Solid free-form fabrication in fired ceramic as a design aid for concept modelling in the ceramic industry

Design cased study:

Peter Walters – Ceramic Beaker

Peter Walters is a member of the 3D printing research team at the Centre for Fine Print Research. He has an academic and professional background in Industrial Design and rapid prototyping technologies. At the time of this case study, he had no previous practical experience in ceramics and therefore lacked the “hands-on” understanding of ceramic materials that may be possessed by more experienced ceramic designer makers. This case study therefore illustrates how a designer with no previous experience of ceramics can work creatively with ceramic materials and achieve successful results through the ceramic 3D printing process.

Figure 1 and 2 show the design concept of a double-walled cup and beaker which was created in the 3D CAD software Rhinoceros (Robert McNeel Associates). The outer wall of the piece is pierced to reveal the inner wall. This design lends itself to the ceramic 3D printing process since it would be difficult to create by traditional ceramic forming processes.

Figure 1 Double-walled ceramic cup

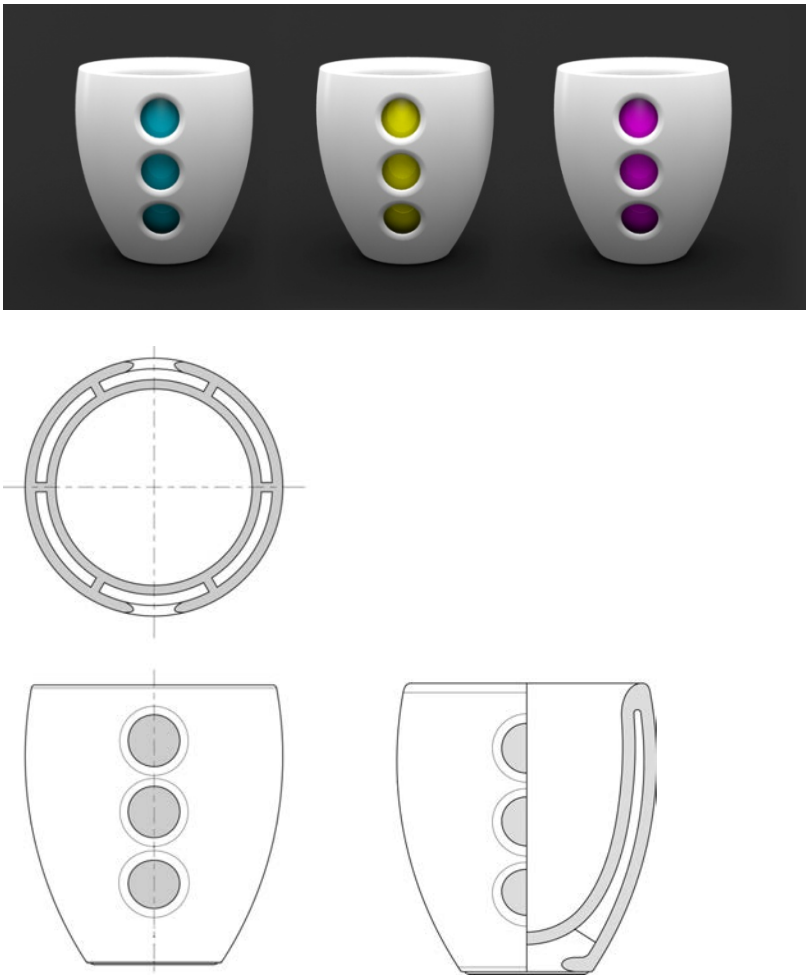

Figure 2 Double-walled ceramic beaker

The cross-sectional views in figure 2 show the double-walled design and the presence of internal ribs which connect the inner and outer walls of the beaker. Concept models of the beaker design were first fabricated by 3D printing in the standard Z-Corp plaster-based modelling material. These are illustrated in Fig 3.

Following this the beaker was 3D printed in the UWE ceramic material. 3D printed ceramic beaker was removed from the 3D printer, dried in the oven, de-powdered, and then fired in the kiln. The results of the first firing are shown in figure 4. As can be seen in this figure, the beaker collapsed during the firing process. This is because the beaker was fired without any internal support structure.

Figure 3 Beaker concept model in Z-Corp plaster-based modelling material.

Figure 4 First attempt at firing the ceramic beaker without internal support

A setter was created to support the beaker during firing. The shape of the setter was determined by offsetting the internal surface of the beaker by 0.5 mm. The setter is shown schematically in figure 5. With the setter in place to support the beaker during firing, the distortion was significantly reduced. However some distortion remained, as shown in figure 6.

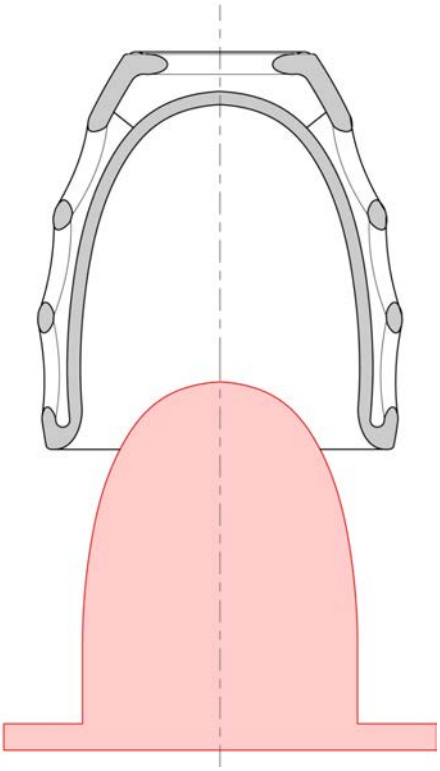

Figure 5 Design of the setter to support the beaker during firing

Figure 6 Firing the beaker on the setter significantly reduced distortion

In order to further reduce distortion in the beaker during firing, the size of the internal ribs around the holes in the external wall of the beaker was increased as shown in figure 7. Increasing the size of the internal ribs helped maintain the shape of the beaker, with only minor distortion present following firing, as illustrated in figure 8.

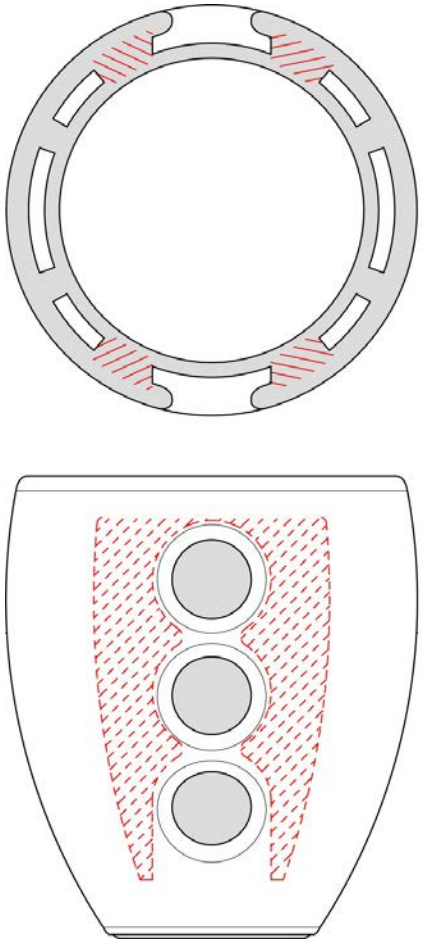

Figure 6 Increasing the size of the internal ribs of the beaker

Figure 7 Distortion due to firing is further reduced due to increasing the size of the internal ribs of the beaker

This remaining distortion is due to the beaker contracting slightly more in the vertical axis than in the horizontal axes during firing. This is evidenced by the holes in the outer wall of the beaker becoming progressively more oval. In order to compensate for the additional vertical contraction as the beaker slumps slightly during firing the 3D CAD model was stretched in the vertical axes. This is illustrated schematically in figure 9.

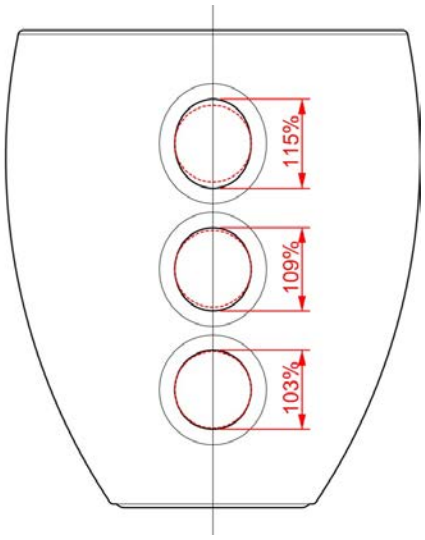

Figure 9 Stretching the beaker to compensate for vertical distortion.

Having adjusted the 3D CAD model, the stretched beaker and setter (internal support) were 3D printed in the ceramic material, then dried and fired in the kiln. The biscuit fired beaker shown in figure 11.

Figure 10 Beakers and setter in kiln

Figure 11 Biscuit fired ceramic beaker alongside 3D CAD model

This case study has demonstrated that an understanding of the material properties of ceramic 3D printing and behaviour during firing was required in order to achieve a satisfactory result. Through a series of iterations, the modifications made to the design of the beaker e served to overcome problems encountered when firing the piece, resulting in a successful outcome.