the design to an oval and readjusted the proportions and placement of the limbs to fit the new shape. The result is shown to the right.



This drawing does not show the intertwining or the final details, because I would create those when I carved the wax master model, or mold blank.

The original was made from a flat sheet of wax to build a master. This wax master is shown to the right. The master included my signature rune and marks on the back where the pin lugs would later go, in very low relief. I also alternated bears and wolves, the totem animals for myself and my lady, by varying the shape of the animals' heads. Carving this master took over three hours. As a result, I was afraid to risk fire-polishing it. I left excess wax around the edge in case I decide to do so in the future. Fire-polishing is further discussed in the hook section below.



I then sand-cast a pewter master from the wax one, which process is described in more detail below. A mold original made from wax is very soft and flexible. This means that when the sand is packed down, the wax will not break, but it will gradually be compressed and lose its

shape. Therefore, if you plan to make more than one or two castings from a wax master, a period technique is to cast from the wax original using a base metal such as pewter or bronze, with a hard-packed mold to capture maximum detail. If the result is good, smooth and polish the resultant casting to use as a master for many future castings.

Preparing the Mold for the Master

Put the flat side of the mold frame on the bench, fill it with sand, and pack it down. The master was fairly flat and would not have to push far into the sand, so pack the sand down hard. Then, turn the frame over, powder it, and press the master, non-detailed side down, into the sand. Powder the master a bit, put the other mold frame on, and sift the sand over it. Once the master is covered with a layer of finely crumbled sand half an inch thick, fill the frame with sand and pack it down. Separate the halves, carefully remove the original, and with a palette knife carve a sprue channel into the sand. The sprue is the cone-shaped piece of metal where you poured into the mold, and will be cut off the casting after it is poured. Put the mold halves together and set the mold up to pour. Depending on the type of mold frame, you should loosely clamp or weight the mold shut, to keep the frames from being forced apart by the momentum of the metal when you pour.

Melting and Pouring the Master

Heat the metal in the crucible, using a kiln, oven, or torch. Silver, brass, or bronze should be heated to about 2000° F; it will have a "sheen" on the top and glow bright orange when the metal is above its "flow" point. Pewter can be heated to about 600° F; it may have a thin gray oxide coating which you should scrape off, and it will be as shiny as a mirror beneath the oxide layer. With either metal, it should "flow," that is, it should be as liquid as water or mercury. If the temperature is too low, the metal will not flow properly and may not enter all the recesses of the mold. If the temperature is too high, the metal may not cool evenly and may create smooth "implosion" pits in the finished casting. When the metal is slightly above flow temperature, pour it into the mold. Pour it all in one smooth motion into the sprue channel, taking only about one second to do so. This also takes practice to do well.

After the visible top of the sprue cools to a dark color, carefully separate the mold halves, take out the casting (it will still be hot), and tap the sprue on the bench to remove the burned sand. Then, polish the casting a bit to see if the pattern came out well. If it did not, you can melt it down and try again. Any sand that is burned black should be thrown away, but the rest can be sifted and reused.

Finishing the Brooch Master

On the pewter master, I cut and filed away the excess material along the edges. Then, I hand-carved an oval depression into a block of pine, the size and depth of the finished brooch. Then, I carefully dapped the pewter brooch master into the wood block with a ball peen hammer, to give it the concave shape. I made the brooch blank thick, and proceeded slowly, so that it did not crack during this process. Pewter self-anneals at room temperature and also softens when hammered, so it is the ideal metal for this sort of procedure.

Casting the Brooch

I sand-cast the brooches from the now-concave brooch blank. I had to be careful to not allow the pewter master to shift while making the mold, and very careful in removing it from the mold, because sand-casting does not allow undercuts, and any mistake damages the decorative detail. After forming the mold, I cut the lugs into the sand on the back of the mold to create the hardware attachment points. It is also important to cut vents, holes through the sand to allow air to escape. I cut vents in the center rear of the mold and around the edge. To show where the lugs and vents should be, the drawing to the right shows the brooch, sprue, lugs, and vents, as it will look when it comes out of the mold.

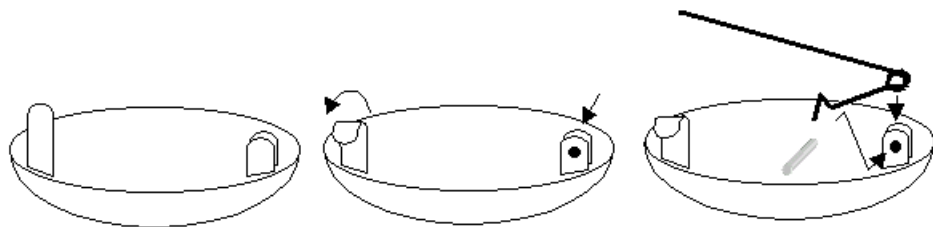


Finally, if you are casting in brass, silver, or bronze, it is important to bake the mold for one hour at 300° F, to heat it thoroughly. For a pewter casting, heating the mold is not necessary, but for brass, silver, and especially bronze, a cold mold will cool the metal before it can flow into the entire pattern, resulting in half a brooch and a lot of wasted effort.

Assembly

Remove the sprue with bolt cutters and/or a jeweler's saw, cut off the vents with wire cutters, and file the remnants flat. To save time, I used mostly power tools for this step. I prefer a 40-grit disk sander for rough grinding, and a 600-grit belt sander (not a common grade, but you can get it from a woodworker's shop in the "sharpening" section) to smooth it off. For detailed areas, I used a set of small files. I left a bit of the center vents sticking out because they are difficult to reach safely with a file or grinder, and because their remnant has no adverse impact on the look or function of the brooch.

After cutting off the sprue and vents, the brooch is ready for assembly. The diagram below shows the brooch after the sprue and vents are removed, how the pin holder is bent and the rivet holes drilled, and finally with the pin being installed. The pins are formed of hardened steel wire, bent in two loops around a large nail. The rivet to hold the pin is made of bronze, made from a vent tube that was cut from the actual brooch casting. If your rivet skills are extremely good, you can mushroom the ends of the rivet, but this is difficult to do in such a small space. You can also bend the ends over as I did.



Finishing

I put the brooches in the oven to age them, i.e. darken the surface copper. I did this so that I could polish the surface detail and leave the recesses dark. The problem was that the first brooch developed a red hue when aged, whereas the second brooch developed a brown hue. The second brooch was cast two weeks later, of metal that had been cast, melted, and re-cast several times since the first brooch. To correct this, I picked the brooches in a solution of vinegar and hydrogen peroxide. Vinegar by itself would work, but the peroxide speeds the process along a bit. The pickle removed the surface copper, rendering both brooches the same dark color.

I used modern tools for finishing in order to save time, because my past experiments have shown that the period methods take about ten times as long to get the same results.

Bronze is fairly hard, so I was able to polish it quite well with a fine wire brush wheel followed by a medium buffing wheel with black polishing compound. I also tried using a succession of the white, black, blue, and green polishing wheels, which took much longer with a slightly better result. These high-tech polishers are excellent on brass, pewter, and silver. While such polishing wheels are designed for a handpiece or Dremel tool, I used them in my drill press at a slow speed (1100 rpm) which gives good results and is much safer.

I look forward to making more brooches like this from brass and bronze.

Necklace Hooks

Designing and Creating the Master Model

The design for the necklace hooks is one of the first free-form designs I have made. That is, I drew it on paper once and then proceeded to carve it. The design is that of a dog, in Jelling style. The only deviation from Jelling style is that I did not put decorative patterns on the animal's body, because I wanted a clean and simple design that did not distract from the necklace it would display or any brooch with which it was worn.

I carved an original model of the hook from a thin slab of beeswax, made by pouring melted wax onto a tin plate. For ease of casting, I left the hook portion as a long thin straight bar. The lugs on the back, used to make the loops, were also cut from beeswax and melted into place. I made them slightly tapered to make it easier to get them out of the sand mold.

The final step in making a wax original is to fire-polish it. This is done over a small heat source, such as an alcohol lamp, and requires great care. Hold the model over the flame, always moving it to keep the temperature under control. To do this properly, it helps to be able to see the underside where the heat is acting on the wax. The idea is to melt the wax enough that its surface becomes smooth, and gravity pulls it into a nice rounded form. Fire-polishing takes a great deal of practice, because overheating the wax or holding it at the wrong angle can ruin the design. Beeswax in particular is difficult to fire-polish, because it goes from solid to liquid in an instant, and is thus much less forgiving of fire-polishing errors than the modern carving waxes. If the fire-polishing goes poorly, however, you can get out your carving tools, solder on more wax, and repair the design.

Casting and Finishing

Cast the hook in the same sand-casting process as described above. Again, it is wise to make a master from which all future castings are made. There is no need to bake the mold as you did with the brooch. The casting is smaller and is less likely to cause the metal to solidify before it can reach the end of the hook, though vents are still important, particularly with bronze.

Cut off the sprue, grind off any flash around the edges, and smooth all the parts down. I was able to do most of the smoothing with the 600-grit belt sander, though certain detailed areas of the edge required me to use hand files. Smooth the front and back, and polish the front and the back of the hook portion (which will become the front when it is bent) to your satisfaction. Due to the small size of the hook, I used the white, black, blue, and pink polishing wheels for this.

Then, anneal the metal and, with the round nose pliers, form the hooks into shape while the metal is still warm. My experiments have shown that it is easiest to put on a necklace hook where the hooks bend forward, toward the decorated side, particularly when the brooch loop is attached to the pin behind the brooch and is not visible, so bend the hook in that direction. If the hook hardens as you bend it to the point that it becomes difficult, STOP and anneal the hook again, or it will break. With brass or silver, one annealing is enough, but bronze requires at least two.

Put the hook in your homemade wooden jig to hold it firmly, and drill the string holes in the lugs. I tried using my hand-powered reciprocating push drill, but I lack sufficient practice with it and the bit kept binding. I had to use the drill press.

File away any sharp edges left by the drill, and polish out the marks left by the pliers. If desired, you can fill the recesses of the design with niello or enamel, use vinegar or muratic acid to darken it, or age and surface-polish the hook as I did with the brooch. I did none of these on these hooks, preferring to let the pattern remain subtle and become more visible over time through a natural oxidation process. While that means the hooks do not exactly match the brooch, my intent with the hooks was that they could go well with any brooch set.

Lessons Learned

I spent dozens of hours experimenting with sand-casting brooches in pewter, brass, and bronze. Each attempt taught me new things, as I suffered nearly a dozen incomplete castings, where the metal failed to fill the entire mold, and two implosions, as the cooling metal shrank away from the mold. Eventually, I was able to refine the process well enough to produce a quality brooch out of bronze more than half the time. As it is, the first brooch had less than the ideal amount of metal flow into the lugs because I accidentally molded them too thin, but it still works, so I kept it. It is important to point out that the procedure, as described here, does work, but the chance of success is reduced when changing from pewter to brass, and from brass to bronze, even with the extra vents, heated molds, and other precautions described. My experience with casting silver is limited, but I believe that it would be easier than brass but more difficult than pewter.

As mentioned before, the second brooch also turned brown instead of red when fire-hardening, presumably because of repeated oxidation. While bronze melts much cleaner than brass, and I always cleaned old castings with a wire brush prior to re-melting, I must not mix too much old bronze into any particular melt. The pickle solution fixed this problem.

The brooch took about 3 hours to carve the original, two hours to make and shape the pewter master, plus dozens of hours of experimental time. With all that done, making one brooch takes about 3 hours of effort, not including one hour to bake the mold.

The hooks took about 2 hours to carve the original, 2 hours to cast both hooks (not counting a metal original for future castings), and 3 hours to form and finish the hooks.

I have used the same hook design to experiment with casting in hard clay molds, which will be the topic of another paper some time next year.

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Jensen, Stig, The Vikings of Ribe, Den antikvariske Samling, Ribe 1991, ISBN 87-982336-6-1. This book provides an excellent overview of the excavations of Viking Age Ribe, the artifacts found, and what it all means, with emphasis on trade, crafts, religion, and the town's history. This book would be very useful to any student of Norse culture, or Dark Ages arts and sciences.

Theophilus, trans. John Hawthorne and Cyril Smith, On Divers Arts, Dover Books, New York, 1979, ISBN 0-486-23784-2. This translation of an early twelfth-century treatise on painting, glassworking, and metalwork is one of the foremost period sources for researchers of these arts.

Various museums in Denmark. In the summer of 2000, my lady and I traveled to Denmark and visited the National Museum in Copenhagen, the Viking Ship Museum in Roskilde, the Viking Museum in Ribe, and the research/reconstruction sites at Fyrkat, Trelleborg, Jelling, and Lehre. We took many photos, saw many artifacts, and spoke to an archeologist or two. What we saw on this trip gave us ideas and research for years of arts and sciences projects. Our only complaint is that we had to take our own photos, which did not always come out well when taken through the glass that protected the artifacts. None of the museums sold information or photos of individual artifacts.

York Archaeological Trust and the National Museum of Denmark, The World of the Vikings (CD-ROM), Past Forward Limited, undated. This CD contains thousands of photos of artifacts, but the historical information about each artifact is quite limited. The CD is still quite useful because it often shows the same artifact from different angles, detail photos, etc. I eagerly anticipate the 10-year anniversary edition that is coming soon.



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