3D Printed Ceramics for Tableware, Artists/Designers and Specialist Applications

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Abstract. The Centre for Fine Print Research at the University of the West of England has over five years experience in the 3D printing of ceramic materials. The first project undertaken was to investigate the use of 3D technologies for artists and resulted in the development of a patented ceramic body suitable for use in Z Corporation 3D printers. After bisque firing this material can be further processed using conventional glazing and decorating techniques. A follow on project has resulted in a modified ceramic body and the development of firing supports to enable thin section ceramic tableware to be produced for ceramic industry concept modelling and short run or one-off pieces for artists and designers. This paper will detail the progress of the research and will explain by using case studies and examples of collaboration with a leading UK pottery manufacturer, individual artists and designers how this novel technique can be utilised to form shapes and forms difficult or impossible to realise by conventional forming methods. The potential of how the ability to form ceramic objects with complex internal structures could be beneficial to more specialist ceramics industries will also be explored.

Introduction

The Centre for Fine Print Research is an interdisciplinary research centre focusing on visual arts and creative technologies based in the Faculty of Arts and Creative Industries. We were first introduced to 3D digital technologies and rapid prototyping techniques during an earlier Arts and Humanities Research Council (AHRC) funded project to investigate CNC milling of photo-ceramic relief tiles. A subsequent project, again funded by the AHRC, “The fabrication of Three Dimensional art and craft artifacts through virtual digital construction and output” was used to investigate the use of 3D rapid prototyping and digital fabrication techniques for artists and crafts persons. The appearance of relatively low cost 3D powder printers and 3D scanners from Z Corp. USA, gave rise to the idea that these technologies could perhaps be used to generate and 3D print artworks. The Z Corp. system uses two moving beds of powder traversed by a carriage consisting of a roller to move a precise thickness layer of powder from the feed bed to the build bed and an ink jet head that moves north and south on the same carriage. The printer software slices a 3D virtual model into layers 100 microns thick and sends each layer to the print head sequentially; each layer represents a cross section of the model. The ink jet head prints binder onto the powder build bed in the pattern of the layer cross section, the build bed drops down by a layer thickness, the roller mechanism moves across to the feed bed which rises by a layer thickness, the roller then sweeps the layer of powder from the feed bed across onto the build bed and the process is repeated until the model is built. After allowing about one hour for the model to set, the model can be removed from the build bed and the excess powder is removed.
Fig. 1a. Z Corp. 3D printer schematic diagram.

Fig. 1b. Z Corp. 3D printing process.

Fig. 1c. Z Corp. 3D printing process.

Fig. 1d. Z Corp. 3D printing process.
Fig. 1e, Z Corp. 3D printing process.

Fig. 1f, Z Corp. 3D printing process.

Fig. 1g, Z Corp. 3D printing process.

Fig. 1h, Z Corp. 3D printing process.
3D Ceramic Printing

Having successfully used the standard Z Corp material to produce artworks it was decided to investigate replacing the Z Corp material with a ceramic body powder. Several researcher teams have investigated the Z Corp 3D printing process (which normally prints with plaster based powders) to fabricate ceramics including the original inventors of the process, Yoo and Cima at MIT [1]. More recently the Centre for Fine Print Research at the University of the West of England, Hoskins and Huson [2], Bowling Green University, Balistreri [3] and University of Washington, Ganter [4], have undertaken research replacing the standard material with a ceramic body material. Ganter has concentrated on producing a low cost open source system to reduce the cost of prototyping in an educational context. Balistreri has also used the process to make ceramic artworks.

Initial attempts to 3D print with commercial spray dried ceramic body powder proved to be unsuccessful, the 150 micron particle size of the spray dried material was too coarse for the Z Corp. 3D printer spreading process and no substantial binding of the material occurred. Over the course of the project a new type of ceramic body that performed in a similar way to the recipes used for tableware manufacture was developed that could be used in Z Corp. printers to replace the proprietary material. In conventional ceramic tableware forming processes, a clay based body that is composed of a mixture of different components that partially melt together to form a fired ceramic is used, an industrial ceramic body will contain clay minerals which exhibit plastic properties when mixed with water and this allows the ceramic body mix to be shaped or formed into mould and provide the green (unfired) strength to the mix. Other components such as feldspathic fluxes are added as they form a glass like structure during firing to bind the materials together. The final ingredient is silica in the form of flint or ground sand that acts as a filler and is vital to obtain the correct thermal expansion of the fired body to ensure a good glaze fit. It was found that the plasticity of the clays in a conventional body was detrimental to the 3D printing process causing the layers to become unstable and to shift during printing. By replacing the clays with a non-plastic materials and adding organic binders to the mix, and with close control over the particle size of the constituents, a body was developed that could be successfully 3D printed and fired.

A series of test shapes were used to demonstrate the process, including a trumpet shaped structure and a lattice sphere with an encapsulated ball to show how shapes impossible to manufacture by conventional ceramic forming methods could be made by 3D printing a ceramic material alongside a conventional vase form.
This project successfully demonstrated that 3D printing with ceramic materials was a viable method for the production of ceramic artworks and a series of ceramic works were produced for several artists. During the course of the project, it was realised that there may be other commercial applications for this process, although the physical properties and characteristics of 3D printed ceramic tableware bodies are not yet comparable with ceramic bodies produced by conventional forming techniques and would not be able to withstand the rigours of daily use in terms of chip resistance and dish washer suitability. One area where the process could find an immediate application would be in concept modeling for new design shapes. In collaboration with Denby Pottery, a leading UK ceramic manufacturer, a successful bid application for follow on funding was made to the AHRC to investigate the viability of using this technology to produce design concept models for the tableware industry.

The Z Corp printing method used by Denby Pottery employs 3D CAD software to develop designs, which are directly printed using standard Z Corp material. The design process allows multiple iterations to take place and creates a model with the same shape and section as the final piece but in a plaster material that cannot be fired or take glaze, decoration or be tested for its functionality. Denby Pottery were seeking a concept model process that looks and feels like the final product which can be fired, glazed and decorated and can be fully tested for functionality. Common characteristics displayed by all 3D printed ceramic forms compared to conventionally formed ceramics are that they exhibit a high firing contraction and distortion, a high porosity and low strength. These disadvantages can be allowed for in the production of one off artworks but can cause serious problems when attempting to reproduce a commercially acceptable tableware shape.

Conventionally, highly vitrified thin section bodies such as bone china and porcelain used in tableware require profile setters during firing to maintain the integrity of the shape. Profile setters are purpose built ceramic supports that have a similar expansion and contraction rate to the object they are supporting. So when fired, the ceramic article, will not warp unduly because its profile setter supports it. However these support systems would not necessarily be suitable or available for new concept shapes. A system was developed to 3D print these support setters at the same time and in the same material as the concept model and to fire the concept model supported by it’s own custom setter, a light dusting of alumina powder is applied to the setter to prevent the two parts sticking together during the firing. By using this process it proved possible to produce industry quality thin section shapes by 3D ceramic printing.

3D printed bespoke ceramics

Using the same techniques of 3D printing a firing support at the same time as the model developed during the project with Denby pottery, a bowl inspired by a 16th century Italian Majolica bowl was created by the CFPR 3D printed ceramic process.

A 3D CAD model of the bowl was first created. This was based upon measured drawings made from photographs of 16 century majolica bowls. The design for a setter to support the bowl during firing was also created at this time (fig. 5).

The bowl with setter was 3D printed in ceramic and was then dried in the oven, de-powdered and placed in the kiln to be fired at 1200 °C. Following this, an opaque white glaze was applied to the bowls and they were then fired for a second time at 1050 °C. On-glaze ceramic transfers were applied to the glaze surface of the bowls and then they were fired for a third and final time at 800 °C. The glazed and decorated bowls are shown in fig.8.

This case study demonstrates that the ceramic powder-binder 3D printing process developed by the Centre for Fine Print Research at the University of the West of England can be exploited to create bespoke and limited edition ceramic artefacts which can be fired, glazed and decorated, resulting in a similar look and feel to conventionally-produced ceramics.
Fig. 4, 3D printed ceramic Denby sugar bowls, fired and glazed.

Complex structures

One more area investigated during the research project was the development of 3D printed ceramic complex structures, these objects demonstrate the ability of the 3D printed ceramic process to form lattice shapes and complex high surface to volume ratio structures in ceramic that would be impossible to construct using conventional processing.

Summary

The project has shown that 3D printing of ceramics using a modified tri-axial tableware type ceramic body is a viable process for the production of industrial concept models and one off/limited run ceramic artworks. The development of complex internal structures and high surface to volume shapes has the potential to be of use in more diverse industries using ceramic components.
References


