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# The development of strategies for working with three-dimensional glass forms using two-dimensional waterjet cutting

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**Abstract**

This enquiry will suggest ways in which the scope of the artist may be expanded by the use of CAD/CAM technology, with a focus on waterjet cutting. Consideration will be given to strategies for processing three-dimensional models for the most commonly available two-dimensional water jet cutting process.

## 1. INTRODUCTION

Anecdotally, artists talk of barriers to technology, such as cost; lack of familiarity, knowledge and skills; a squeamishness associated with computers; incomprehension of ‘jargon’; and a discomfort within an engineering environment.

Despite these misgivings, there is a nascent awareness amongst artists and craftspeople of the potential offered by technology. The work of practitioners such as Michael Eden(1) and Geoffrey Mann(2) for example, has been widely exhibited and contributed to a greater interest in rapid prototyping processes by craftspeople.

An early-adopter of waterjet cutting technology was Robert Knottenbelt, who made use of the process in his glass practice from 1986 onwards(3). More recently the work of Vanessa Cutler(4) has brought the use of waterjet cutting to a contemporary audience within the glass-art scene.

This paper will seek to suggest ways in which the use of the waterjet cutting process can be further expanded and incorporated within a glass-art practice. The researcher’s practice involves the creation of mainly kiln-formed, three-dimensional sculptural objects. Therefore, a focus of this enquiry will be the production of three-dimensional glass objects.

The scope of the enquiry will be limited to a 2-axis waterjet cutting machine, that technology being the most commonly-available both within university departments and via industry subcontractors.

It will therefore be necessary to assess the design strategies required to create three-dimensional objects using a two-dimensional cutting process. As well as glass cutting, the paper will address – through case-studies – less direct methods to include the cutting of moulds and formers as well as wax models for subsequent processing by lost-wax casting. The paper will illustrate how the use of technology can segue seamlessly with the hand-made through the documentation of the design and production of glass artefacts.

## 2. DESIGN STRATEGIES – CASE STUDIES

### 2.1 Cutting and assembly

One approach employed by Vanessa Cutler is to cut two-dimensional profiles from15mm thick float glass and assemble and bond to create stacked towers.

**Figure 1. 'Transformers' by Vanessa Cutler**

This approach makes a fairly pure use of the technology and is suggestive of the artist's acceptance of the influence of process upon design. As Cutler comments "...the generation of ideas comes about from the influence of the process... it suggested the shapes and forms that could be translated from paper into glass" (4).

**Figure 2. '007' by Margareth Trolli**

Another artist making effective use of contour cutting and assembly is Margreth Trolli. After cutting, the glass is edge-polished, assembled and bonded.

## 2.2 Contouring

Contouring or sectioning is a useful strategy for processing a three-dimensional CAD model for production by two-dimensional cutting.

Contouring is an approach to construction with links to architecture, aircraft and boat-building. As such it is a function embedded within most CAD software.

As a starting point, the researcher used an existing model which had been milled to produce a former for a kiln-cast glass panel illustrated below.

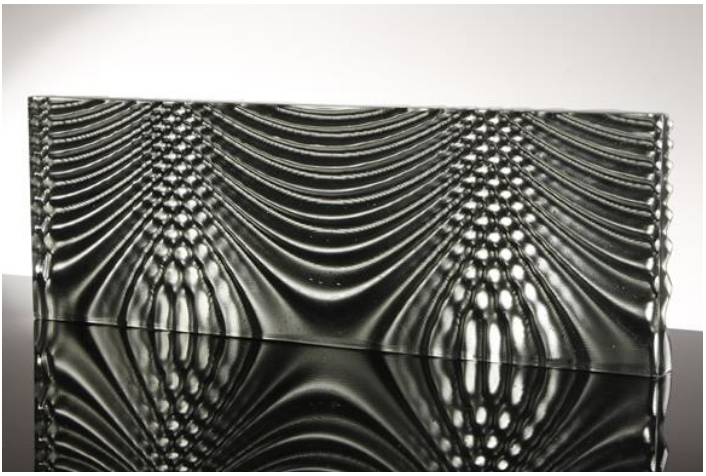

**Figure 3. 'Iteration 135' by Shelley Doolan**

The three-dimensional computer model was then processed using a simple contour function, with the interval set at 4mm (being the thickness of glass used).

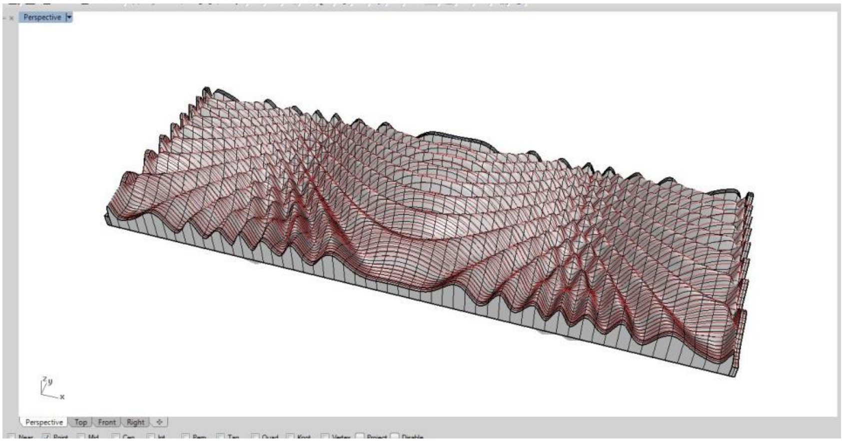


**Figure 4. Contoured model**

The contour profiles are then laid out and nested for waterjet cutting in glass.

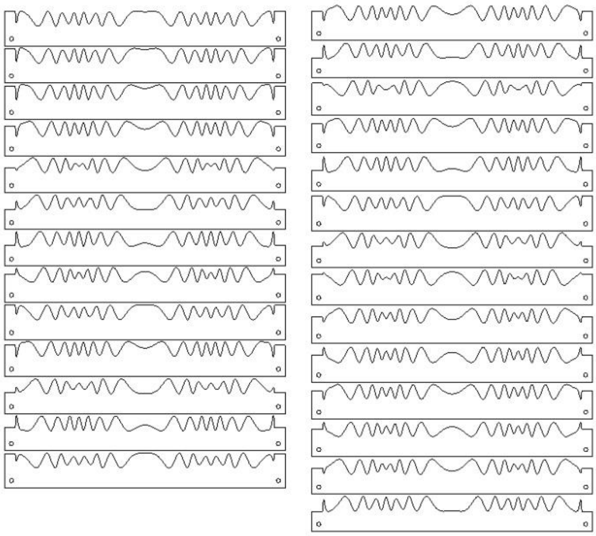

**Figure 5. Layout of contour sections for waterjet cutting**

The glass was cut using 120mesh garnet abrasive, with a lead-in from the edge, enabling high pressure of 5500psi to be used. An abrasive flow rate of 225g/minute was used, with a traverse rate of 1000mm/minute.

After cutting, the glass profiles can be edge polished and assembled.

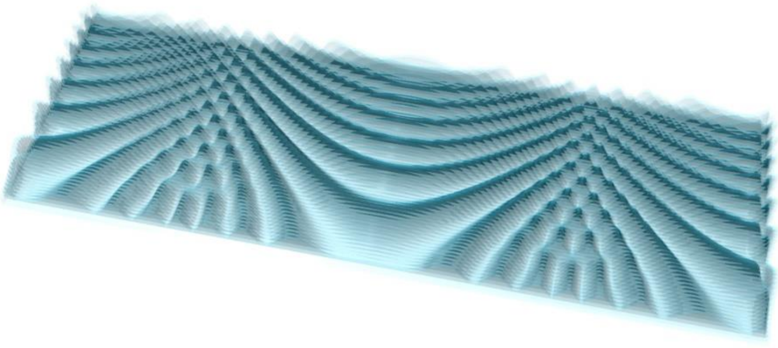

**Figure 6. Waterjet cut and assembled glass profiles**

Despite the simplicity of the process, the results are effective.

## 2.3 Intersecting waffles

A design strategy which lends itself to two-dimensional cutting is the creation of intersecting, interlocking waffles taken from a three-dimensional object.

Using a script within three-dimensional modelling software, a base geometry is sectioned to enable the creation of ‘waffle’-type intersecting profiles.

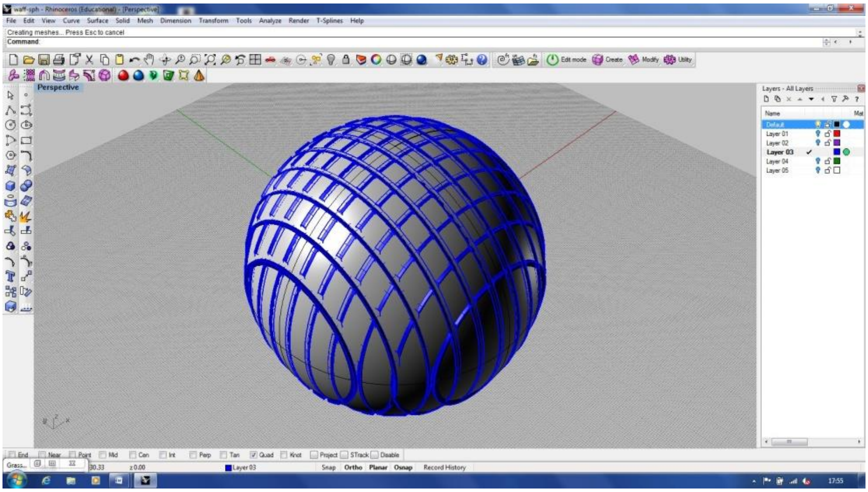

**Figure 7. Sectioning of base geometry**

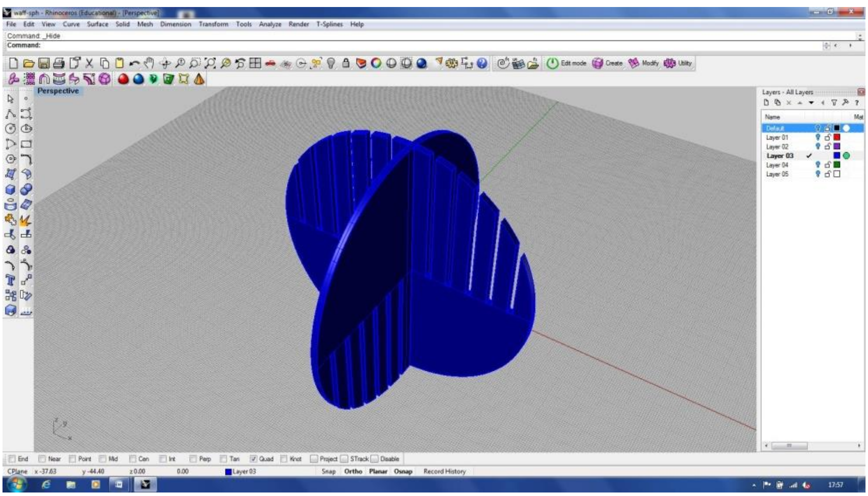

**Figure 8. Interlocking profiles**

The profilesare processed for 2D cutting

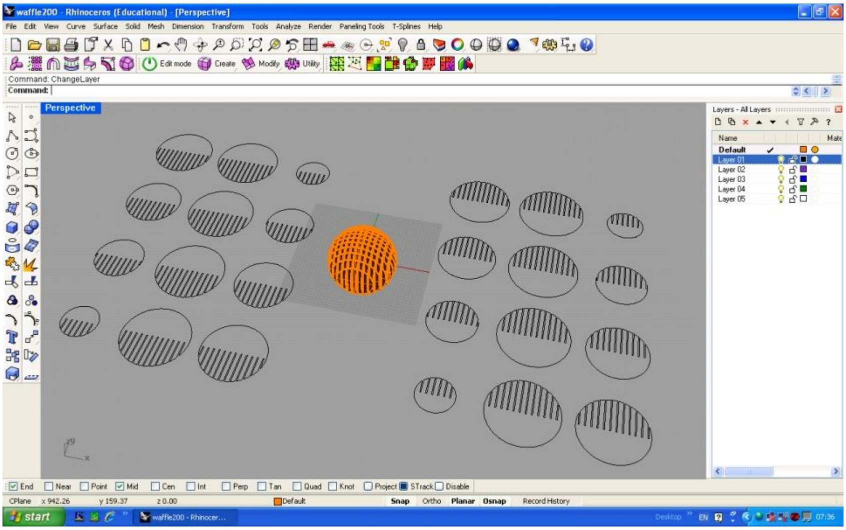


**Figure 9. 2D profiles**

Once cut, the glass can be assembled and UV bonded.

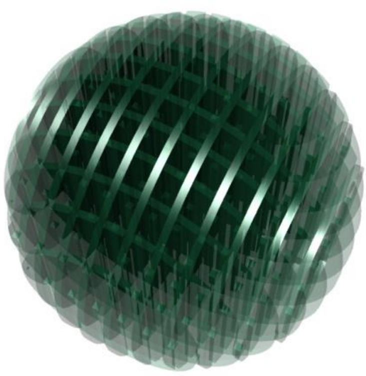

**Figure 10. Assembled glass sphere**

### 2.4 Manual waterjet 'carving'

The researcher has experimented with a process of carving into pre-cast blocks of glass to create internal cavities and sculpting. In this instance, the waterjet machine was operated manually, without programming, with the researcher adjusting the speed control during the pass of the abrasive jet to create variances in the depth of jet penetration of the glass block.

Three lines were cut into the block with a gradation in overall depth to create a layering effect.

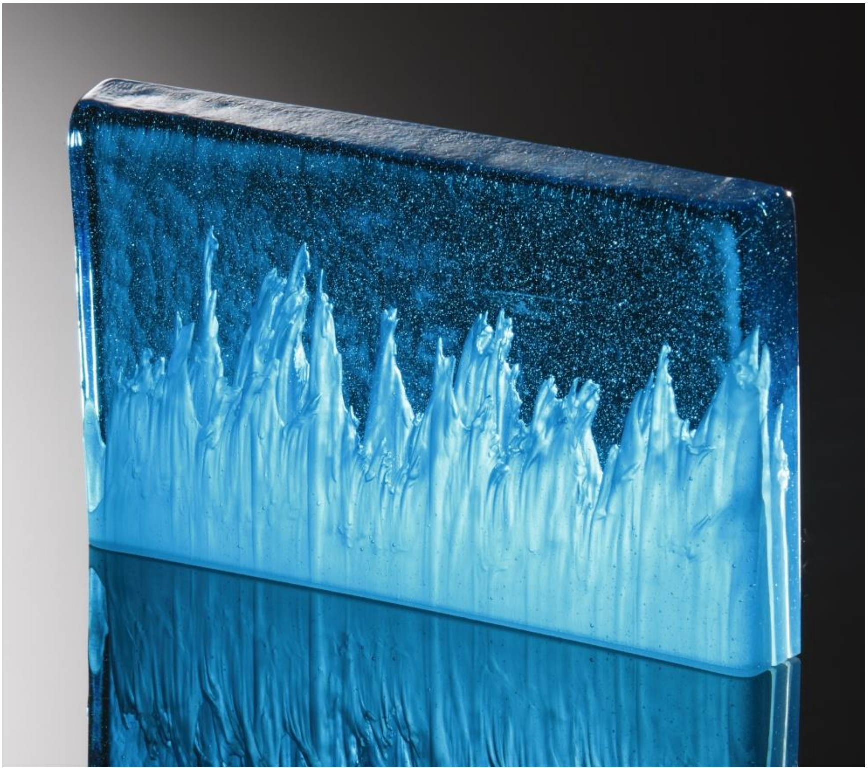

**Figure 11. 'Vertiginous' by S Doolan**

This has proved to be an interesting area of enquiry, using the waterjet in a more 'hands-on' way, introducing an element of uncertainty to the outcome. The effect is to create work which begins to have a more three-dimensional sculpted quality.

### 2.5 Unrolling developable surfaces

One approach to fabricate forms too large to be practicably or economically prototyped or milled, is – where possible – to unroll the developable surfaces.

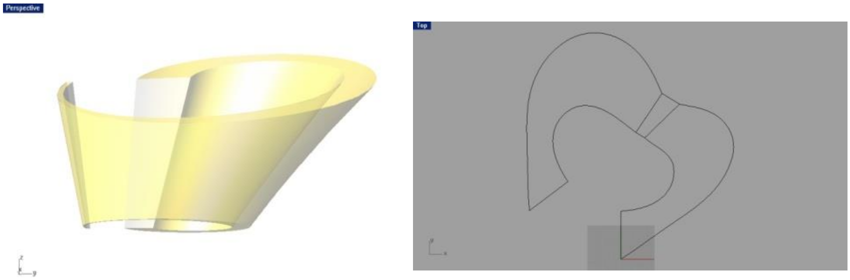


**Figure 12. 3D model and unrolled surfaces**

Once unrolled, the profile can be cut to provide a former for the model. In this case, thin gauge aluminium was cut, folded, rolled and secured to a base board to allow molten wax to be poured in to create a wax replica of the original model for subsequent lost wax casting. All subsequent processes reverted to traditional craft techniques. The finished glass pieces were 75cm x 55cm x 38cm.

**Figure 13. Cast glass, by S Doolan**

## 2.6 Cutting the mould and negative space

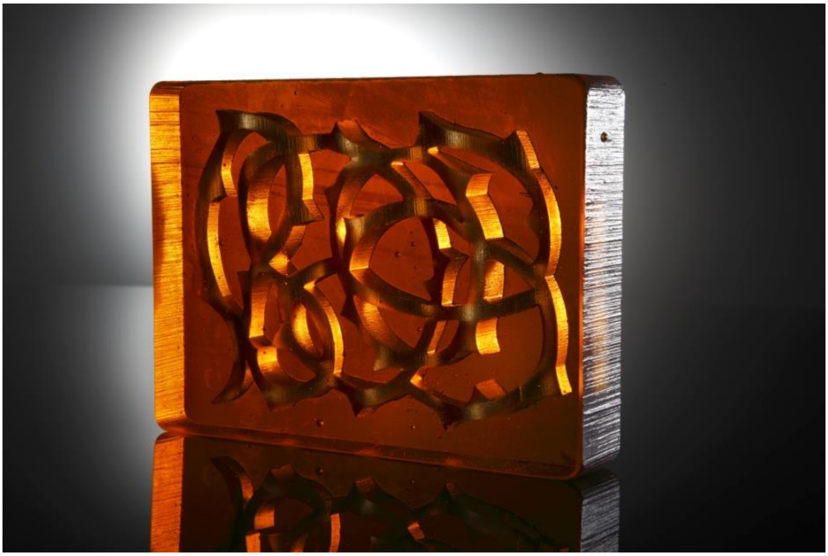

**Figure 14. 'Brambles' blocks by S Doolan**

After initial trials, the researcher decided to use the waterjet machine to create the mould and components to cast glass blocks with relief detail – in this case a bramble motif.

Refractory plaster blocks were cast and waterjet cut. The initial profile being a sinusoidal wave, cut along one plane of the block. The block was then rotated and cut from a different plane to create a plaster positive of the bramble. When cast in glass, this would form the negative space within the block of glass.

**Figure 15. Cutting of the bramble motif**

To save time, a plaster collar was also cut to provide the perimeter of the mould.

**Figure 16. Moulds in preparation for kiln-firing**

This was a useful and effective way to prototype designs. The use of the waterjet enabled the crisp and precise cutting of the plaster motif.

## 2.7 Cutting for lost-wax

The researcher wished to introduce a greater degree of three-dimensionality to work produced. To this end a number of test cuts were carried out on plaster (as mentioned above) and also on wax.

**Figure 17. 'Scale' by S Doolan**

The tests proved promising. The cut edge of the wax showed minimal signs of jet-lag or taper.

Another advantage was that wax blocks up to 165mm height could be cut (the maximum clearance under the jet), and that a 'reasonable' cutting speed could be used.

A typical traverse rate of 70–250mm/minute (depending on the thickness of the material), and a stand-off distance of 2mm was used

The object was designed with a curved front face. It was decided to experiment with first cutting this profile in the top plane of the block of wax before rotating to cut the pattern from the front plane.

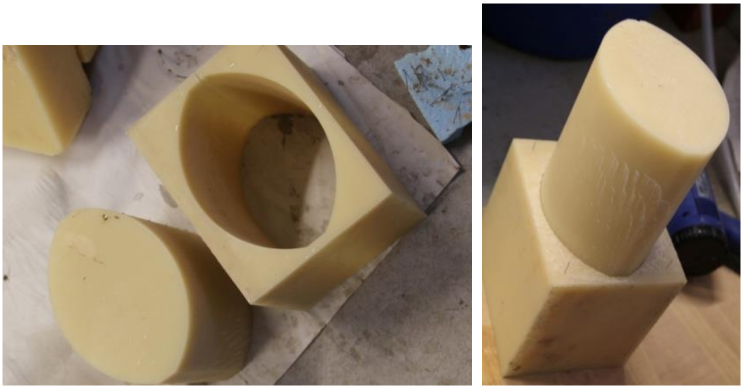

**Figure 18. Initial phase of cutting profile and re-assembling**

The maximum clearance under the cutting head was 165mm. This also proved to be reaching the limits of depth of cut whilst retaining an acceptable surface at acceptable traverse rates. Therefore the block was cut into four sections and the same curved profile cut from each. The blocks were then reassembled prior to being rotated and cut from the front face.

**Figure 19. Cutting of pattern on front face**

The cut wax pieces were then joined and refined by hand before being invested in refractory plaster for subsequent lost-wax casting.

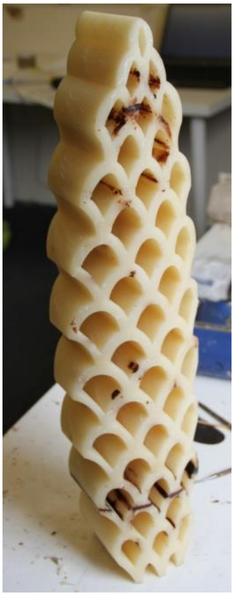

**Figure 20. Assembled wax model, invested in plaster mould**

The technique was subsequently made more efficient by the pre-casting of the wax into a former to create the curved front face. This necessitated cutting from one plane only and obviated the need for time-consuming re-assembly.

The researcher has used the technique of waterjet cutting wax for further pieces. It has proved to be an effective way of working, enabling the neat and precise cutting of forms from CAD data. The process allows for objects to be created with a depth currently of 165mm. Further work is planned to see whether this can be increased with satisfactory results by submerging wax blocks into the tank.

Cutting the wax for subsequent casting enables the production of work of a greater thickness than would be easily achievable by cutting glass directly. The work of Cutler(4) noted that cutting glass beyond a thickness of 50mm produced a cut surface with significant taper and a visually poor finish. It should also be noted that the traverse rate even at a thickness of 50mm would significantly slower to achieve a visually acceptable surface. A further advantage of cutting the wax is that no abrasive is used and the wax itself is endlessly recyclable.

**Figure 21. 'Propagate' by S Doolan**

## 3. CONCLUSION

Through a process of experimentation, and material and cutting tests, it has been possible to apply the findings to achieve the cutting of complex forms in wax and plaster. This has added to the repertoire of the glass-maker. By employing the various strategies illustrated above, it has been possible to create work with a greater sense of three-dimensionality, despite the use of a two-dimensional cutting process.

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## FIGURES