Prime Negatives: Parametric Sponge-Forming and Slip Casting for Ceramics

Mark Weston
University of South Florida, USA
MW@usf.edu

Abstract

Traditional methods for slip casting require the creation of prototype "patterns" for the making of molds. Computer modeling, however, can be understood to produce virtual positives, thereby suggesting a CNC production focused on the creation of negatives, or molds, without the need for a physical pattern. Three experiments in slip casting for ceramics are examined as a means of producing production parts without first making prototype patterns in the positive. Two techniques leverage computer modeling and CNC tools to directly produce formwork for casting positives, while the third technique uses a lost positive formwork for production of the final part.

Keywords: Ceramics; Digital fabrication; CNC; Computer aided manufacture; Parametric modeling.

Thinking in Negative

This project seeks to integrate ceramics, a traditional manufacturing technique, with parametric 3d modeling, a digital technique, to produce a hybridized system of manufacture which bridges the gap between the handcrafted object and industrial processes. Traditional modes of casting clay require a "pattern," or prototype positive part, from which to shape a mold, the negative of the pattern, for production casting. Researchers and practitioners have increasingly been seen to use CNC tooling and computation as a means to streamline patternmaking (Caldas & Duarte, 2005), but little has been done to address the possibility of skipping the prototype altogether; computers and machines can be used to make the negative, the mold itself (Muslimin, 2010), as a first step in the production process. The root of this line of thinking takes the premise that computer modelling can be understood as true analogue to the traditional patternmaking process. In other words, in this new mode of production the positive prototype is virtual. To address this thesis, three experimental modes of negative manufacture provide an empirical framework for inquiry: stitch and pour formaking, pour and carve formaking, and CNC spongeforming.

Casting

Traditional casting techniques for casting complex forms in liquid clay require mastery in the forming and shaping of plaster. Plaster is a porous material which, as a molding matrix for clay, has the dual benefit of possessing an incredible ability to absorb water, combined with a relative inability to adhere to dried clay. Plaster, however, is both heavy and brittle. This means that as the dimensions of the piece to be cast grow larger, so too do the logistical complications of moving and de-molding large, heavy plaster molds. It is well known among craftsmen that due to chipping and other forms of wear, the lifespan of plaster molds is limited. As work grows larger, mold lifespan grows logarithmically shorter, and the detail of each finished product declines. Additionally, plaster molds for complex forms require compound pieces, the multiplicity of which increase dramatically as the formal complexity of the part to be cast increases. This cumulative intricacy represents both an increase in labor and a decrease in mold life due to wear between parts (Reijnders & EKWC, 2005). The use of cad cam technology for the creation of ceramics allows the integration of traditional craft with existing and emerging industrial technologies (Celento, 2009). The constraints of the manufacturing process are challenged by a material that is otherwise bound only by physical characteristics such as size and moisture content.

Stitch and Pour Form Making

Stitch-and-Glue is a form-making process which comes directly from the modern boat building industry (Figure 1). A three dimensional form for a boat is modeled, simulated, streamlined, then flattened into panels. The panels are cut on a cnc router, then "stitched" together using copper wire, cable ties, or cellophane tape. Once the edges of the flat panels are reunited along their length, a 3-dimensional form of a boat emerges from these lines. This form is then fiber glassed and finished. The result is a handmade boat with a digital genesis; a hybrid of two worlds of craft in making. Extrapolating from this process, a form was devised for a twisted, lofted, ceramic object. In a normal ceramics process for creating molds for slip casting, it is necessary to create multi-part molds to avoid undercut. For this experiment, the lofted trumpet shape was devised to create a situation where a traditional mold making process would result in such undercuts. The benefit of modeling in the computer allows the creation of complex multi-part molds, but the surfaces of these molds can be controlled directly, and manipulated to avoid undercutting. The result of this thinking is a "stitched" form work for making a mold for slip casting in two parts (Figure 1).

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Figure 1: A stitch and glue canoe in production. Photo: Kevin Saff

This "pre-form work" can possess a complex surface which serves to eliminate undercutting in a two-part mold, as well as to eliminate the various traditional key-making techniques necessary for refitting form work together; the form is sufficiently complex to serve as a "keyless" fitted mold when assembled for casting (Figure 1).

One of the stated goals for this project has been the integration of traditional notions of craft with contemporary practices of making; one aspect of this philosophy is a desire to create a built environment which reflects the process of making in every finished product. The decision to leave the cable ties in place for the creation of the form was deliberate, and can be seen to leave "stitched" impressions on the final form of the cast object (Figure 1). These conceptual stitches will not be cleaned off in the final product, as they might be in a traditional practice, such as in the trimming and smoothing of the seam lines in a slip-cast pot.

Pour and Carve

For the purpose of this exercise, two blocks of plaster were created to be milled on a CNC router (Figure 2). Plaster is an inherently easy material to carve, and offers little resistance to the rotary action of the tool. Plaster dust, however, is extremely fine and tends to find its way into any uncovered surface in the room, including the moving parts of the machine. The abrasive qualities of plaster will gradually destroy typical machinery, and so care must be taken to avoid airborne plaster dust in the cutting room. To this end plaster blanks can be sprayed with water repeatedly during cutting, or indeed cut while the plaster is still quite wet subsequent to curing. Other techniques such as the use of oil to hold down dust can negatively effect the porosity of plaster, and so too its ability to absorb water, an essential characteristic of plaster molds for slip casting.

The form to be created in this experiment resembles a reptilian scale, and is designed to be replicated and layered like the tiles of a Mediterranean roof. Similar to the stitch-and-pour exercise, the CNC milled form work (Figure 2) is sufficiently complex to serve in a "keyless" mating when strapped together for casting and created a perfect leak-free form. The hole in the top of the form serves as a spout for pouring slip into the mold, and likewise for pouring slip out of the mold once a sufficient wall thickness has built on the surface of the plaster. Once de-molded, a hole is thus created in the top of the tile as a didactic device, revealing that the object is hollow, and is a result of a slip casting process. The surface of the mold interior, and thus of the completed ceramic form, is left deliberately rough. These overlapping ridges are a result of the tool path of the CNC router bit, in this case a spiral flush-end mill. The tool path was created to deliberately texture the surface of the object. Design choices in this realm leave much room for exploration within both the appearance and material performance of the object itself. In the case of roofing tiles for example, increased surface area and porosity can allow the absorption, and thus evaporation of water in the surface of material (Figure 2). This can be used to create a deliberate passive cooling effect from the energy absorbed due to the heat of evaporation of water. Surface textures can be specifically designed to take advantage of such effects (Lilley, et al., 2012).

Figure 2: Left to Right; Stitching the pre-form, preform ready for plaster pour, assembled plaster mold, liquid clay fills the mold, mold is opened as the clay becomes leather hard, completed ceramic object ready for firing.

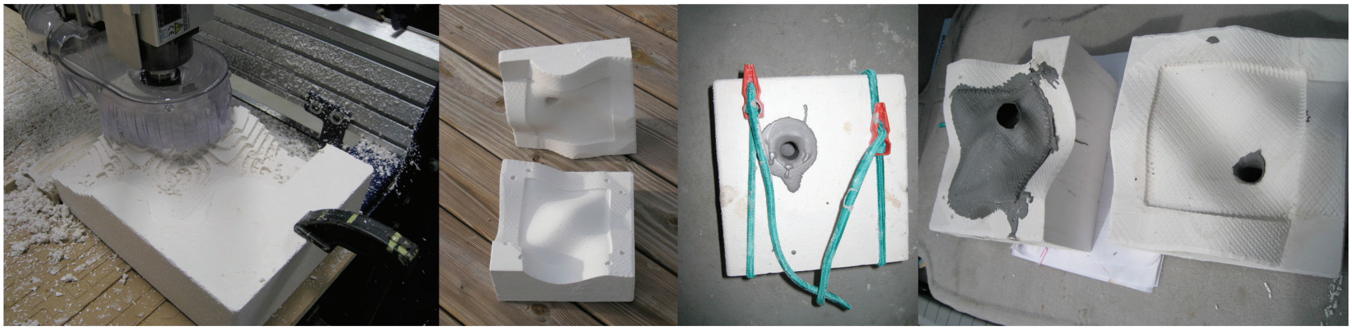

Figure 3: Left to Right; milling wet plaster, completed plaster mold, assembled plaster mold filled with liquid clay, mold is opened as the clay becomes leather hard.

CNC Sponge Forming

This experiment focuses on a the exploration of novel mold making technique for casting liquid clay using CNC milled, flexible, open-celled foam as a temporary shape holder during firing. The foam acts as a “lost positive” formwork which can neither be considered a traditional positive prototype, nor a negative mold. This technique offers the possibility to allow the creation of complex forms in ceramics which would be either impossible or prohibitively expensive using traditional plaster mold making practices. The idea involves a conceptual breakdown of a complex form into a primary shape with a secondary level of detail. This secondary detail of any cast piece, when translated to plaster, is the most expensive and least durable portion of a mold. A primary or platonic form such as a cylinder, sphere, or prism however, can be quite durable as a plaster understructure. It is the layer of secondary detail therefore, which can be flattened in the computer to be milled from flexible foam on a CNC router. Inexpensive and commonly available flexible foams, such as those used in kitchen sponges and mattresses are difficult materials to mill. They have a tendency to spall, melt or accumulate at the end of a rotary cutting tool, or to actively deform away from the tool with each pass (Figure 4).

The research accounts for this behavior by stiffening the material using combinations of rice or potato starch, cellulose gum, or even dried clay. Stiffened foam cuts quickly and precisely, thus reducing machine time. Since the foams in question contain roughly ninety percent air, shop dust and material waste are also greatly reduced.

Figure 4: Spalling in an unprepared sponge

The cut foam is then soaked with liquid clay, wrung to remove excess clay, and wrapped around or inside a primary plaster formwork for drying. The clay impregnated sponge, once dry, is then fired in its entirety, burning away the sponge and leaving only a lightweight, porous ceramic matrix. The resulting material is porcelain, stoneware, or earthenware foam which exhibits excellent fine secondary detail and perfect primary form (Figure 5). As an avenue for future research in architectural cladding materials, the eventual products would potentially exhibit high thermal and acoustic performance for buildings, and could also aid in the absorption of environmental pollutants.

Figure 5: Machining hardened sponge, completed part soaked in clay slip, part placed over rounded primary form for drying, fired part showing excellent detail

Conclusion

Traditional mold making is done through a "sculpt and pour" process in which a prototype for the final product to be created is sculpted by hand, then used as a positive for a mold making process involving plaster. It is possible to mimic this method by first creating a positive from a CNC manufacturing process, and then to take molds from that form, and in fact this has been done with great success The 3d modeling process, however, can be understood to create a virtual positive without the need for the output of a positive prototype.

The experiments presented here are by no means perfect methods for the creation of slip cast objects; much room is left to optimize or build on the basic framework of a negative-first approach. Stitching together pre-forms for plaster, for example, is time consuming and is prone to leaks. Milling plaster causes significant wear and tear on machinery without proper preparation. Foamed ceramic, without a means to create a perfectly even slip saturation through the sponge form, can become extremely fragile. Indeed, as for the premise itself of the "prime negative," one misses the hands-on relationship to scale provided by physical prototypes which can never be matched in a computer simulation. Nevertheless, the results of these short experiments do successfully demonstrate viable alternative methods for production. And while the value of a model versus a simulation should be understood to be different, clearly an effective type of empirical process can be undertaken by skipping the positive form, and instead sculpting, from plaster, a negative formwork.

Acknowledgments

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References

Benyus, J. (1997). Biomimicry: Innovation Inspired by Nature. New York: Morrow.

Caldas, L., & Duarte, J. (2005). Fabricating Ceramic Covers Rethinking Roof Tiles in a Contemporary Context. In Duarte, Ducla-Soares, & Sampaio (Ed.), Digital Design: The Quest for New Paradigms, 23rd eCAADe Conference Proceedings (pp. 269-276). Lisbon: Architecture in the Network Society [22nd eCAADe Conference Proceedings].

Celento, D. J. (2009). Digital Craft Meets the Ancient Art of Ceramics: Would the Bauhaus Approve? Proceedings of the 13th Congress of the Iberoamerican Society of Digital Graphics, (pp. 104-106). Sao Paulo.

Lilley, B., Hudson, R., Plucknett, K., Macdonald, R., Cheng, N. Y.-W., Nielsen, S. A., et al. (2012). Ceramic Perspiration: Multi-Scalar Development of Ceramic Material. San Francisco: ACADIA 12: Synthetic Digital Ecologies [Proceedings of the 32nd Annual Conference of the Association for Computer Aided Design in Architecture (ACADIA).

Muslimin, R. (2010). Parametric Fabrication for Traditional Ceramics: A Dialectical Integration of Traditional and CAD/CAM Methods in Computational Design. SIGraDi 2010_Proceedings of the 14th Congress of the Iberoamerican Society of Digital Graphics, 1, pp. 222-228. Bogotá.

Reijnders, A., & EKWC. (2005). The Ceramic Process: A Manual and Source of Inspiration for Ceramic Art and Design. London: AC Black.