# The synthesis of waterjet cutting with ‘hot-glass’ for the creation of murrini

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**ABSTRACT**

This paper outlines experimental work relating to the creation of murrini using a combination of waterjet cutting and ‘hot-glass’ techniques.

Murrini are traditionally created in the hot-shop[1] from canes of coloured glass arranged to create patterns that are revealed when cut through in cross section (akin to Brighton Rock).

The paper introduces the work of Professor Cutler in her role as facilitator for artist Scott Chaseling; as well as Doolan’s independent creative experimental work and cutting on behalf of artist Owen Johnson.

## 1. HISTORICAL OVERVIEW

Murrini (Murrina, *singular*) are small patterned tiles of glass historically used to create mosaic vessels, paperweights and decorative objects. The Murrini technique creates a cane of glass that when sliced up in cross-section will produce a small number of complex repetitive glass tiles that can contain images, motifs or abstract visual structures. This process involves stacking different coloured canes or sheets of glass. This layered block of glass is then heated up and stretched, elongating and shrinking the design into a long glass cane. Each cane is then cut every 5mm to 8 mm in cross-section.

The first known examples of mosaic glass involving a technique similar to Murrini, are a number of slumped mosaic bowls found across the Eastern Roman Empire. The exact source of these small vessels is unknown, but they appear throughout the Mediterranean during the course of the 2$^{nd}$ and 1$^{st}$ centuries BC, in locations from Syria and Egypt, to Italy and Greece (Figure 1). During this period the first image-based Murrini also appear, in the form of small opaque glass tiles that display a decorative mask (Figure 2).

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[1] The hot-shop is a term commonly used for a glass-blowing studio/workshop

**Figure 1. Murrini bowl**

**Figure 2. Mask murrina**

**Figure 3. Murrini vessel**

These cross-sectional slices of glass are then picked up either as separate elements onto a hot-blown form to be heated up and incorporated into the surface to create decorative detailing; or are arranged in a tiled sheet.

These decorative objects slowly fell out of favour following the introduction of glassblowing, a decline in popularity that can be attributed to the time-consuming nature of the making methods involved. The technique was to be revived in the 17th century, on the island of Murano. The Venetians reverse-engineered the technique from ancient objects, developing glassblowing methods that utilised Murrini tiles to create more complex mosaic vessels (Figure 3). The Venetians also began making Murrini using chevron shaped optical moulds and multiple layers of colour glass, a practice that has continued right up to the present-day.

**Figure 4. Millefiori**

**Figure 5. Murrina figure**

**Figure 6. Lorian Stump glass**

During the last 300 years of continual use, the Murrini technique has fallen in and out of favour a number of times. During the 17th and 18th centuries one revival created a new name for the method, *Millefiori*; which translates directly from Italian as ‘a thousand flowers’. The name would become synonymous with one very popular object, the decorative Venetian paperweight, constructed by gathering a ball of clear glass around a flat plate of detailed, floral inspired circular Murrini (Figure 4).

The 18th-century also saw the adaption of the technique to bead making and flame-working, aiding the revival of pictorial Murrini. A development led by Giacomo Franchini, a Venetian bead maker that used flame-worked Murrini to make some of the most detailed miniature portraits of all time (Figure 5). Franchini developed a technique that squashed and shaped coloured glass, instead of bundling the pixels of the desired image, a technique that is still being researched and reproduced by contemporary glass artist like Lorian Stump (Figure 6).

In the 1960s, as the American studio glass movement began to gain momentum, glassmakers including Dale Chihuly and Richard Marquis began to explore the techniques of Venetian glassmaking. Marquis in particular focused on Murrini, increasing the technical boundaries by using casting and hot working to create mosaic tiles with symbols and text, incorporating these tiles into playful vessels and sculptures (Figure 7). Marquis, along with other makers, entrenched the Murrini technique into the canon of glassblowing and flame-working techniques available to the studio glass movement. This canon would be taught in the universities and glass education sites throughout the world, leading to further technical development.

**Figure 7. Richard Marquis**

**Figure 8. Giles Bettison**

**Figure 9. Scott Chaseling**

One such development would occur in Australia during the 1990s, when two glass artists would begin creating Murrini with sheet glass. Giles Bettison (Figure 9) and Scott Chaseling (Figure 8) were both studying at the Australian National Universities CSA glass workshop, when Bullseye Glass Company initiated the Latitudes project. The project encouraged the students to use Bullseye's coloured sheet glass in new ways. Bettison and Chaseling began to stack sheet glass to form striped, textile like blocks of glass that could be stretched and cross-sectioned in the same fashion as a traditional Murrini. Bettison and Chaseling, along with other artists, have continued to experiment and develop the Murrini technique over the last 20 years.

In 2009 this experimental nature led Scott Chaseling to seek out Vanessa Cutler to attempt the first water jet cut Murrini. This paper continues on from that first effort to combine one of the world's oldest glass making methods, with one of the worlds more recent technical developments.

## 2. EXPERIMENTAL WORK

### 2.1 Case study: Scot Chaseling

Cutler's initial trials on behalf of artist Scot Chaseling were made using blocks of Bullseye glass approximately 76mm x 76mm x 54mm thick. The intention was to see how the shape would cut and how detailed the form could be. Two shapes were chosen. The intention was to integrate each of the three colours into the murrini, mixing and matching like a jigsaw.

The following parameters were constant throughout:
Low-pressure pierce (11,000 psi)
High-pressure cutting (55,000 psi)
120 mesh garnet abrasive
0.76mm aperture nozzle with a 0.25mm aperture sapphire
Abrasive flow rate of 225g/minute
Stand-off distance 2mm

A rotation pierce was used to cut the internal shapes; it was noted that the rotation created an uneven kerf, causing the width of the hole to be larger at the base to the top. However in discussion with the artist it was decided a glass rod could be inserted into the space in so doing generating a small black glass eye for the duck.

**Figure 10. Scott Chaseling 'duck' murrini**

**Figure 11. Scott Chaseling 'duck and train' murrini**

The duck shape was the simpler of the two shapes. Three shapes where generated in the block: the beak, body and outer shape. The eye was the lead in point for both the beak and the body. The intention within the programming was to minimise the amount of rotation into the block and the amount of piercing required to generate the cut forms. The train required more piercing points and when reduced lost some of its sharpness. This may be down to the colours chosen and softness of the glass. Various colours distort easier in the heat and can lose their form.

The experimental work produced some positive results but raised further questions relating to the manufacture of the murrini subsequently explored by Doolan and Johnson.

**2.2 Creative experimental enquiry: Shelley Doolan**

**Cutting set up**

The following parameters were constant throughout:
Low-pressure pierce (11,000 psi)
High-pressure cutting (55,000 psi)
120 mesh garnet abrasive
0.76mm aperture nozzle with a 0.25mm aperture sapphire
Abrasive flow rate of 265g/minute
Stand-off distance 2mm

**Phase 1**
A simple profile was drawn for the initial enquiry (Figure 12).

Gaffer[2] glass was kiln-cast into plaster moulds to create cylindrical blocks (80mm diameter by 60mm high) for waterjet cutting.

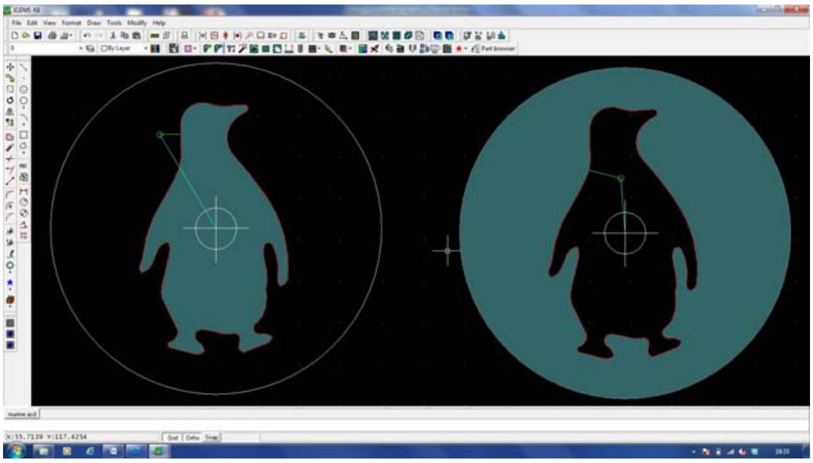

**Figure 12. Toolpath for penguin murrini**

**Programming**
As can be seen in Figure 12, the contours were used to create 'parts'. Two contrasting colours were used for each murrina, with the positive shape being cut from one colour and the negative shape from the other (Figure 13).

**Waterjet cutting**
The glass was cut at observed speeds of between 5 and 10mm/minute. The hole created by the low-pressure circular pierce and the 'lead-in'[3] required for cutting effectively created one 'good' part and one 'sacrificial' part for each profile. The effect of the pierce and lead in is visible in Figure 14 on both parts.

As can be seen in Figure 13 and Figure 14, there is a tighter fit between the two 'good' parts than the two sacrificial parts. This is due to the way in which the waterjet programme compensates for the thickness of the jet (and consequent loss of material) by creating an offset into the 'sacrificial' material.

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[2] http://www.gafferglass.com/
[3] Lead-in refers to creating an initial pierce and cut before the jet reaches the cutting contour

**Figure 13. Cut and assembled glass**

**Figure 14. Effect of lead-in and pierce**

Both ‘good’ and ‘sacrificial’ parts were used for the murrini tests. As the glass was to be heated and shaped, the gaps between the parts closed up and were therefore of little significance.

**‘Hot-glass’ processing**

The cut and re-assembled glass was loaded into a small kiln in the hot-shop to bring it up to temperature. The glass must be pre-heated in this way prior to being heated and shaped. Picking the glass up from cold and heating in the ‘glory hole’[4] would cause it to crack immediately from thermal shock.

The process of hot-working the murrini was carried out by the glass Technicians at the University of the Creative Arts in Farnham[5]. Glass was gathered from the furnace and shaped to make a disc the same diameter as the murrini cylinder (Figure 15). Two of these discs were made.

[4] The ‘glory-hole’ is a cylindrical horizontal barrel gas-powered furnace used by glass-blowers to re-heat the glass in the hot shop.

[5] www.ucreative.ac.uk


**Figure 15. Gathering and shaping glass**

The murrini cylinder was then picked up from the kiln using one of the hot glass discs.  It was transferred to the glory hole for bringing up to a workable temperature (figure 17).

**Figure 16. Heating in glory hole**

**Figure 17. Marvering murrini block**

After heating, the glass was marvered[6] to shape it and to close up the gaps between the two parts of the murrini pattern (Figure 17).  The second disc was attached to the other end of the murrini block (Figure 18) and then adjusted (Figure 19). The cane was then pulled (Figure 20).

[6] Marvering is a term used to describe the shaping of hot glass on a steel bench (marver)

Figure 18. Attaching disc to murrini

Figure 19. Evening out thickness

Figure 20. Cane pulling

**Observations**
The waterjet cutting worked very well, with a consistent dimensional accuracy to the top and bottom of the material and minimal jet lag. The decision to programme the cutting by creating parts resulted in one tight-fitting ‘good’ part and one looser fitting ‘sacrificial’ part. Due to the process of heating and shaping the glass, the holes and gaps in the sacrificial part were of less significance than they might otherwise have been.

Unfortunately the ‘hot-glass’ stage did not go well, with further work being required to refine the process of pulling the cane, most notably selecting the appropriate colours. There was a problem where a soft coloured glass was used for the outside shape (blue) and a hard colour used for the internal shape. When the glass was heated and pulled, the external glass became much softer and less viscous than the internal shape, with the result that when pulled, the softer glass pulled away separately, with the remainder being unmanageable and unusable (Figure 21). The selection of colours would therefore be an important consideration for future trials.


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**Figure 21. Failed murrini**

**Figure 22. Sample murrini slice**

The process proved to be a promising test and suggested the effectiveness of using the waterjet process to create the ‘blanks’ for further hot-glass work. A different sample with an arrow motif was more successful, due to the selection of colours. It was possible to make useable murrini slices as shown in Figure 22.

**Areas for further development of the process**
The profiles used for the murrini cutting were very simple. This was largely due to the thickness of the glass being cut which limited the complexity of the geometry. Cutting glass of this thickness necessitated using a very slow traverse speed to achieve a reasonable cut quality. The consequent material erosion means that fine details can be lost, especially on tight curves (Figure 23).

**Figure 23. Example of material erosion cause by slow cutting speeds**

A potential refinement to the process was identified. This would be to waterjet cut the inner and outer detail from sheet glass of different colours, and to pre-fuse these in a kiln to create blocks for subsequent pulling into cane. Cutting from sheet glass (typically 3mm thick) would allow for more complex details to be achieved.

**Phase 2**

The previous investigation indicated that cutting from 3mm sheet glass for subsequent assembly into blocks offered some advantage in terms of enabling more complex geometry to be cut and also reducing machine time.

A new profile was drawn (Figure 24). The dimensions were 85 x 85mm from 3mm thick glass.

**Programming**

A ‘quick cut’ command was selected for the internal shapes, with the external square cut as a ‘part’ as illustrated in Figure 24. The ‘quick cut’ command creates a tool path along the contour, with material erosion to the inside and outside of the contour.

The glass was cut at observed speeds of 1500 to 2478mm/minute.

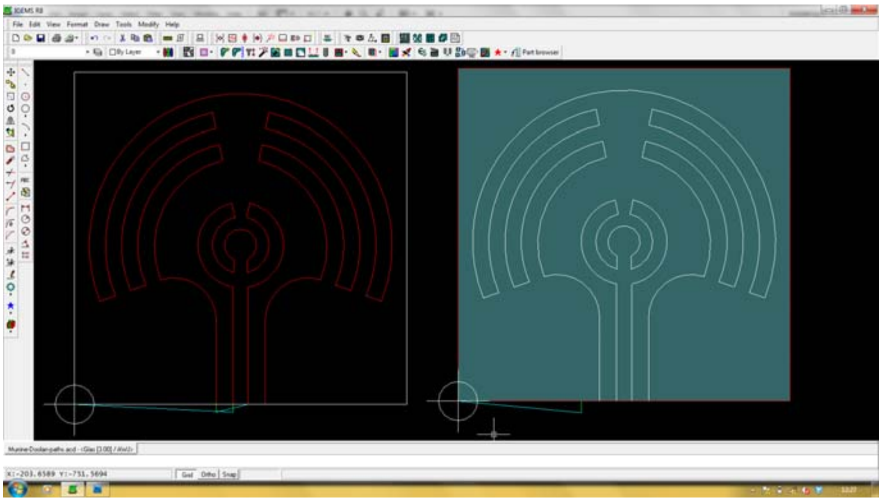

**Figure 24. More complex murrini pattern for 3mm glass**

The consistent material erosion of each coloured block enabled the pieces to be swapped between blocks and slotted in easily (figure 26 refers). The fit was quite loose but given the subsequent hot glass processing, these gaps closed up and were therefore of little significance. The internal details could be cut by leading in from the edge of the material, thus avoiding signs of piercing in the body of the glass.

**Figure 25. Cut 3mm glass murrini pattern**

**Subsequent processing**
The cut and assembled 3mm glass was placed into a small kiln in the hot-shop, picked up, shaped and stretched (as outlined above) by Johnson.


**Figure 26. Stretched murrini rod**

The resulting stretched glass (Figure 26) was then cut on a diamond saw by Johnson and returned to Doolan for further processing. Figure 28 shows the cut slices of murrini assembled prior to kiln-fusing.

Both the waterjet cutting and hot-glass aspects worked very well and produced promising initial results. Further work is underway to use the murrini slices to create a finished object.


**Figure 27. Cut murrini slices prior to kiln-forming**

## 2.3 Case study: Owen Johnson

The glass used was a soda-lime glass manufactured by Bullseye[7]. Johnson pre-fused[8] sheets of coloured glass to create individual blocks. The cutting set up was as per section 2.2.

**Phase one**

Glass blocks of 70mm x 70mm x 20mm were cut. This initial trail enabled Johnson to observe first-hand the operation of the waterjet and to gain a depth of understanding of the effect of the selection of different parameters upon material outcomes. Johnson was advised by Cutler to cast thicker blocks for the second phase of experimentation.

**Phase two**

Working with Doolan, the second batch of blocks cut had approximate dimensions of 70mm x 70mm x 50mm thick. Johnson provided a .dxf file which was imported to IGEMS software for programming.

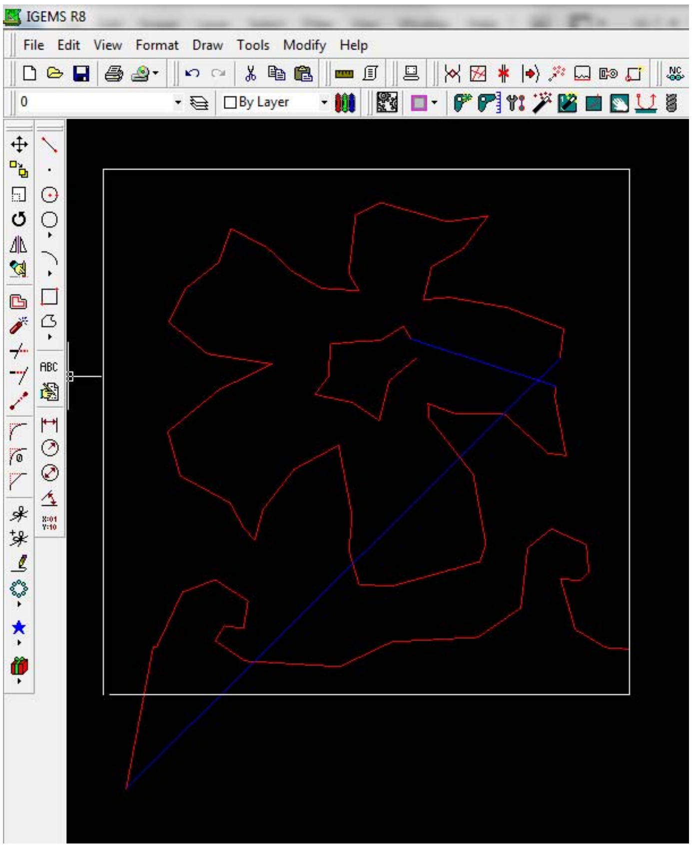


**Figure 28. Quick-cut tool path. Johnson murrini**

**Programming**

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[7] www.bullseye.com

[8] Fusing refers to thermally bonding layers of glass in a kiln

A ‘quick cut’ command was selected, as illustrated by Figure 28. Due to the small scale of the work and the risk of the pieces falling through the grilles, it was decided to leave small sections of the contours uncut to enable the parts to be tabbed to the body of the block to be broken out by hand later. The ‘quick cut’ command creates a tool path along the contour, with material erosion to the inside and outside of the contour.

The consistent material erosion of each coloured block enabled the pieces to be swapped between blocks and slotted in easily. Test cuts led to the selection of cutting speeds. The observed cutting speeds ranged between 9 and 36mm/minute.

**Observations**
The cut was of a high quality with a good dimensional consistency between the top and bottom surface and minimal jet lag. The shapes could easily be swapped between different coloured blocks and slotted together. For the purpose of creating murrini, the loss of material (approximately 1.5mm) was not a problem. The cut and re-assembled glass blocks were loaded into a small kiln in the glass-blowing studio, picked up, shaped and stretched (as described in section 2.2). During this process the gaps between components caused by material erosion were joined up.

**Phase three**
In an attempt to speed up the process of cutting, Johnson produced thinner blocks, 70mm x 70mm x 25-29mm high. This enabled a faster traverse rate to be used. The observed speed ranged between 32 and 85mm/minute.

**Observations**
The cutting produced a high quality surface with minimal jet lag and good dimensional consistency. The faster cutting speeds enabled the same overall volume of glass to be cut in a faster time when cutting the 25mm – 29mm thick pieces compared with the 50mm blocks (as shown in Table 1). The table further illustrates the advantage of pre-cutting 3mm glass to create the profiles for the murrini.

**Table 1. Comparison of cutting times relative to different glass thicknesses, for the same murrini pattern (figure 26 refers).**

| **Glass dimensions** | **Glass thickness** | **Cutting time** |
|---|---|---|
| 70mm x 70mm | 50mm | 22 minutes 1 second |
| 70mm x 70mm | 30mm | 9 minutes 22 seconds |
| 70mm x 70mm | 3mm | 46 seconds |

**Figure 29. 'Adeney Translation #1' Kiln-fused murrini panel. Owen Johnson**

## 3. CONCLUSIONS

The initial experimental work of Cutler and Chaseling was a valuable enquiry and raised a number of questions for further investigation. Doolan's experimental work independently and in collaboration with Johnson further refined the process and evaluated the relative merits of cutting glass of different thicknesses for the creation of murrini 'blanks' for subsequent hot glass processing.

It was evident that there were benefits in terms of overall reduced cutting time to using a 3mm sheet glass to cut the profiles (as illustrated in Table 1). A further advantage identified by Doolan was the ability to cut more complex geometry in 3mm sheet glass compared with the thicker blocks, as outlined in section 2.2.

Johnson reflected that a further advantage to cutting the profiles from thinner sheet glass was a reduction in the number of kiln firings of the glass. The pre-fused thicker blocks comprised 3mm sheet glass thermally bonded in a kiln prior to waterjet cutting. By waterjet cutting the murrini patterns from 3mm sheet glass, the pre-fusing phase could be eliminated. The 3mm cut pieces were assembled and loose-stacked immediately prior to pick up in the hot shop.

Feedback from Johnson indicated that whilst the 3mm glass pieces were fiddly to assemble in the kiln, there were no significant problems with the hot-glass aspects of the work. Johnson noted that the easiest glass to work with in the hot-shop was the 50mm thick blocks. However, the thickness of the blocks necessitated a slow cutting speed which had disadvantages in terms of cost and reduced accuracy of the image created.

The creative experimental work produced a successful synthesis of the waterjet cutting process with the traditional processes of hot-glass forming.

Johnson successfully processed his murrini to create finished pieces (Figure 29) which were exhibited as part of his final year PhD exhibition. Doolan is currently processing her experimental murrini to create a body of work.