Ceramic-based Mixed Media Topological Sculpture

Robert Fathauer

Tessellations Company, Apache Junction, Arizona, USA; rob@tessellations.com

Abstract

I describe several hand-built ceramic sculptures that make use of additional materials, including cane, leather, raffia, wood, metal, and stone beads. These other materials add uniqueness and interest in addition to delineating aspects of the mathematics underpinning the work. In particular, the different materials distinguish edges from surfaces in pieces based on Möbius strips and on knots with their associated Seifert surfaces.

Introduction

An important goal and major challenge for artists is the creation of genuinely unique and new work. Incorporating sophisticated mathematics in artworks is one tool that can help achieve this goal. Another challenge that is particularly relevant to mathematical forms is creating artworks that can't be readily generated by technologies such as 3D printing and artificial intelligence now or in the near future. When it comes to ceramics, the ability to create objects using 3D printing has existed since the 1990s and has been steadily advancing [2]. While several other materials, including metals, polymers, and concrete are readily 3D printed [6], many natural materials like wood, stone, and leather present significant challenges for 3D printing technology.

Möbius bands and knots have been widely used as subjects for sculpture, but for the most part with a single material such as stone, metal, or wood. Notable sculptors who have worked with these forms include Max Bill, Keizo Ushio, Helaman Ferguson [4], Charles O. Perry, and Brent Collins. These topics remain popular with contemporary artists whose work combines math and art [5].

I've previously made and exhibited mixed-media sculptures based on hyperbolic geometry. These were made by combining hand-built ceramic bases with crocheted hemp or yarn, the latter applied by a collaborator [3]. In this paper I describe six sculptures based mathematically on topological objects and artistically on hand-built ceramics. Half of these sculptures are based on Möbius bands and half on knots or links with their associated Seifert surfaces. A common theme is the use of a second material to differentiate surfaces and edges. The eye is natually drawn to the suface rather than the edge in these sorts of mathematical objects. Using different materials for edges and surfaces creates a more balanced perception.

In all of the pieces described in this paper I used a cone-10 (typical for stoneware, maximum firing temperature around 1085°C) white clay not containing sand. With the exception of the beaded Möbius strip, the starting point for each piece was a ball of clay. This was gradually formed into the desired shape over a period of several days, as the clay became more firm (dryer) and able to hold a more refined form. Once the built forms were sufficiently dry, sanding was performed prior to a relatively low-temperature bisque firing at cone 012 (≈ 860°C). An example of this process is shown in Fig. 1, where the Seifert surface for a figure-eight knot is shown at six progressive steps prior to firing. After some additional sanding, a final cone-6 (≈ 1220°C) firing was performed without the application of a glaze. Underfiring a cone-10 clay reduces the amount of distortion of the forms due to softening of the clay at the maximum temperature.

Sculptures Based on Möbius Bands

I based the first three sculptures (Figures 2–4) on Möbius bands, two with one half twist, and one with three half twists. With the exception of the last piece, incorporating metal wire, I fired them before the non-ceramic portions were added. This was required by the high firing temperatures of clay. It is possible to incorporate high melting-point metals and alloys in mixed-media pieces before firing.

Figure 1: *A figure-eight-knot Seifert-surface clay sculpture at various stages prior to firing, with successive refinements from a–d (before cutting holes around the edge) to e and f (after holes made).*

The starting point for the first piece was a clay Möbius band. Once the form of the band was relatively polished, I made uniformly-spaced holes around the edge, set back slightly from the edge. I cut these holes straight through with a pottery hole punch (essentially a metal tube cut at an angle). I chose caning pegs for the wood portion as an economical and esthetically-pleasing option. These pegs are designed for use in applying cane strips to objects such as wooden frames for chair seats. The pegs are approximately 3 inches long and tapered. To ensure a good fit, I pressed a peg into the uniform-diameter holes to give them a taper that matched that of the pegs. This allowed the pegs to be press fitted into the finished piece without the use of an adhesive (Fig. 2).

If one traces the single edge of a Möbius strip it takes two full revolutions to return to the starting point. The pegs, inserted such that they protrude much further in one direction than the other, emphasize this feature. In a short segment of the band there are pegs near both edges, oriented in opposite directions. The large size of the pegs adds drama to the piece and creates a very different impression from that of a plain Möbius strip.

In the second Möbius-band piece, I chose to define the band with the non-ceramic material and the edge with clay. I began this piece by wrapping a long strip of clay around a ceramic Möbius band to determine the form for a ceramic ribbon, essentially the edge of the band, that would support beads. I bowed the ribbon slightly inward to provide visual interest. When the clay was firm enough, I made small holes along the centerline using a pottery needle tool. In order to have the bead strings running at right angles between opposing portions of the strip, I had to vary the hole spacing. I used a uniform spacing in the half with tighter curvature, with a small wooden dowel used to determine the location of the wider-spaced opposing holes. I chose natural jasper for the beads and stainless-steel wire for stringing (Fig. 3).

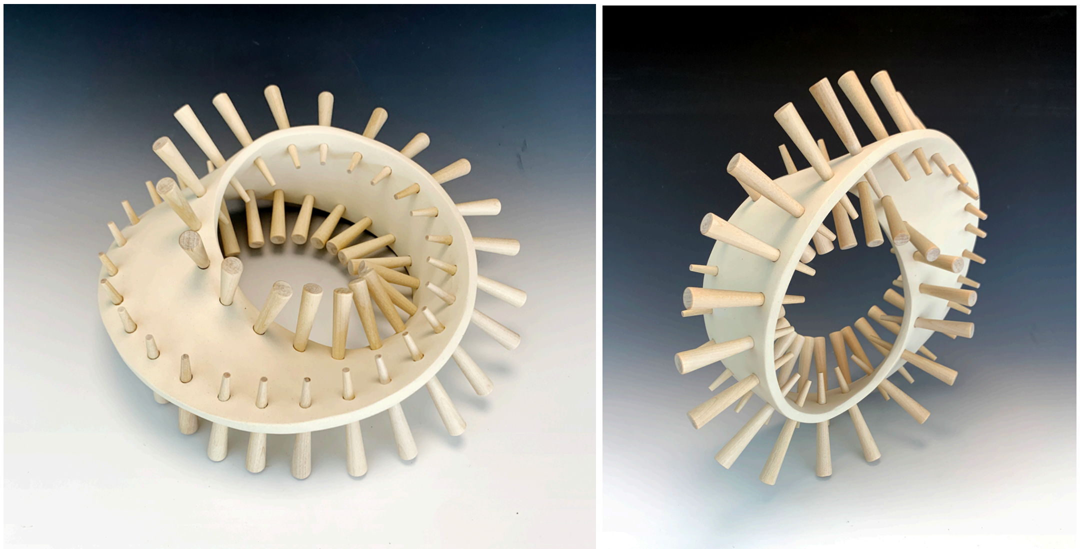

Figure 2: *Two views of a ceramic Möbius band with wooden pegs spaced along the edge.*

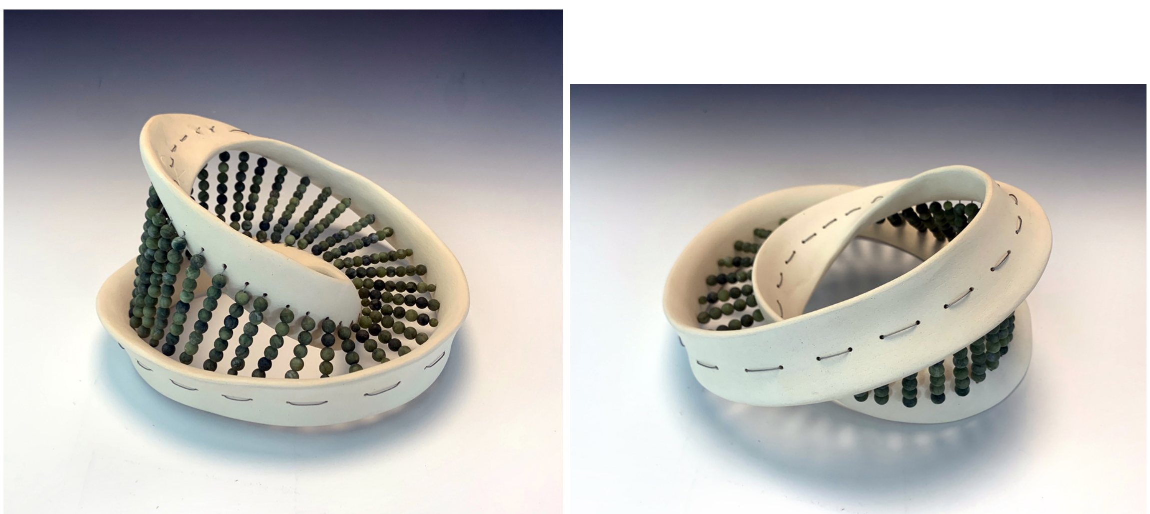

Figure 3: *Two views of a ceramic ribbon with natural jasper beads strung on stainless-steel wire to define a Möbius band.*

A band with three or any other odd number of half twists, like the canonical Möbius band, is one sided. The boundary of a band with three half twists describes a trefoil knot [1]. I formed a band of this sort out of clay, and before the clay became too firm pressed short pieces of 17-gauge CrNi (20:80) wire into the edge at regular intervals. Bisque firing was thus carried out with the metal wires in place (Fig. 4). The structural integrity of the wires is maintained, but there is some oxidation, changing the original shiny surface to a matte one. Assessing the piece at this point, I didn't think the wire emphasized the knot enough, so I decided to decorate the edge with rough smoky-quartz beads. The holes in the beads were too small to slip over the metal wire posts, so I strung them between the posts using stainless-steel wire (Figure 4)

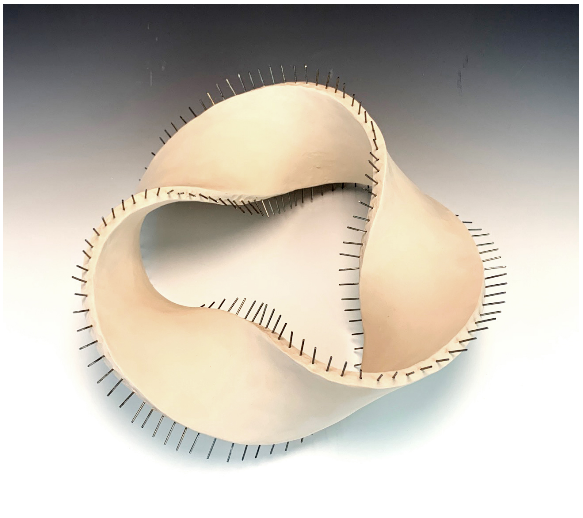 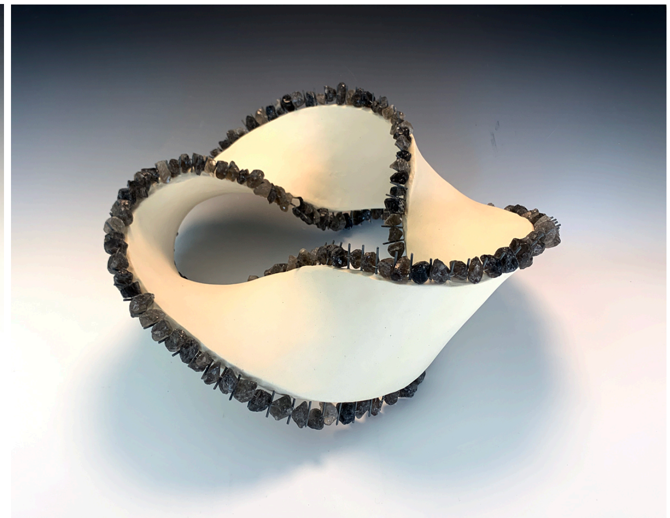

Figure 4: *A Möbius band with three half twists and metal wire decorating the edges to emphsize the trefoil knot; after bisque firing, and after final firing, with rough smoky-quartz beads.*

Sculptures Based on Seifert Surfaces

A Seifert surface for a knot or link is an orientable surface whose boundary is the given knot or link [1]. A convenient tool for visualizing Seifert surfaces is the computer program SeifertView [7]. I used this program to generate multiple views that I printed out and taped to a large board to serve as a visual reference during building of the clay portions of these pieces.

I based the first piece in this group on the Hopf link, which is simply two interlinked loops [1]. I formed a series of uniform holes, inset slightly from the edge, with a pottery hole maker. I chose raffia, which is fibers from palm leaves, as the material for the edge. This choice was inspired by the use of raffia on African masks. I wound numerous strips of raffia along the two edges and affixed them to the ceramic surface by looping raffia through the holes (Fig. 5). The juxtaposition of a traditional organic material with modern mathematics adds interest to the piece.

I based the second piece in this group on the trefoil knot, the lone knot with three crossings. Due to the fact that raffia was found to be less robust than desired for this application, I used cane strips. I affixed these to the ceramic surface using leather string (Fig. 6). This resulted in a sturdier edge treatment that is more likely to survive the rigors of handling and shipping over time. In the third piece in this group, I utilized the same construction method and materials but made use of the four-crossing figure-eight knot (Fig. 7).

One of my goals for this work was to explore the effectiveness of different materials for use with ceramics in topological sculpture in regards to esthetic impression, ease of building, and robustness to handling and shipping. Details of the interfaces between the ceramic and non-ceramic portions are shown in Fig. 8 for each of the five combinations of materials used. As noted above for raffia, strung beads were found to be somewhat less robust to handling of the finished piece than desired. Metal wire lengths were difficult to insert cleanly and keep in place during subsequent handling prior to firing. They also fail to visually bring out the edge strongly, a problem fixed by adding rough quartz beads. Esthetically, I think the wooden pegs and cane are the most effective. Compared to the wooden pegs, application of the cane was trickier and more labor intensive. Both should be relatively robust to handling and shipping.

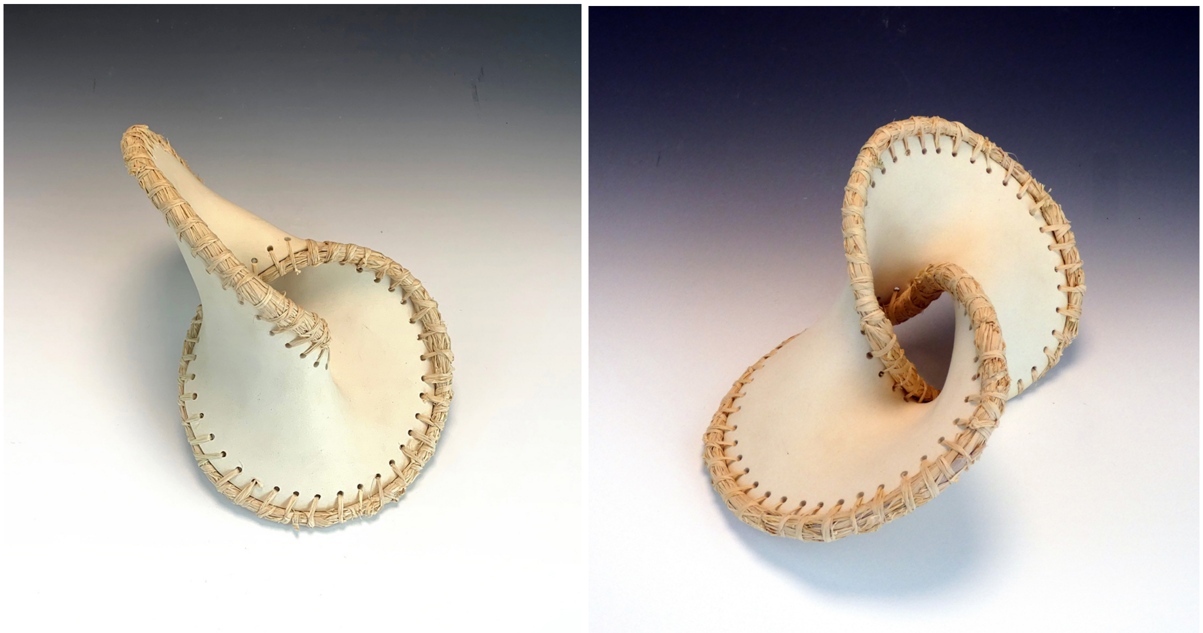

Figure 5: *Two views of a raffia Hopf link affixed with raffia to a ceramic Seifert surface..*

Figure 6: *Two views of a cane trefoil knot affixed with leather string to a ceramic Seifert surface.*

Summary and Conclusions

I used five different materials combinations in conjunction with clay to create sculptures of simple 3D topological objects with contrasting edges and surfaces. Cane strips affixed with leather string and wooden pegs produced the most satifying results overall. One extension of this work would be the use of cane with more complex Seifert surfaces such as those associated with the Borromean rings or a five-crossing knot. I could also use wooden pegs with Seifert surfaces. There are many types and forms of both wood and stone that could be employed in these sorts of sculptures. In regards to other materials that could be used alongside clay, one possibility is glass.

Figure 7: *Two views of a cane figure-8 knot affixed with leather string to a ceramic Seifert surface.*

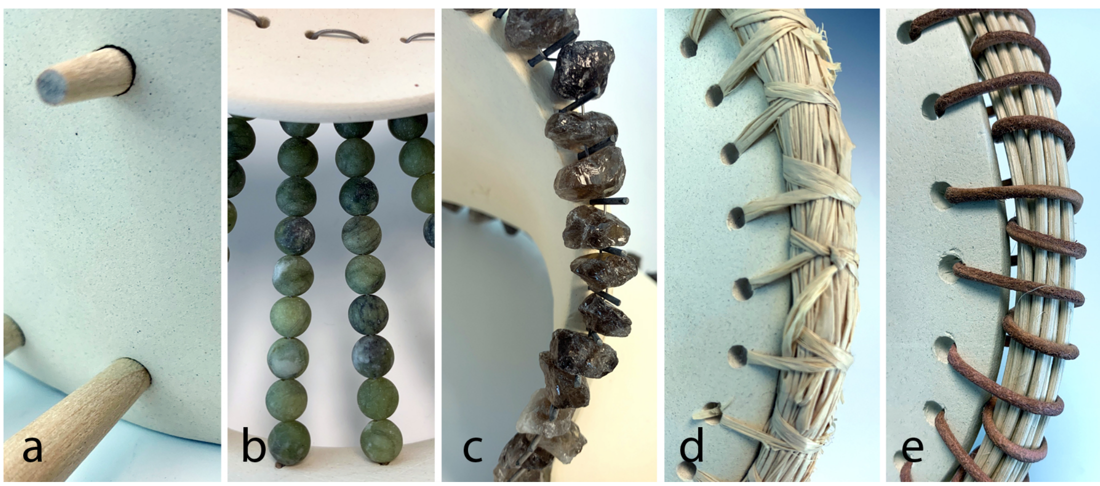

Figure 8: *Details of the use of different materials with clay: a) wooden caning pegs, b) jasper beads with steel wire, c) rough smoky-quartz beads strung between NiCr metal wire posts, d) raffia, and e) cane strips with leather string.*

References

[1] C.C. Adams. *The Knot Book*. American Mathematical Society, 2001.

[2] Z. Chen, Z. Li, J. Li, C. Liu, C. Lao, Y. Fu, C.Liu, Y.Li, P.Wang, and Yi He. "3D printing of ceramics: A review." *J. European Ceramic Society*, vol. 39, 2019, pp. 661–687.

[3] Robert Fathauer: Art inspired by mathematics and nature. http://robertfathauer.com/Ceramics.html.

[4] H. Ferguson and C. Ferguson. "Celebrating Mathematics in Stone and Bronze." *Notices of the AMS,* vol. 57, 2010 pp. 840–850.

[5] Mathematical Art Galleries. https://gallery.bridgesmathart.org/.

[6] T.D. Ngo, A.Kashani, G.Imbalzano, K.T.Q. Nguyen, and D. Hui. "Additive manufacturing (3D printing): A review of materials, methods, applications and challenges." *Composites Part B: Engineering*, vol. 143, 2018, pp. 172–196.

[7] J.J. van Wijk and A.M. Cohen. "Visualization of Seifert Surfaces." *IEEE Trans. On Visualization and Computer Graphics*, vol 12, 2006, pp. 485–496.