Photo Ceramic Relief Imaging

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Abstract

The Photo Relief technique, developed at the turn of the 20th C, is one of the few methods of ceramic decoration able to reproduce a permanent fully continuous tone image on a ceramic surface by combining the use of varying glaze depths with a relief image on the ceramic surface.

David Huson and colleagues at The Centre for Fine Print Research have conducted a research project to re-examine the original photo ceramic relief imaging techniques, to assess how modern technology and materials may facilitate both its improvement and application for contemporary use in tiles, architectural panels and other ceramic artifacts.

One of the principal strands of investigation has focused on the use of digital technology for the creation and conversion of images into relief surfaces to establish alternatives to the traditional photomechanical relief forming processes.

By the use of digital image processing techniques, 3D design software and a desktop CNC milling machine, it has proved possible to develop a process that enables a 3D relief image to be machined into a ceramic mold, or directly into a ceramic substrate. The application of a specially tinted glaze to the relief produces a permanent continuous tone photographic image.

Introduction

Photo Ceramic Relief Imaging is the subject of a 3-year research project conducted by the Centre for Fine Print Research based in the Faculty of Art, Media and Design at the University of the West of England in the UK.

The ceramic relief tiles created in the early 20th C by the Staffordshire potter George Cartlidge, and the patented experiments of the American Walter Ford from the late 1920's inspired the project. The aim of the project has been to re-examine the traditional processes used to produce these low relief continuous tone photo ceramic images and to assess how modern technology and materials may facilitate the improvement of the techniques, its visual appearance and the potential application for contemporary use in tile decoration. One of the principal strands of investigation has focused on the use of digital technology for the creation and conversion of images into relief surfaces to establish alternatives to the traditional photomechanical relief forming processes. This is achieved through both digital capture and file conversion to conventional CNC milling technology.

The Centre for Fine Print Research at the University of the West of England, Bristol, has been successful in applying modern techniques to forgotten methods of image production within the field of traditional printing technologies and has built up a considerable expertise in 19th C photo mechanical printing processes.

This project was approached from three areas:

1. An investigation into the historical context of the process and the traditional methods of producing a photo relief.
2. The use of digital technologies for the conversion of images to relief surfaces and the use of rapid prototyping machinery to produce a physical relief.
3. An investigation into the type of glaze, stain and application methods needed to reproduce the photo ceramic image.

Original Techniques

Origins

The origins of the photo ceramic relief process can be traced to the invention of the lithophane, patented in 1827.

For this technique, a relief design was modeled by hand in wax and then cast in plaster. From the plaster, a thin sheet of porcelain was cast and then fired. On firing, the porcelain became semi-translucent, and when lit from the behind allowed the finished lithophane to reveal a fully toned image in its surface. Another traditional ceramic technique influencing the development of the photo relief was the Emaux Ombrant. This was essentially a ceramic tile cast from a hand molded plaster relief. After bisque firing, the tile was covered with a lightly colored glaze, and fired again. During the second firing, the glaze pooled into the various depths of the decorative relief; the deepest parts of the glaze filled relief forming the darker, more opaque parts of the design, while the shallower more translucent areas, formed the lighter tones. Unlike the lithophane, the Emaux Ombrant image could be seen clearly on the surface of the tile without the necessity of using a translucent porcelain body or backlighting.

Developments

By the end of the 19th C the photo ceramic tiles of George Cartlidge had appeared. Despite their obvious photographic look there has always been some controversy about these tiles, this stems mainly from a claim made by Cartlidge himself that the work was entirely modeled by hand. The most comprehensive collection of Cartlidge tiles is in the City Museum of Stoke-on-Trent in the UK, it includes examples of Cartlidge's earlier hand modeled Emaux Ombrant technique as well as a complete series of the later photographic portraits. In what context Cartlidge made his statement is open to conjecture, however, it is certainly known that photographs were used, at least as a reference for the creation of the portrait tiles. Whatever the means used, it is difficult to deny that the image character of Cartlidge's tiles closely resembles many of the continuous tone photomechanical printing techniques popular during the latter part of the 19th C.

Research undertaken as a part of this project at the Bags Memorial Ceramic Museum, Columbus, Ohio, in many ways confirmed this notion through the discovery of the work of another photo ceramic tile practitioner, Walter Ford. Although Ford's experiments with photo relief tiles were conducted several years later, they possess the same qualities as the Cartlidge tiles. There is documentary evidence to confirm Ford used a photographic negative to generate a gelatin matrix, from which his tiles were cast.

Based upon this evidence, it was decided to try to produce a photo relief matrix by using these bichromated gelatin techniques. Although the techniques used by the 19th C printers differ slightly from the methods documented by Walter Ford, both involve exposing a light sensitized sheet of gelatin through a continuous tone photographic negative and then either washing away unexposed gelatin, or swelling the hardened gelatin (the Ford method) to produce a relief. Reliefs were produced both ways, but better results were obtained by using the Ford method, and it proved possible to produce sufficient relief to give a photographic effect when used to produce a cast mold and a subsequent glazed tile, although the depth of relief was not as great as that observed on the Cartlidge tiles.

The process to produce the gelatin relief is time consuming, complicated and not always successful, and as part of the projects remit to investigate modern technology and materials, it was decided to utilize research conducted into photopolymer plates at the CFPR to produce a relief matrix by this modern method. Several types of photopolymer plates of varying thicknesses and properties were used. By careful control of the exposure, it was possible to produce a relief matrix that could be used to form a tile mould. From these molds tiles were cast and glazed and compared to tiles produced by the gelatin methods. Although these tiles exhibited a greater, more controllable, relief, than the tiles produced from a bichromated gelatin relief, and were much quicker and easier to make, they had difficulty in reproducing the fine detail exhibited by the gelatine relief and the image produced was less satisfactory. This method has not been pursued any further.

The Digital Approach

Software

The use of digital technology means that the photographic image can be manipulated by using a software program such as Adobe PhotoShop, and original images can be produced entirely by using such software. While it is possible to process these images and output them to film for the relief matrix to be produced by the traditional gelatin process, a more controllable method for producing the relief matrix was needed. Research into alternative methods for producing a photo relief matrix revealed that software was available that could be used to convert digital images into 3D relief data. After investigating the software, it was decided to use a package called ArtCAM produced by Delcam. This software converts a photographic image into a grayscale, and then assigns, across a preset range, usually 256 grays, a relief height in direct relation to the tonal ranges in the image; the darkest tones in the image assume the lowest height in the relief, while the lightest tones assume the highest values. All the other tonal ranges are distributed as different stepped heights between these assigned values. The digital relief generated can be visualized on screen and can be further manipulated if required, in the relief conversion software, by the application of different filters and adjustment tools. It can be reversed or inverted as required for mold making purposes, and modified to provide the optimum parameters for the production of the photo ceramic image.

The relief generation software gives all the tools to produce a "virtual relief" but a way still has to be found to translate this to a physical relief to allow a mold to be made to produce the photo ceramic tiles.

Wax Deposition

To confirm that the software would produce a viable photo relief matrix, trials were run on a wax deposition rapid prototyping machine and a working mold in potters plaster was produced from this matrix. From this mold tiles were cast, fired and glazed, with very successful results. Unfortunately, although the wax deposition equipment proved that the process was viable there were a number of limitations. The wax matrix produced was fragile and could not be used directly to produce a working cast mold in plaster to form a ceramic tile. A castable silicone rubber interface had to be produced and then used to make the working plaster mold required. The wax deposition machine is also relatively costly and a more affordable alternative would be preferable.

CNC Milling Machine

Previous research within the Centre for Fine Print Research had indicated that a computer controlled milling machine (CNC) might be suitable for this purpose and desktop 3-Axis CNC milling machines are now available for about a tenth of the cost of a wax deposition machine. Preliminary trials on a CNC milling machine in the Engineering Department of the University showed promise, and a SIGEAVISEO desktop CNC machine with GALAAD control software was subsequently obtained. The machine has a work envelope of 300 mm × 210 mm × 100 mm in the X, Y and Z planes. The CNC machine uses a tool mounted in a rotating spindle to cut into a machinable substrate, the movement of the tool is controlled by a computer and moves with an accuracy of 0.01mm on three axes, allowing a three dimensional relief to be cut into a substrate.

Substrate

Work was required to discover the best material to use as a substrate; investigations were carried out into the various types of machinable substrates available. It was decided to use plaster as the substrate because of its ready availability and ease of machining without dust extraction. The fact that it could be easily cast into the required size and shape and that it opened up the possibility of it being machined directly to produce a working mold.

Tools and Tool Paths

Once a satisfactory conversion of an image to a relief has been performed by the software, it is then necessary to generate a tool path file. The ArtCAM software creates this. The size and the shape of the tool are selected, along with the machining strategy and an ISO file containing the code necessary to drive the machine is produced. This file is imported into the GALAAD control software and used to run the CNC machine. The choice of tool type and diameter along with the machining strategy adopted is crucial to the success of using this process to produce relief images. Tools of varying shapes and diameter have been tried, but the tool used is a compromise between resolving the detail in the image and the time taken to cut the relief. From the point of view of resolution it is preferable to use a fine tipped tool. A pointed engraving tool was tried and gave good results but because of the fine step-over distance between the tool paths, the time taken to machine large images would have been prohibitive. Fine ball nosed tools of 1mm diameter were tried and gave good results but again the step-over settings produced a prohibitive machining time. After many tests it was decided to use end slot tools of 0.8mm diameter with a step over of 0.3 mm. Care has to be taken not to drive the tool too fast as this can result in breakage. This combination enabled an image matrix of 290 mm by 200 mm to be machined in approximately 15 hours using a simple X-axis raster machining strategy. The very mechanical nature of CNC milling means that the stepped image file is translated into continuous tone, because the milling machine takes the shortest route between two points, thus avoiding stepped pixelation. The close control over all the steps in the process means that this procedure is much more precise than the traditional methods examined. In conventional printing terms a fairly crude photographic image may be used, as the pixelated steps are treated as points on a three-dimensional mapped graph.

Production of Photo Ceramic Tiles

Molds and Casting

Dust pressing, a mass production process that uses heavy metal dies and expensive equipment suitable for large-scale production methods, was used to produce the original 19th C photo ceramic tiles. In this project for reasons of cost and flexibility this method was replaced by slip casting, a ceramic process that uses high-density clay slurry cast into plaster molds to produce the clay tile. After drying, the tile is fired to a bisque state, glazed and then fired again to produce the finished tile. This process enables simple one-piece molds to be made quickly and easily for the initial experimental tests. For the production of larger tiles, two-part casting molds were used. Tiles were initially produced by machining into a plaster substrate; a copy of the machined surface was produced using a castable silicone rubber molding material. The silicone rubber was used as an insert into a hard plaster case mold to provide the relief image. This case mold was then used to produce a mold for casting the tiles. This traditional method for producing working plaster molds for slip casting is time consuming and labor intensive, it employs multiple positive and negative physical copies of the relief image and the tile body shape, thus allowing new mold components to be made as the existing molds wear out.

By utilizing the 3D design software and the CNC milling machine it has proved possible to move away from this traditional process. All of the necessary design information can be stored on the computer rather than in physical form. By using potters plaster as the machinable substrate, it is possible to machine a new mold from a plaster blank to replace worn out molds. For the production of a short series of tiles, and to facilitate development work, a procedure has been adopted where the image and tile form is machined into a plaster substrate, to produce one half of a working mold. By the addition of a previously made blank mold back, a two piece mold for tile casting can be produced quickly and simply. With increasing experience of the machining process, it has been discovered that it is possible to successfully cut directly into a dry clay surface and tiles have been produced by the milling of unfired dust pressed tiles, for the production of one off tiles this method gives an exceptionally clear and precise image.

Glazing

A lightly stained glaze applied on top of the relief surface cast into the tile produces the image on the photo ceramic relief tile. For the first set of trials standard leadless glazes were used, in conjunction with a selection of commercially available glaze stains. Results gained from these tests however were not able to produce the photographic effects observed in the original 19th C tiles. Instead, a milky, over-glazed effect was observed, which obscured the image detail of the relief. Reducing the percentage of stain addition to the glaze made the image clearer, but apart from in the lower parts of the relief, the photographic quality of the image was still not entirely apparent. To achieve the required tonal range it was required to use a glaze with a very small quantity of stain addition. This meant applying a very thick layer of glaze, up to 2mm of fired thickness, to ensure that the dark areas of the image were sufficiently opaque. With the leadless glazes being used, applying this amount of glaze meant that glaze rejection would be a problem, as would the lack of translucency in the thick glaze layer. To resolve this problem and to achieve the degree of translucency needed, it was necessary to use a glaze system more tolerant of a heavy application, as well as the ability to retain a high degree of translucency at these application levels. In the original 19th C tiles, a lead based glazed would have been used as it had all of the required characteristics. It is impossible to use raw lead glazes today because of the obvious health and safety considerations, but it is possible to use a low solubility lead fritted glaze. Where the lead component of the glaze is encapsulated in an insoluble glass form. The use of low solubility glazes gave a considerable improvement in the image quality produced, and results comparable with the original tiles achieved.

Summary

Through the application of digital image processing technology allied to fine CNC milling subtractive rapid prototyping technology it has proved possible to re-vitalize a neglected form of ceramic decoration and reproduce a continuous tone image on a ceramic surface. As part of the project ten artists were invited to submit a contemporary image, and photo ceramic tiles were produced by the process described. The tiles were exhibited at the City Museum of Stoke on Trent in the UK alongside a collection of tiles produced in the 19th C by George Cartlidge.

References

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Author Biography

David Huson is a Research Associate at the University of the West of England. Previously he has worked in the ceramic industry, holding positions of Research and Development Manager, Technical Manager and Works Manager. He also ran his own business for five years producing commercial ceramics. He is currently researching photo ceramics and the use of digital fabrication techniques for ceramics. Professor Stephen Hoskins is the Director of the Centre for Fine Print Research at the University of the West of England, Bristol, UK. Stephen studied at West Surrey College of Art and The Royal College of Art. His primary area of research is in continuous tone photomechanical processes and their application with current technology, particularly in relation to printed ceramics. Dr Paul Thirkell is a Senior Research Fellow at the Centre for Fine Print Research at the University of the West of England Bristol UK. He is currently carrying out post-doctoral research at the CFPR