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CORE-DRILL SAMPLING WITH THE SHERLINE MILLING MACHINE

ANTHONY SIGEL

Core samples are often needed for the analysis of ceramics, glazed and unglazed, high fired and low. Sampling of any kind is both unpleasant and challenging. To extract a sample containing a full stratigraphy can be difficult, and often the fracturing off of material adjacent to a chip or other damage with tools is difficult to control. The author has had success using diamond-coated core drills in a milling machine at slow speeds and describes the machine and its setup, explaining the techniques, fixtures, and special tools used. The importance of practice on nonart objects cannot be overstated. The pros and cons of destructive sampling and the prerequisites to be met before taking such an irreversible step are discussed.

KEYWORDS: Core drilling, Sampling, Ceramics, Milling machine

1. INTRODUCTION

This article discusses the use of a variable-speed, three-axis milling machine, such as the Sherline 5400 Deluxe Mill (fig. 1), manufactured by the Sherline Company, for taking ceramic core samples used for SEM and thin-section analysis. Core samples for thermoluminescence testing (TL) may be necessary for more vitrified wares and can also be obtained with these techniques but require additional safeguards against exposure to light to remove and store the sample.

2. ADVANTAGES AND DISADVANTAGES OF THE MACHINE

The drill head angle, speed, and movement can be controllable by the operator to a very fine degree: the number of revolutions per minute can be dialed down by rheostat to almost zero, the positioning of the X-Y support table and the speed at which the drill is lowered into the ceramic can be finely regulated, and the depth of the hole can be accurately measured and limited to 100th of a millimeter.

The machine's shape and size may limit the size or position of the object to be sampled. There is no direct pressure feedback from the handwheel as the drill bit is lowered, such as is found using a quill/lever-operated type of drill press machine. This can be largely compensated for in other ways, as will become clear later.

3. JUSTIFICATION FOR SAMPLING

Before contemplating irreversible, destructive sampling, it is important to ask and be able to answer in the affirmative these questions:

1. Is the research product to be gained worth the permanent alteration of the work(s) of art? Is the intellectual basis for the project sound, and is there a reasonable likelihood that the project will be successful?
2. Has the owner/curator given written permission for the sampling and are they fully aware of the resulting visual/physical change to the object? Have a test object on hand from which a practice sample has been taken to show the resulting appearance. Does the owner/curator expect aesthetic compensation of the sample hole, and to what degree?
3. Can the sample(s) be safely extracted, and will it provide enough material for an accurate analytical result?
4. Is your scientific team fully committed? Has the necessary funding, instrument access time, and operator time been secured and scheduled, and are the analytical resources in place for successful interpretation of results, completion of the project, and its eventual publication if envisioned?

Only if all of these questions can be answered affirmatively should you proceed.

4. PRACTICE

When beginning to learn this (or any other sampling technique), practice on a similar-bodied modern cup, mug, or plate until you are comfortable with the drilling and sample extraction procedure.

5. EVALUATION OF SAMPLE SITES

Evaluate the object to choose the sample sites, preferably with the owner/curator and the scientist carrying out the analysis. Establish the sample location based on the glaze/interface/body components you want to study. Ensure that the area is representative, and that the interior diameter (ID) of the core drill you choose will provide enough coverage. Note that the size of the sample, or core, will match the inner diameter, or hole, of the core drill bit. The sampling procedure will leave a hole the size of the outer diameter (OD) of the core drill bit (fig. 2).

Look for the most inconspicuous places, but also those that will not create a structural weakness. Discuss the locations with colleagues/project advisors, then review them for approval with the owner/curator. Mark the location sites with fine tape pointers, and number each sample site.
5.1 DRILL SIZE SELECTION

Calculate the depth to be drilled, and measure the thickness of the object at the sample location with a digital caliper or other means. Subtract the hole depth from the overall thickness of the ceramic wall to ensure that there is no possibility of drilling all the way through. Sample extraction seems easiest if the hole depth is at least equal to, or slightly longer than, the ID of the core drill. It may be possible to drill a shallower hole, but the risk is greater of breaking off the core stalk above the bottom, possibly losing some of the strata in which you are interested. Example: the Metalliferous (Eurotool brand) DIB-503.00 diamond core drill bit has an OD of 3 mm and an ID of 1.75 mm. Therefore, an ideal drilling depth would be at least 2 mm.

6. DOCUMENTATION

Prepare all of your recordkeeping materials: camera, spreadsheet, labels, permanent pen, vials, and gelatin capsules. Take macro-photos to show the original surface appearance and location of the sample sites before sampling. Pull back to provide overall context information if needed. Prepare a spreadsheet or other means of capturing your sampling information. Without sample site photography, clear labeling, and tracking of samples, you may doom your analysis to incoherence.

7. SETUP: WORKSPACE

If you have an assortment of vessels/objects, group them into similar shapes and sizes to take advantage of like setups. Reserve adequate table space for this project, with a designated separate object storage, and keep your tools in a segregated area. Use a piece of mat board or Volara foam as an immediate
“object-only” staging area, with tools and other hazardous items never allowed on it. Keep your workspace neat and uncluttered, and develop methodical and careful work habits.

Examine your hand tools and the drilling machine for projecting metal elements that could cause damage. Pad elements and projections that could come in contact with your objects. An ounce of prevention…never, ever rush or work in a hurry.

7.1 SETUP: MACHINE

Prepare a wood sampling platform—¾-in. plywood works well—and attach to the milling machine with the “T” nut hold-down clamps provided by the manufacturer. Cover the exposed fasteners with plastic caps or Plasticine to avoid damaging contact with the artifact. Gather the tools and materials needed, including safety glasses, a dropper bottle of water for lubricating the drill bit, Plasticine for object padding, and plastic wrap or Parafilm for protection and isolation from the Plasticine if needed. You can use a small jeweler’s screwdriver to remove the core “plug” after drilling, but I prefer a purpose-made tool for this purpose, fabricated from brass tubing sized to fit the hole (fig. 3).

7.2 SECURING THE OBJECT

Devise a method of securing the object. The ceramic must be held firmly in a stable position and able to resist the downward pressure of the drilling without movement. A thin bed of Plasticine applied to the wood platform cushions the object, distributes the pressure over the slightly uneven rim, and absorbs vibration (fig. 4).

If the Plasticine is used below the object, additional clamping may not be needed, as the Plasticine is somewhat “tacky,” especially on glazed ceramics. Avoid staining lower-fired ceramics by isolating the Plasticine with Parafilm or Cling Wrap (see fig. 13). Shapes such as closed vessels can be accommodated by cutting cradle shapes from blocks of wood and following the same steps for cushioning.

Fig. 3. Brass sample removal tool (Courtesy of Anthony Sigel)
7.3 PREPARING TO DRILL

Examine the drill bit. Is it the right size? Is the tip clean and in good condition (fig. 5)? Insert it fully into the drill chuck, tighten, turn on the machine, and be sure that the bit is running true and concentrically. Some core drills are fabricated from relatively soft hollow brass tubing—be sure not to crush the drill shaft. Others have a solid shaft, and the chuck may be firmly tightened.
Check for clearances by rehearsing the procedure. Make sure that as the drill is lowered into the object, no part of the milling head or spinning drill chuck can strike the object. Be sure that there is adequate light, and wear safety glasses. You should be in a relaxed, concentrated state of mind, in as distraction free an environment as possible. Most of your feedback will be audible.

7.4 CALIBRATION

Center your drill over the sample site. Lower the bit slowly with the upper handwheel, trapping a slip of paper between the drill bit and the ceramic surface to act as a spacer, needed to “zero out” the depth calculation (fig. 6). Raise the bit just enough to remove the paper.

To calibrate the milling machine/drill, loosen the small black knob on the handwheel, which allows you to zero out the calibrated ring, and retighten the knob (fig. 7). Each complete clockwise revolution of the handwheel lowers the drill bit 1 mm; the scale on the ring is divided into 10ths and 100ths of a millimeter. Decide on your target depth—2.3 mm for example, which would be 2.3 full turns of the wheel. Write it down somewhere. Do a last check of everything: object stability, placement, clearances, and equipment.

8. DRILLING

With the dropper or squeeze bottle of water, make a small, penny-size puddle where the bit contacts the ceramic. The water will cool and lubricate the cut and clean the bit (fig. 8). If the object surface is level, surface tension will hold it there. If it is at an angle, you will need to make a small dam of Plasticine to keep it in contact with the bit. Refresh the water as needed to cool and lubricate the drill bit and flush away “drilling mud.”

Turn on the drill at the lowest speed—virtually a crawl—and very slowly turn the handwheel clockwise, lowering the bit into the ceramic and establishing the hole. Use the lightest pressure—your guide will be the faint grinding sound. This is where practice on nonart ceramics will pay off. Depending on the vitrification of the ware, the drilling may be a very slow process, although you will be able to
increase the speed and pressure slightly after establishing the hole. Listen to the sound—it will be your
guide as to how quickly to lower the spinning bit into the ceramic. Do not overdrive it!

Backing the drill bit out to check one’s progress or to clear debris is generally not a good idea, as
it can cause chipping or difficulty in reinsertion. When the target depth is reached, keep the drill running
while turning the handwheel counterclockwise to raise the bit (fig. 9). With the bit up and out of the
way, shut off the machine. Turning one of the lower handwheels, move the object a safe distance away
from the drill bit. Remove the object. Flush the area with water to remove sludge from the channel, and
clean and dry the surface with swabs.
9. SAMPLE REMOVAL

To safely remove the core “plug,” one needs to break the core off at its base by applying sideways pressure at the base of the core “plug.” Use the tool fabricated from brass tubing, sized to fit the hole. The side of the tube, which is levered against the top edge of the hole and away from it, should be padded with a piece of tape to lower the risk of surface spalling. Levering the tool toward the hole will likely chip the core and break it well above its base, possibly losing the stratigraphy you seek.

First, cover the hole with a piece of 3M clear tape. This will stick to the core and prevent the core from flying across the room and ending up under a radiator. Push the core removal tool through the tape to the bottom of the drilled hole (fig. 10), then ease it out fractionally. Apply gentle sideways pressure away from the core, until you feel the core fracture, and voila! Lift the tape—your sample should come with it (fig. 11).
Gently scrape the sample into a gelatin capsule or other container and label immediately. Place it in a properly labeled container and put in a safe place. Enter the sample number, description, accession number, and other data on the spreadsheet. Take the after photo if required. Splash your face with cool water. Sampling is a difficult, unpleasant thing to do, which permanently affects an object (fig. 12). Only do it when you really, really have to.

10. CASE STUDY: SHALLOW BOWL

Prepare the platform for a circular, shallow dish with a Plasticine bed and barrier film. The plywood platform allows for the attachment of stabilizing clamping cauls if needed to hold the dish in position (figs. 13, 14).
11. CASE STUDY: TALLER VESSEL

The Sherline machine allows the milling head to be swung off to the side to accommodate taller and differently shaped objects. A substantial counterweight must be added to the base (fig. 15). This vessel was sampled adjacent to a loss area that was to be filled and inpainted (figs. 16a–d).

Fig. 16a. Preparing to sample adjacent to area of loss; 16b. Preparing to extract sample through tape; 16c. Successful sample extraction; 16d. Loss area after filling and inpainting by Straus Center Associate Conservator Susan Costello (Courtesy of Anthony Sigel)
12. AFTERWORD

These techniques have evolved in our lab in an effort to develop and refine safe and effective sampling methodologies, and are by no means ideal. We are extremely interested in learning how other practitioners solve these problems and look forward to hearing more about smaller-diameter, thinner-walled diamond drills, and machines that might combine a lever-operated drill head (quill type) with the micrometer-like precision and rheostat speed control offered by the Sherline machine.

SOURCES OF MATERIALS

Diamond core drills
Metalliferous
34 W. 46th St., 3rd Fl.
New York, NY 10036
212-944-0909
Suppliers of good-quality, perforated thin wall core drills with solid shanks; 2.5-, 3-, 3.5-, and 4-mm OD are available. Our lab has found the 3-mm OD to be a good balance of outer hole diameter/sample size.

Mylar sheet, Volara polyethylene foam
University Products
PO Box 101
517 Main St.
Holyoke, MA 01041-0101
800-628-1912
https://www.universityproducts.com

Newplast (formerly Harbutts) Plasticine
Conservation Resources International LLC
5532 Port Royal Rd.
Springfield, VA 22151
703-321-7730
www.conservationresources.com

Sherline milling machine and accessories
Sherline Products Inc.
3235 Executive Ridge
Vista, CA 92081-8527
800-541-0735
http://sherline.com/product/5400a5410a-deluxe-mill-package/
ANTHONY SIGEL is the Senior Conservator of objects and sculpture at the Straus Center of Conservation, Harvard Art Museums, responsible for three-dimensional art from ancient to contemporary. He was trained as a conservator at the Art Institute of Chicago Museum and received a BFA from its school. He was awarded a Certificate of Advanced Training in Objects Conservation from the Center for Conservation and Technical Studies, Harvard University Art Museums. He has worked five seasons at archaeological excavations in Sardis, Turkey, most recently as supervising conservator, and has published, lectured, and taught widely on conservation practice and technical art history. He is a Fellow of the American Academy in Rome, winning the Rome Prize in 2004, and of the Society of Antiquaries of London. In 2013, he co-curated the exhibition and co-wrote the catalog *Bernini: Sculpting in Clay* at the Metropolitan Museum of Art and the Kimbell Art Museum. He was appointed as Robert Lehman Visiting Professor at Villa I Tatti, Florence, Italy, in September 2016, studying the techniques of Renaissance sculptural models. He is currently program chair of the Objects Specialty Group, AIC. Address: Harvard Art Museums, 32 Quincy St., Cambridge, MA 02138. E-mail: tony_sigel@harvard.edu